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THE LIGHTCURVE AND ROTATION PERIOD FOR 268 ADOREA AND (16735) 1996 JJ

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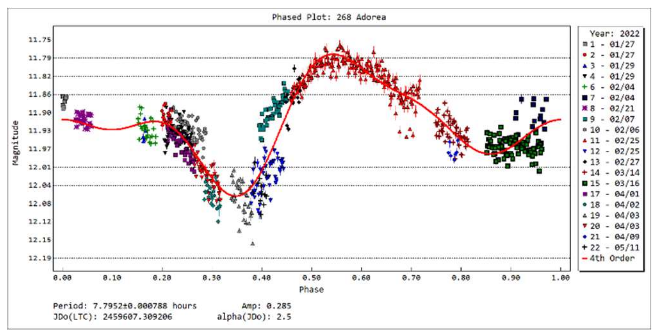
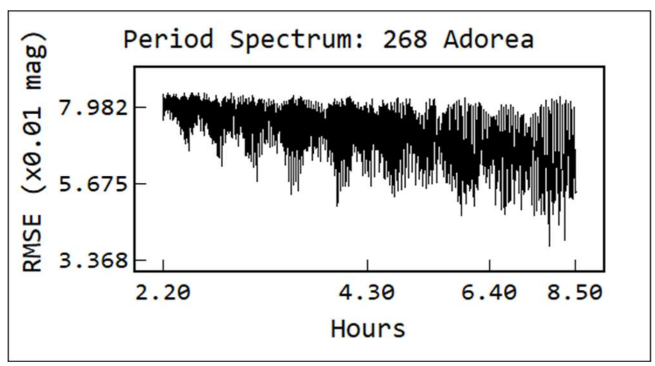
Lightcurve period and amplitude results from Old Orchard Observatory are reported for 2022 January-May, 268 Adorea (7.7952 ± 0.0008 h and 0.285 mag). 2023 April-May, (16735) 1996 JJ (3.1796 ± 0.0008 h and 0.436 mag).

The author operates a single telescope at Old Orchard Observatory (MPC Code Z09) in Somerset, United Kingdom, a 10-inch Meade LX200 f/10 telescope on a fork mount coupled with a Starlight Xpress 694 Trius Pro mono CCD. The images were measured, and period analysis were done using *TychoTracker Pro* which uses differential aperture photometry to determine the results.

The results are summarized in the table below. Column 3 gives the dates over which the observations were made. Column 4 is the range of phase angles over the whole date range, if this is preceded by an asterisk this means the asteroid reached a minima during the period. Columns 5 and 6 give the range of values for the Phase Angle Bisector (PAB) longitude and latitude respectively. Column 7 gives the period and column 8 the error in hours. Columns 9 and 10 give the amplitude and error in magnitude.

268 Adorea is a large main-belt asteroid, a member of the Themis group/family. Holliday (1995) previously reported a period of 9.44 hours while Tedesco (1979) reported a period of 6.1 hours. Behrend (2006web) reported a period of 15.595 h resulting in a four extrema light curve. Stephens (2006) reported a period of 7.8 hours. The 7.7952 hours is close to the preferred period listed on the known lightcurve periods maintained by Harris and Warner (Warner et al., 2009).

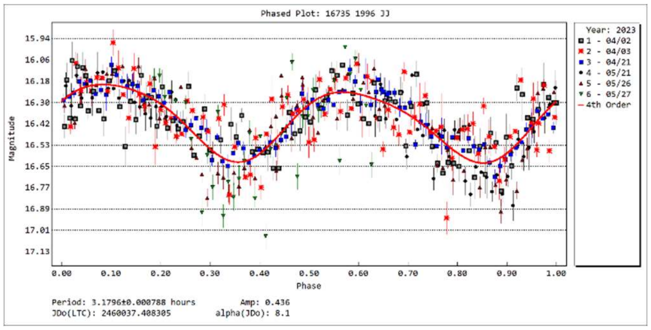


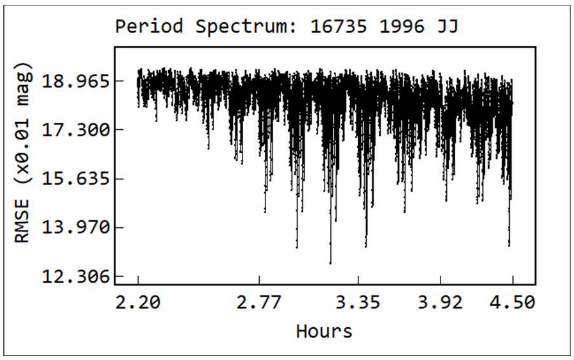


(16735) 1996 JJ an inner main-belt asteroid. Behrend (2003web) previously reported a rotation period of 3,1798 hours, this is in very close agreement with the figure reported here of 3.1796 hours.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
268	Adorea	2022 01/27-05/11	2.5,20.5	123	0	7.7952	0.0008	0.28	0.03	THM
16735	1996 JJ	2023 04/02-05/27	8.0,29.0	129	10	3.1796	0.0008	0.44	0.12	9104

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).





Acknowledgements

Thanks are given to Dr Richard Miles of the British Astronomical Association for all his support and encouragement and Daniel Parrott author of *TychoTracker Pro* for all his patience with my many questions.

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ROTATION PERIOD DETERMINATION FOR ASTEROID 8861 JENSKANDLER

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Photometric observations of the asteroid 8861 Jenskandler were conducted between 2023 April 14 and 2023 April 26 with the objective of estimating its rotation period. The preliminary rotation period was approximated at 2.9992 +/- 0.0019 hours. However, due to insufficient data, we were unable to ascertain the asteroid's lightcurve shape conclusively.

8861 Jenskandler is a main-belt asteroid first discovered on 1991 October 3. Named after astronomer Jens Kandler, who is credited with numerous asteroid discoveries at Drebach Observatory. This particular asteroid has a semi-major axis of 2.602 AU, an eccentricity of 0.206, inclination of 10.9577°, and an orbital period of 4.2 years. Its absolute magnitude is 13.2, and it has a diameter of approximately 14 km and a geometric albedo of 0.041 (JPL, 2016).

The University of Maryland authors observed asteroid 8861 Jenskandler on five nights between 2023 April 14 and 2023 April 26 from the Siding Springs Observatory located in Australia. We used a 0.43-m f/6.8 reflector telescope, a FLI ProLine PL4710 CCD camera with an array of 1024 × 1024 pixels, and a clear filter. The pixel scale was 0.92 arcsec when binned at 1×1 pixels and the exposures were 300 seconds long (iTelescope Support Document).

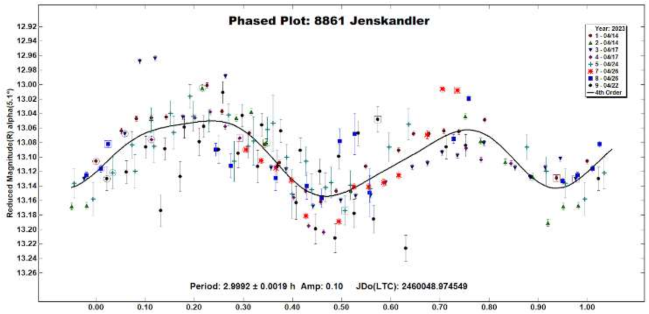
Charles Galdies observed from Znith Observatory, Naxxar, Malta using Moravian CCD G2-1600 with 0.20m SCT, C filter and 1×1 binning on 2023 April 22 and 2023 April 26.

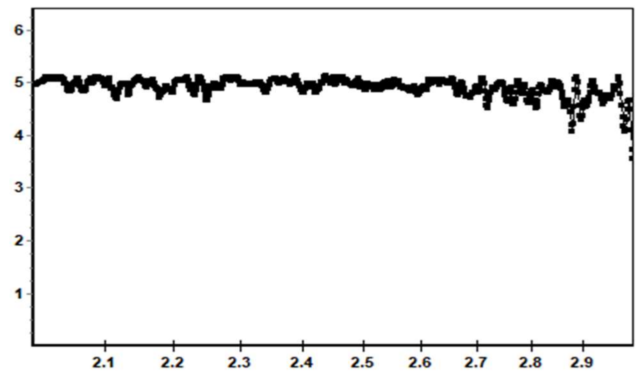
Data processing and analysis took place using *MPO Canopus*, and we used aperture photometry to find the differential magnitudes of the asteroid compared to the comparison stars (Warner, 2019). Phased lightcurves were obtained using the *MPO Canopus* fourier fitting function and examining the fits with the lowest RMS value, varying the parameters in order to find the best lightcurve and rotation period. The resulting observation geometry is given in the table.

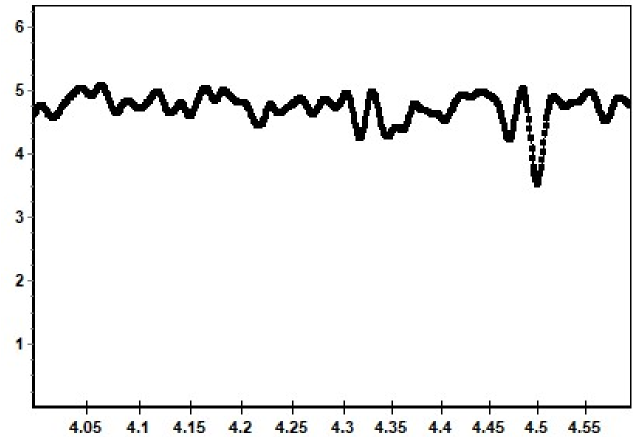
Before conducting our analysis, we checked the Asteroid Lightcurve Database (LCDB; Warner et al., 2009) and found that there were no previously-recorded rotation periods for this particular asteroid. Our analysis yielded two lightcurves. One fit the data with two maxima and minima, as is typical, with a period of 2.9992 +/- 0.0019 h. However, as seen from the figure, this lightcurve is quite noisy.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E	Grp
8861	Jenskandler	2023 4/14-4/26	*4.8, 1.7	212.4	-1.6	2.9992	0.0019	0.10	0.05	MB-A

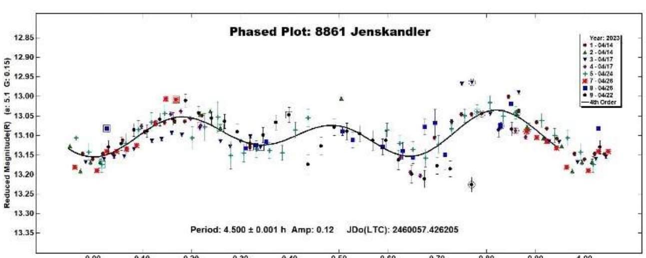
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. LPAB and BPAB are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).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







The second fit presents an odd scenario having three maxima and minima, indicating a potential irregularity in the asteroid's shape. The period is 4.500 +/- 0.001 h, which is an alias of the prior period. However, this phased plot is noticeably less noisy. The RMS plot displays a more distinct minimum for this period compared to the RMS for the 2.99-h period. This anomaly is not without precedent: there have been other instances of oddly- shaped asteroids yielding similar phased lightcurves, such as 1580 Betulia (Tedesco et al., 1978). Nevertheless, we prefer the 2.99 h period due to its more typical lightcurve and suspect the ambiguity is due to a lack of high-quality data in our lightcurve.



Acknowledgements

Funding for iTelescope observations was provided by the University of Maryland department of Astronomy. The iTelescope data from Siding Springs Australia made this research possible, while *MPO Canopus* (Warner, 2019) and DS9 made finding phased lightcurves possible.

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ROTATION PERIOD DETERMINATION OF 3214 MAKARENKO

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We report observations of the main-belt asteroid 3214 Makarenko in April 2023. Our results show P = 10.114 ± 0.015 h with an amplitude of 0.10 ± 0.04 mag.

3214 Makarenko was discovered on 1978 October 2 by Lyudmila Zhuravlyova at the Crimean Astrophysical Observatory in Crimea, Ukraine. This asteroid has an absolute magnitude of 11.57, a geometric albedo of 0.136, a diameter of 18.442 km, and an orbital period of 5.2315 years. With a semi-major axis of 3.0136 AU, it is located in the main belt between the orbits of Mars and Jupiter (NASA Small-Body Data Base).

According to the Asteroid Lightcurve Database, there are no previously found rotation periods for 3214 Makarenko (Warner et al., 2009).

The observations conducted of 3214 Makarenko were performed partly using the Beryl Junction observatory in Utah. The observations were completed using iTelescope T21 which is a Planewave 17" CDK that used a FLI-PL6303E CCD camera and used a pixel scale of 0.96 arcsec per pixel with an array of 3072 × 2048 (iTelescope Support Document). When observing, a luminance filter was used in order to be sure that all of the visible wavelengths are able to pass through. The exposure time of the images was set to 300 seconds and the binning was set to 1.

Additional observations of 3214 Makarenko were conducted at the Flarestar Observatory in San Gwann, Malta using a Meade SCT 0.25-m SCT telescope. The telescope had a Moravian G2-1600 CCD camera and used a pixel scale of 0.99 arcsec per pixel.

Analysis of the lightcurve was performed using *MPO Canopus* (Warner, 2012), using differential photometry techniques to determine the best polynomial approximation of the data. This period analysis gives a solution of P = 10.114 ± 0.015 h with an amplitude of 0.10 ± 0.04 mag.

This period gave a bimodal phased lightcurve, however, the two maxima are not spaced equally in the period, and one minimum is extended for about half of the period length. Because of this unusual lightcurve shape, more observations would be required to confirm period results.

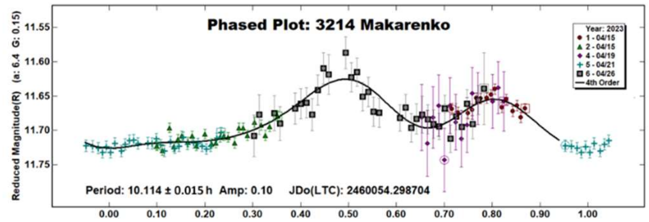

Figure 1. Phased lightcurve of 3214 Makarenko.

Acknowledgments

We would like to thank Hannah Suresh for her support and mentorship with data analysis. Additional thanks to the iTelescope team for continued access and assistance with their equipment.

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3214	Makarenko	2023 4/15-4/26	6.3,8.8	198.5	14.2	10.114	0.015	0.10	0.04	MBA

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 DETERMINATION OF ASTEROID 1821 ACONCAGUA

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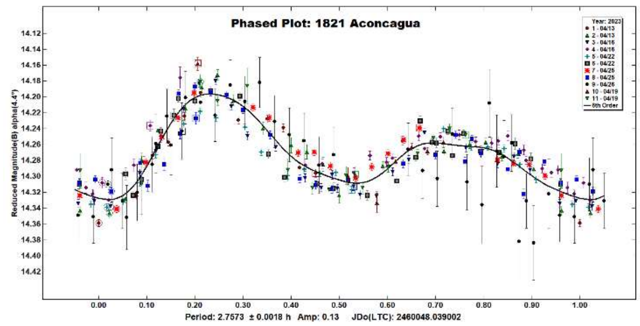
Lightcurve analysis was conducted on data from observations of main-belt asteroid 1821 Aconcagua between 2023 April 13 and 2023 April 26. Images were taken using two telescopes in Siding Spring, Australia and Naxxar, Malta. *MPO Canopus* was used for the data analysis, resulting in a rotation period determination of 2.7573 ± 0.0018 h, with amplitude 0.13 ± 0.02 mag.

1821 Aconcagua is a main-belt asteroid first discovered on 1950 June 24 by Miguel Itzigsohn. It has an eccentricity of 0.20, semi-major axis of 2.38 AU, orbital period of 3.67 years, inclination of 2.10°, and absolute magnitude of 13.30 (NASA JPL). The rotation period is currently unknown in the Asteroid Lightcurve Database (Warner et al., 2009). We present a lightcurve analysis to determine a rotation period for 1821 Aconcagua.

Images were collected during 13 nights between 2023 April 13 and April 26. The University of Maryland observers used the iTelescope T17 in Siding Spring, Australia (MPC Code: Q62) on April 13, April 16, April 19, April 22, and April 25. The Planewave 17" CDK telescope has a focal length of 2912mm and an aperture of 431mm. The FLI ProLine E2V CCD camera used has a pixel size of 9 µm square, array of 1024 × 1024 pixels, and a resolution of 0.92 arcsec/pix. The luminance filter was used for all observations.

Galdies observed from the Znith Observatory in Malta on April 26 using a 200mm SCT telescope with a Moravian G2-1600 CCD camera at 1 × 1 binning and a C filter.

A lightcurve analysis was performed on 234 images using *MPO Canopus* (version 10.7.12.9; Warner 2019). Images from each night were used to generate raw lightcurves, and lightcurves were generated before and after meridian flips when relevant. A typical two-peak and two-trough phased lightcurve was then generated using the raw lightcurves. The rotation period was determined to be 2.7573 ± 0.0018 h, with amplitude 0.13 ± 0.02 mag.



Acknowledgements

The authors would like to thank the Department of Astronomy at the University of Maryland, College Park for funding. They would also like to thank iTelescope for use of their telescope, and Lacey Allee-Press for support and assistance with *MPO Canopus*.

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1821	Aconcagua	2023 04/13-04/26	4.6	209.9	-2.9	2.7573	0.0018	0.13	0.02	MBA

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

ROTATION PERIOD DETERMINATION AND LIGHTCURVE ANALYSIS OF ASTEROID 1852 CARPENTER

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We report on photometric observations of the main-belt asteroid 1852 Carpenter that were acquired from 2023 April 13 to April 26. The observations yielded a synodic rotation period of 29.8685 ± 0.0185h and an amplitude of 0.41 ± 0.06 mag.

During 2023, photometric observations of main-belt asteroid 1852 Carpenter were carried out from two observatories located in Utah, United States and Malta, Europe. Observations were carried out on 5 nights beginning on 2023 April 13 until 2023 April 26.

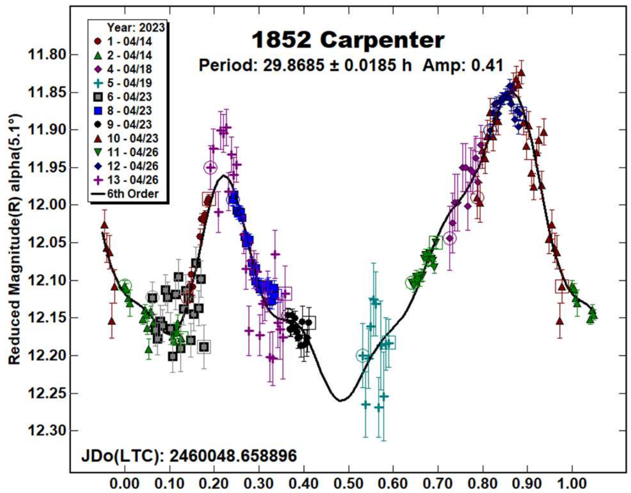
Observations from the Utah Desert Remote Observatory, MPC code U94, were conducted with telescope 21. T21 is a Deep Field Planewave 17” CDK telescope that uses a FLI-PL6303E CCD. It has a focal length of 1940mm, a pixel size of 9 µm square, an array of 3072 × 2048 pix, and resolution of 0.96 arcsec/pix. The luminance filter was used for all observations.

Observations were also obtained from Manikata Observatory, MPC code A40, in Malta using an OTA Meade 8in with a Mount Skywatcher EQ6-R Pro. The telescope utilized a SBIG ST10XMe CCD.

Photometric reduction, lightcurve construction, and period analyses were done using *MPO Canopus* software 10.7.12.9 (Warner, 2019). Differential aperture photometry was used and photometric measurements were based on the use of comparison stars of near-solar color that were selected by the Comparison Star Selector (CSS) utility available through *MPO Canopus*. Asteroid magnitudes for all nights except 2023 April 22 were based on the MPOSC3 catalog supplied with *MPO Canopus*. For the observation on the 22nd, we used the APASS catalog due to the dearth of comparison stars in the MPOSC3 catalog.

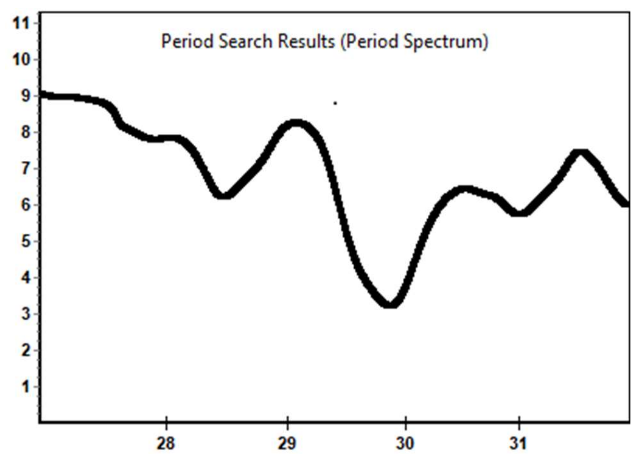
1852 Carpenter is a main-belt asteroid discovered on 1955 April 1 at the Goethe Link Observatory located in Indiana. This outer main-belt asteroid has a semi-major axis of 3.02 AU, an eccentricity of 0.06, a diameter of 21.38 km, and an absolute magnitude of 11.35 (JPL, 2020). Following a search of the Asteroid Lightcurve Database, we did not find any data previously recorded regarding a rotation period for this asteroid (LCDB, Warner et al., 2009).

Raw light curves were created for each night in *MPO Canopus* for data collected in Utah as well as Malta. In total, 208 images were used for analysis. After combining the individual raw lightcurves, we did Fourier analysis, adjusting the zero points of the magnitude system to find a lightcurve. The phased plot shows a fit with 6 orders, which has a full amplitude of 0.41 ± 0.06 mag and a potential lightcurve showing a period of 29.8685 ± 0.0185 h.



We experienced difficulty collecting data on a few nights due to excessive clouds and other weather conditions. This likely contributed to scatter in our phased plot and variance in uncertainties. Despite the scatter, the majority of data points in the lightcurve follow the reported shape well.

The period spectrum for this 21.38-km main-belt asteroid shows one primary solution. The Fourier analysis finds a pronounced RMS minimum between 29 h to 30 h. Further observations are needed to refine our lightcurve and overall period.



Number	Name	2023/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1852	Carpenter	04/13-04/25	5.0,6.7	202.1	13.3	29.8685	0.0185	0.41	0.06	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).

Acknowledgements

We would like to give thanks to the University of Maryland Astronomy Department for providing us with the resources and funding for this project. We would like to express our thanks to Melissa Hayes-Gehrke and Lacey Chanah Allee-Press for their unwavering support and without whom this report would not have been possible. We would also like to thank iTelescope for allowing us to use telescope T21, making our observations possible.

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PHOTOMETRY AND LIGHTCURVE ANALYSIS OF VESTA FAMILY ASTEROID (14645) 1998 XR9

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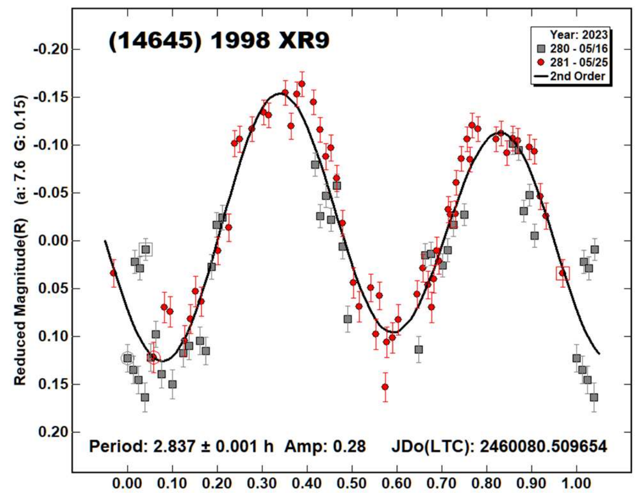
Photometric observations of the Vesta family asteroid (14645) 1998 XR9 were obtained, and a rotational period of 2.837 ± 0.001 h was determined, with a lightcurve amplitude of 0.28 mag.

Photometric observations of asteroid (14645) 1998 XR9 were obtained with the 0.6m telescope of the Southeastern Association for Research in Astronomy (SARA) consortium at Cerro Tololo Inter-American Observatory. The telescope is coupled with an Andor iKon-L series CCD. A detailed description of the instrumentation and setup can be found in the paper by Keel et al. (2017). The data was calibrated using *MaximDL* and photometric analysis was performed using *MPO Canopus* (Warner, 2021).

(14645) 1998 XR9 is a member of the Vesta family. The asteroid was chosen as only one prior measurement of the rotational period existed. (14645) 1998 XR9 was observed over two nights. The derived rotational period of 2.837 ± 0.001 h with an amplitude of 0.28 mag is in excellent agreement with the result previously obtained by Pál et al. (2020, 2.83685 h).



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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
14645	1998 XR9	2023 05/16,05/25	7.6,11.9	222	-0.6	2.837	0.001	0.28	0.02

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).

ROTATION PERIOD DETERMINATION FOR ASTEROID 5355 AKIHIRO

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Photometric observations of the main-belt asteroid 5355 Akihiro were conducted to determine its synodic rotation period. We found $P = 2.983 \pm 0.002$ h, $A = 0.13 \pm 0.04$ mag as the most likely bimodal solution.

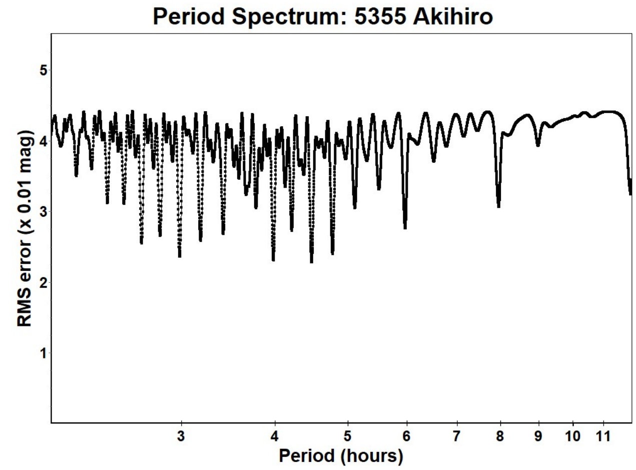
CCD photometric observations of the main-belt asteroid 5355 Akihiro were carried out in May 2023 at the Astronomical Observatory of the University of Siena (K54). We used a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E NABG CCD camera, and clear filter; the pixel scale was 2.30 arcsec when binned at 2×2 pixels and all exposures were 300 seconds.

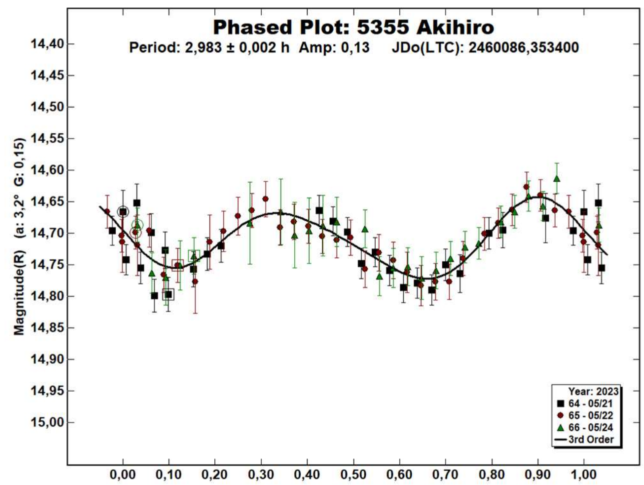
Data processing and analysis were done with *MPO Canopus* (Warner, 2018). All images were calibrated with dark and flat-field frames and the instrumental magnitudes converted to R magnitudes using solar-colored field stars from a version of the CMC-15 catalogue distributed with *MPO Canopus*. Table I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

5355 Akihiro (1991 CA) was discovered on 1991 February 3 by S. Ueda and H. Kaneda at Kushiro and named in honor of Akihiro Ueda, son of the first discoverer. It is an inner main-belt asteroid with a semi-major axis of 2.311 AU, eccentricity 0.168, inclination 0.745°, and an orbital period of 3.51 years. Its absolute magnitude is $H = 13.20$ (JPL, 2023). The WISE/NEOWISE satellite infrared radiometry survey (Masiero et al., 2011) found a diameter $D = 5.750 \pm 0.211$ km using an absolute magnitude $H = 12.9$.

Observations were conducted over three nights and collected 85 data points. The period analysis suggests a rotational period of $P = 2.983 \pm 0.002$ h with an amplitude $A = 0.13 \pm 0.04$ mag as the most likely bimodal solution.





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Number	Name	2023/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
5355	Akihiro	05/21-05/24	3.1,4.9	236	1	2.983	0.002	0.13	0.04	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).

A NEW LIGHTCURVE OF 357 NININA

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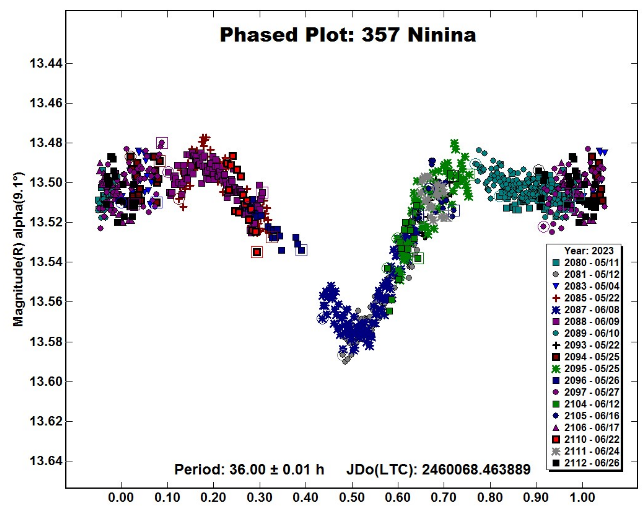
An international collaboration of observers from North America and Europe presents a lightcurve of the Earth commensurate asteroid 357 Ninina that shows a synodic rotation period 36.00 ± 0.01 hours, amplitude 0.08 ± 0.01 magnitudes with a single deep minimum in an otherwise nearly flat lightcurve.

Five previously published values of the rotation period of 357 Ninina, as presented in Warner et al. (2009), are all within 0.1 hours of the accepted best value of 35.983 hours. A new lightcurve was desired at a celestial longitude different from all those at which the previous observations were made to facilitate a lightcurve inversion study. With a rotation period almost exactly 1.5 Earth days, it is not possible to sample the entire lightcurve near a single opposition at a single observatory location. Therefore, the several authors of this paper, from both North America and Europe, agreed to collaborate. Their equipment is listed in Table I. Photometric 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 points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes.

Eighteen sessions 2023 May 4 - June 26 can be fitted to a lightcurve with period 36.00 +/- 0.01 hours, amplitude 0.08 +/- 0.01 magnitudes, with one deep minimum in each rotational cycle. The period is consistent with previously published periods. The monomodal lightcurve shape and small amplitude are encountered for many asteroids at near polar aspect. These new data will be useful for future LI modeling.



Observatory (MPC code)	**Telescope**	**CCD**	**Filter**
Organ Mesa Observatory (G50)	0.35-m SCT f/10	SBIG STL-1001E	C
Astronomical Observatory, University of Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e(bin 2x2)	Rc
Iota Scorpii(K78)	0.40-m RCT f/8	SBIG STXL-6303e (bin 2x2)	Rc
HOB Astronomical Observatory (L63)	0.20-m SCT f/6.0	ATIK 383L+	C
Osservatorio Astronomico Nastro Verde (C82)	0.35-m SCT f/6.3	SBIG ST10XME (bin 2x2)	C
GAMP (104)	0.60-m NRT f/4	Apogee Alta	Rc
Osservatorio Astronomico Margherita Hack (A57)	0.35-m SCT f/8.3	SBIG ST10XME (bin 2x2)	Rc

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

Number	Name	2023/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
357	Ninina	05/04 - 06/26	*10.7, 9.6	251	17	36.00	0.01	0.08	0.01

Table II. Observing circumstances and results. The phase angle is given for the first and last date, and the * indicates that a minimum (second value) was reached between these dates. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

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LIGHTCURVES ANALYSIS OF THREE MAIN-BELT ASTEROIDS: 3602 LAZZARO, 10468 ITACURUBA AND (53437) 1999 WL2

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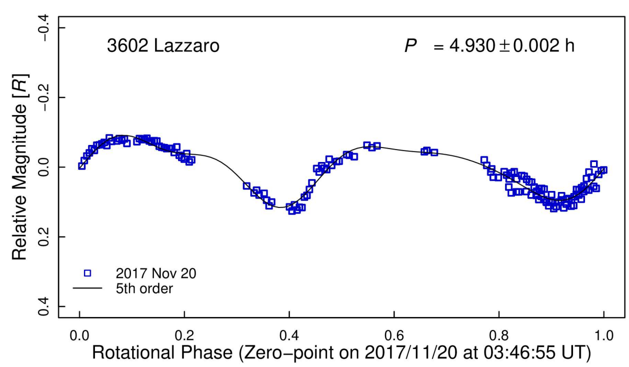
We present rotational lightcurves for three main-belt asteroids, 3602 Lazzaro, 10468 Itacuruba and (53437) 1999 WL2, obtained at the Observatório Astronômico do Sertão de Itaparica (OASI, MPC code Y28). For 3602 Lazzaro, we found a rotation period of 4.933 ± 0.002 h, for 10468 Itacuruba a period of 13.040 ± 0.002 h and for (53437) 1999 WL2 a period of 8.573 ± 0.004 h.

CCD photometric observations of three main-belt asteroids, 3602 Lazzaro, 10468 Itacuruba and (53437) 1999 WL2, were carried out at the Observatório Astronômico do Sertão de Itaparica (MPC code Y28, Nova Itacuruba). Images were obtained with the 1.0-m *f*/8 telescope (Astro Optik, Germany) of the IMPACTON project and a CCD Astra Apogee Instruments (2048×2048 pixels) that was binned 2×2. This configuration gave a field-of-view of 11.8×11.8 arcmin and an image scale of 0.343 arcsec/pix. More details on the available instrumentation at OASI are given in Rondón et al. (2020). All the observations were performed using sidereal tracking and an R-Johnson-Cousins filter. The exposure time varied depending on the asteroid's brightness and sky motion.

For the three asteroids, data processing and differential photometry measurements were performed using *MaxIm DL* package following the standard procedures of flat-field correction and sky subtraction. Relative magnitudes were computed to obtain the lightcurves and the rotation periods were determined using a Fourier series analysis method (Harris et al., 1989). In the figures below is given, for each asteroid, the composite lightcurve with different colors representing different nights and the line best fit.

The observational circumstances for each observed asteroid are given in Table I along with the results, which are discussed individually below. In this table we give for each obtained rotation period a reliability code (Warner et al., 2009).

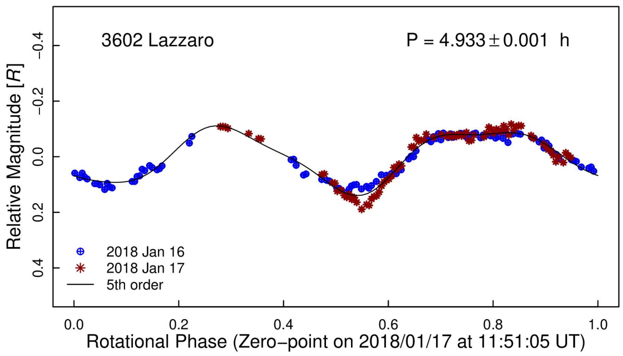
<u>3602 Lazzaro</u>. This asteroid was discovered at Siding Spring Observatory, Australia, by S.J. Bus on 1981 February 28. It has about 4.0 km of diameter and an albedo of 0.27 (Masiero et al., 2012). Lazzaro was observed on one night in April 2017 and two nights in January 2018. The April lightcurve fits a synodic period of $P = 4.930 \pm 0.002$ h. It has a small dispersion and small amplitude of 0.19 ± 0.01 mag, but it lacks a few points for complete coverage.



Number	Name	yyyy mm/dd	Exp	Phase	L_{PAB}	B_{PAB}	Period	P.E	Amp	A.E.	U
3602	Lazzaro	2017 11/20	90	10,5,10.4	75	-1	4.930	0.002	0.19	0.01	2
		2018 01/16-01/17	100	21.5	80	-3	4.933	0.001	0.25	0.02	3
10468	Itacuruba	2017 04/20-05/02	100	9.5,3.2	225	-3.4	13.04	0.002	0.25	0.02	1
53437	1999 WL2	2014 05/23-05/31	100	20.0,19.6	220	2.5	8.573	0.004	1.00	0.01	3

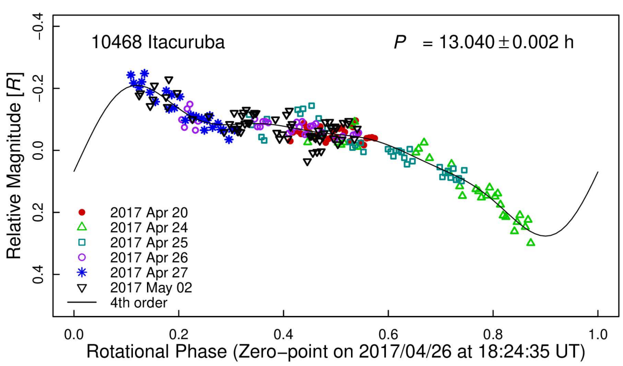
Table I. Observing circumstances. Exp is average exposure time, seconds. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude. The U rating is our estimate and not necessarily the one assigned in the asteroid lightcurve database (Warner et al., 2009).

On the other hand, the January lightcurve has a better coverage, with two well-defined maxima and minima. It fits a period of P = 4.933 ± 0.001 h, using a 5th-order Fourier fit, with a small amplitude of 0.25 ± 0.02 mag. Although this value has been determined from just two nights of observations, we consider the rotational period well-established. Previous result was reported by Waszczak et al. (2015), which found a rotational period of 4.9390 ± 0.0009 h, but it is based on incomplete data. In any case, their result is in good agreement with ours.

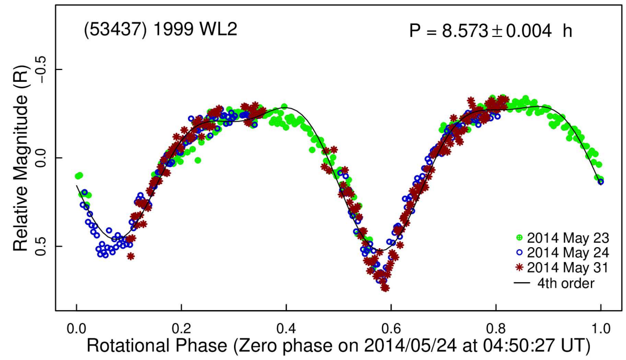


10468 Itacuruba. This main-belt asteroid was discovered at Siding Spring Observatory, Australia, by S.J. Bus on 1981 March. It was observed for about 23 hours from 20 April to 02 May 2017. With a diameter of about 2.0 km to 7.0 km, Itacuruba is also the name of the city in the state of Pernambuco, Brazil, where the site of the Observatório Astronômico do Sertão de Itaparica (OASI) is located. A Fourier analysis indicated a period of P = 13.040 ± 0.002 h, but this is based on incomplete coverage as seen in the monomodal lightcurve reported here.

Thus, it is possible that the true rotational period of Itacuruba is double the result reported by us. It is worth mentioning that we found no previously reported results for this asteroid in the Asteroid Lightcurve Database (Warner et al., 2009), or other resources.



(53437) 1999 WL2. This asteroid was observed for about 20 hours on three nights from 23 to 31 May 2014. According to Mainzer et al. (2011), this asteroid has 2.28 km and an albedo of 0.26. The 4th-order Fourier fit to the data revealed a period of P = 8.573 ± 0.004 h. The composite lightcurve reported here has two maxima and minima and an amplitude of 1.0 ± 0.02 mag which suggests an elongated shape, with $a/b \geq 2.5$. Previous result, based on less than full coverage, was reported by Pal et al. (2020), which found a rotational period of 8.57357 ± 0.00005 h.



Acknowledgements

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ROTATION PERIODS FOR 2707 UEFERJI AND (23552) 1994 NB

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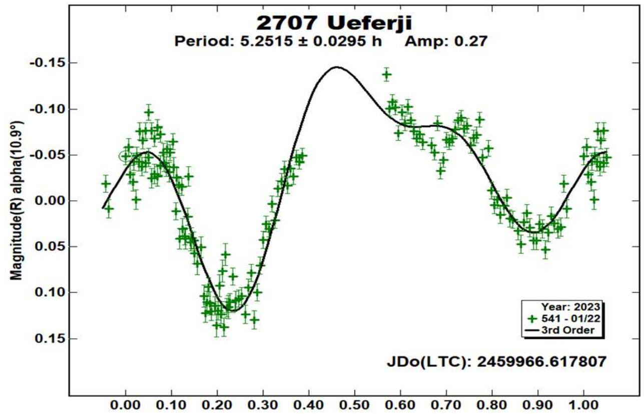
We present photometric optical lightcurves and derived rotation periods for a sample of two asteroids: 2707 Ueferji (P = 5.2515 ± 0.0295 h) and (23552) 1994 NB (3.628 ± 0.001 h). Observations were carried out at the Observatorio Astronómico Carl Sagan (OACS) of the Universidad de Sonora in Hermosillo, México.

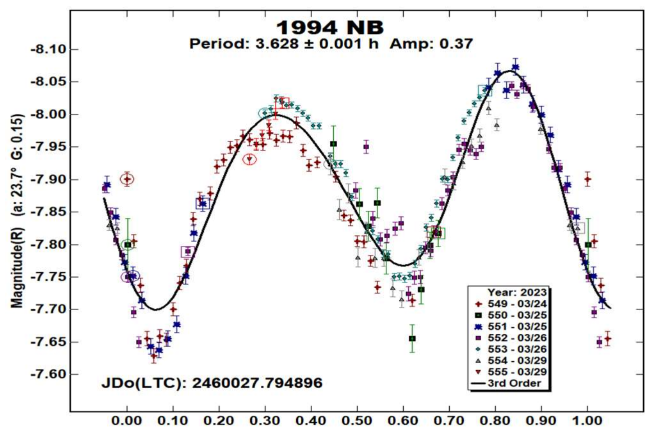
As part of our permanent campaign of asteroid observation at the Carl Sagan Astronomical Observatory, we obtained photometric data for two main belt asteroids (2707 Ueferji and 1994 NB). Asteroid observation provides an excellent opportunity to prepare students in observational techniques and data reduction as well as obtaining results such as lightcurves and rotation periods, and a way to fully take advantage of nearby astronomical facilities. This campaign was aimed to accomplish the above-mentioned objectives.

The equipment used at the OACS was a 512×512×20 μm SBIG ST-9 CCD camera mounted on a Meade LX- 200GPS 0.41-m *f*/10 telescope. Images yielding a final plate scale of 1.03 arcsec/pix and an effective 9×9 arcmin FOV. Data reduction was made with *IRAF* or *MaxímDL* following standard procedures to correct for bias, dark current and flat-field effects. Photometry and lightcurve analysis were made using *MPO Canopus (*V.10.8.6.15*,* Warner*,* 2023) software package, which allowed us to obtain the synodic period for each object.

2707 Ueferji (1981 QS3) was discovered in 1981 August 28 by H. Debehogne at La Silla Observatory (Schmadel, 2003) and was originally named 1981 QS3. Ueferji is a main-belt asteroid and has a size of 25 km, absolute magnitude H=11.84 and albedo of 0.082. We observed Ueferji during the night of January 22 for 6.5 h. A period of P = 5.2515 ± 0.0295 h was obtained with a lightcurve amplitude of A = 0.27 mag using a 3rd order fit. These values are similar to the one reported on the LCDB (REV. 2023-February) by Warner et al. (2009) of P=5.286 h. Both results come from less than complete lightcurves. Further observation of this object was impossible due to weather.



(23552) 1994 NB. Discovered by E.F. Helin, at Palomar Observatory on 1994 Sep 3 (Schmadel, 2003). This asteroid has an absolute magnitude H=13.7. We observed 1994 NB during 4 nights in 2023 May. A period of P = 3.628 ± 0.001 h was obtained with a 3rd order fit and with a lightcurve amplitude of A = 0.37 mag. A similar result P = 3.63 h was reported in the LCDB (REV. 2023-February) by Warner et al. (2009).



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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2707	Ueferji	2023 01/22	10.8	93.5	1	5.2515	0.0295	0.27	0.05	MB
23552	1994 NB	2023 03/24-03/29	23.7,23.9	191.9	33	3.628	0.001	0.37	0.09	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).

ASTEROID PHOTOMETRY OF SEVEN ASTEROIDS

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(MPC G05) - Piconcillo (Córdoba-España)

Observatorio Astronómico El Gato Gris
(MPC I19) - Tanti (Córdoba-Argentina)

Observatorio de Sencelles
(MPC K14) - Sencelles (Mallorca-Islas Baleares-España)

Osservatorio Astronomico "La Macchina del Tempo"
(MPC M24) - Ardore Marina (Reggio Calabria-Italia)

Observatorio Los Cabezones
(MPC X12) - Santa Rosa (La Pampa-Argentina)

Observatorio Galileo Galilei
(MPC X31) - Oro Verde (Entre Ríos-Argentina)

Observatorio Antares
(MPC X39) - Pilar (Buenos Aires-Argentina)

Observatorio Río Cofio
(MPC Z03) - Robledo de Chavela (Madrid-España)

Specola "Giuseppe Pustorino 3"
(GORA GC3) - Palizzi Marina (Reggio Calabria-Italia)

Observatorio de Ariel Stechina 2
(GORA OA2) - Reconquista (Santa Fe-Argentina)

Observatorio de Damián Scotta 1
(GORA ODS) - San Carlos Centro (Santa Fe-Argentina)

Observatorio de Damián Scotta 2
(GORA OD2) - San Carlos Centro (Santa Fe-Argentina)

Observatorio Astronómico Municipal Reconquista
(GORA OMR) - Reconquista (Santa Fe-Argentina)

Observatorio de Raúl Melia Carlos Paz
(GORA RMG) - Carlos Paz (Córdoba-Argentina)

(Received: 2023 May 24)

Synodic rotation periods and amplitudes are reported for: 957 Camelia, 1030 Vitja, 1135 Colchis, 1903 Adzhimushkaj, (97034) 1999 UK7 A and B components, (97514) 2000 DL1, and (199145) 2005 YY128.

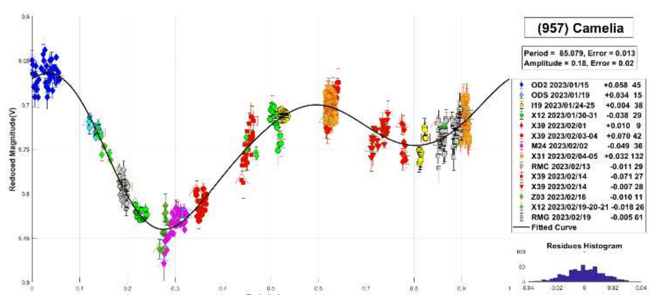
The periods and amplitudes of asteroid lightcurves presented in this paper are the product of collaborative work by the GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In all the studies, we have applied relative photometry assigning V magnitudes to the calibration stars.

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).

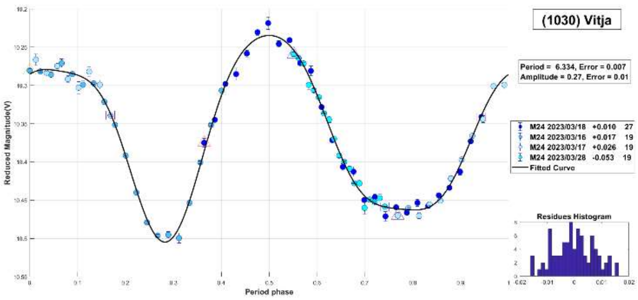
Below, we present the results for each asteroid studied. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - 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, 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.

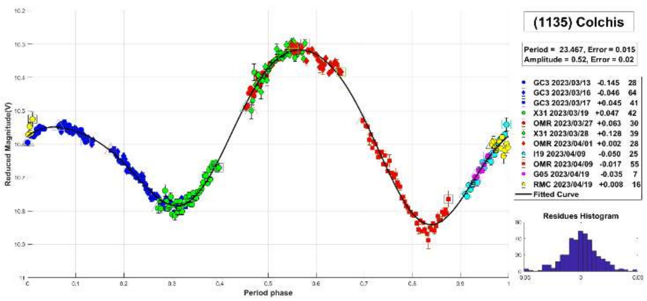
957 Camelia. It is a main-belt asteroid. It was discovered in 1921 by K. Reinmuth. Two authors measured a short period for this asteroid: P = 5.391 ± 0.02 h (Warner, 2001) and P = 8.894 ± 0.004 h (Behrend, 2020web). On the other hand, Polakis (2022a) published a longer period of 85.05 ± 0.11 h. The results we obtained are P = 85.079 ± 0.013 h and Δm = 0.18 ± 0.02 mag. Our period well agrees with the one measured by Polakis. The diagram published by Polakis has the virtue of having extended light curves of many hours each. The light curve presented in this paper has the advantage of showing several light curves with linked nights.



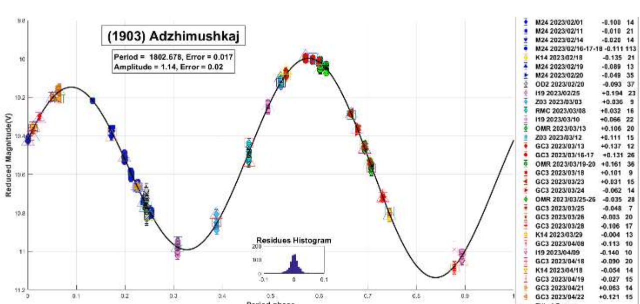
1030 Vitja. It is a main-belt asteroid. It was discovered in 1924 by V. Albitzkig. The three most recent periods published in the literature correspond to P = 6.332 ± 0.001 h (Ferrero, 2014), P = 6.336378 ± 0.000002 h (Ďurech et al., 2019), and P = 6.346 ± 0.008 h (Polakis. 2022b). We have determined a period of 6.334 ± 0.007 h, which is consistent with those previous results. Notably, we present full coverage lightcurve in this work, in contrast to those previously published.



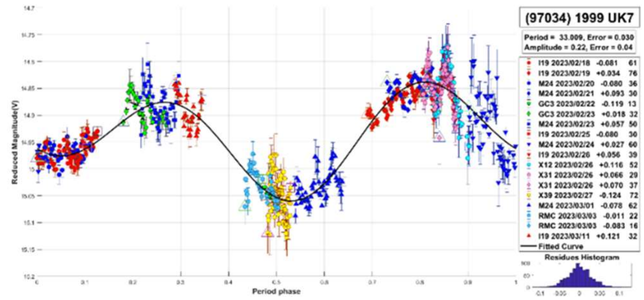
1135 Colchis. It is a main-belt asteroid. It was discovered in 1929 by G. Neujmin. Recent periods in the literature (Hanus et al., 2016; Behrend, 2016web) coincide with the period formerly measured by Hanuš et al., (2016): P = 23.483 h. However, these authors did not present lightcurves with full coverage. In this paper, we present full lightcurve coverage, thus giving confidence to our result. We measured a period of 23.467 ± 0.015 h with Δm = 0.52 ± 0.02 mag.

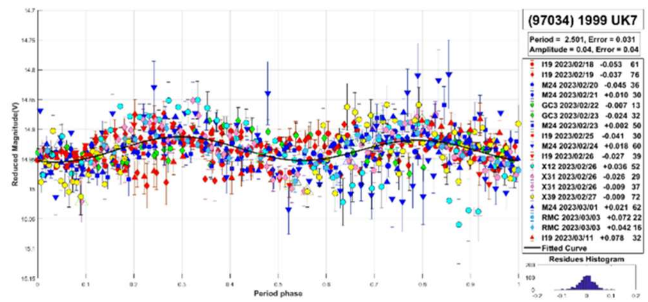


1903 Adzhimushkaj. It is a main-belt asteroid. It was discovered in 1972 by T. Neujmin. We found in the literature two rather different periods calculated for this object: P = 46.65685 ± .0006 h (Ďurech et al., 2020) and P = 1783.8 ± 3.6 h with Δm = 1.17 ± 0.06 mag (Polakis, 2022c). Our period P = 1802.678 ± 0.017 with Δm = 1.14 ± 0.02 mag agrees with the one measured by Polakis. This object is the slowest rotator measured by our group. It was achieved using 668 images taken between February 1 and March 29, 2023. Moreover, its period of about 75 Earth days is one of the slowest known so far by the scientific community (according to the Asteroid Lightcurve Photometry Database).

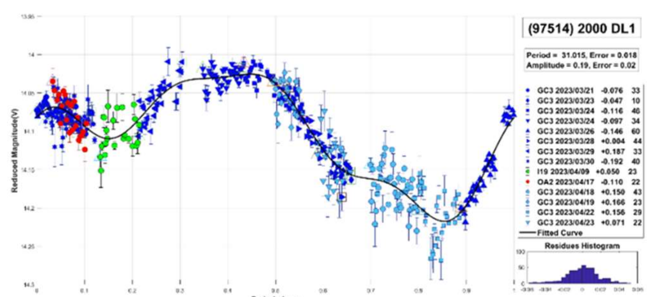


(97034) 1999 UK7 (A & B). It is a Mars-crossing asteroid. It was discovered in 2000 by LINEAR. On March 6, 2023, it had a close encounter with our planet, with a minimum distance of 0.38 AU. We present two diagrams for this asteroid: one of higher amplitude and period, the second of lower amplitude and period, whose curve we detect mounted on the first one. We observed a pattern with two peaks and two valleys in the span of 2.5 h, accompanied by increases or decreases in brightness that showed that we were in the presence of a period of greater amplitude and period. This behavior led us to assume binarity, as confirmed by telegram CBET 5232: 20230312. We obtained a second period of 33.009 ± 0.003 h with Δm = 0.22 ± 0.04 mag. On the other hand, for the primary, we measured a period of 2.501 ± 0.031 h with Δm = 0.04 ± 0.04 mag.

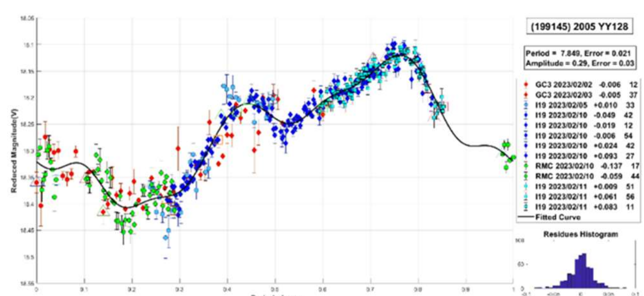




(97514) 2000 DL1. It is a Mars-crossing asteroid. It was discovered in 2000 by LINEAR. We could not find a reported period for this object in the literature. In this paper, we present full lightcurve coverage. We measured a period of 31.015 ± 0.018 h with Δm = 0.19 ± 0.02 mag.



(199145) 2005 YY128. It is an Apollo and potentially hazardous asteroid. It was discovered in 2005 by Spacewatch. On February 16, 2023, it had a close encounter with our planet, with a minimum distance of 0.08 AU. For this asteroid, we could not find a published period in the literature, either. In this work, we propose a period of P = 7.849 ± 0.021 h with Δm = 0.29 ± 0.03 mag.



Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
957	Camelia	23/01/15-23/02/21	*11.3,10.4	135	-19	85.079	0.013	0.18	0.02	MB-O
1030	Vitja	23/03/18-23/03/29	12.3,08.4	206	4	6.334	0.007	0.27	0.01	MB-O
1135	Colchis	23/03/13-23/04/20	*3.0,11.6	179	-1	23.467	0.015	0.52	0.02	MB-M
1903	Adzhimushkaj	23/02/01-23/04/22	*2.4,20.1	138	2	1802.678	0.017	1.14	0.02	Eos
97034	1999 UK7 (A)	23/02/18-23/03/11	*17.7,14.6	167	-5	33.009	0.030	0.22	0.04	M-cr
97034	1999 UK7 (B)	23/02/18-23/03/11	*17.7,14.6	167	-5	2.501	0.031	0.04	0.04	M-cr
97514	2000 DL1	23/03/21-23/04/23	10.5,26.9	174	1	31.015	0.018	0.19	0.02	M-cr
199145	2005 YY128	23/02/02-23/02/11	*21.8,26.9	149	-5	7.849	0.021	0.29	0.03	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 extremum 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). MB-O: main-belt outer, MB-M: main-belt middle, Eos: 221 Eos, M-cr: Mars-crosser, NEA: near-Earth asteroids.

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
X31 Obs.Astr.Galileo Galilei	RCT ap (D=405mm; f=8.0)	CCD SBIG STF-8300M
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
GC3 Specola Giuseppe Pustorino 3	RCT (D=400mm; f=5.7)	CCD Atik 383L+Mono
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
OMR Obs.Astr.Municipal Reconquista	Newtonian (D=254mm; f=4.0)	Player One Ceres-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.

Acknowledgements

We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analyses, Fernando Mazzone for his *Periods* program, 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 (*http://sbn.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.

We dedicate this work to our dear Aldo Mottino. A great person, researcher at CONICET, renowned astrophotographer in our amateur community in our country, and member and co-founder of GORA. Thank you for sharing your love for astronomy with us over these years. May your memory and your passion be with us always.

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LIGHTCURVES FOR KORONIS FAMILY OBJECTS (2498) TSESEVICH AND (2742) GIBSON

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We present lightcurves for (2498) Tsesevich and (2742) Gibson during 2022. Observations of Tsesevich made at the Union College Observatory are consistent with the previous period (Wilkin and Schechter, 2022). Observations of Gibson on two nights at Chi-4 yielded a partial lightcurve which we combined with ATLAS sparse survey data to obtain a doubly-periodic composite with period 20.60±0.01 h.

We continue our project (Wilkin et al., 2022; Wilkin et al., 2023; Crowley and Wilkin, 2023) to obtain rotation periods and lightcurves for Koronis family asteroids to facilitate subsequent shape and spin solutions. Asteroid spins are subject to YORP torques (Rubincam, 2000) due to interaction with sunlight and subsequent thermal emission. Observations of members of a common family avoid difficulties of interpreting heterogenous samples (see, e.g., Slivan et al., 2008; 2023).

Observation planning was performed using the *Koronisfamily.com* webtool (Slivan, 2003). Telescope and camera properties are given in Table I. Bias, dark, and flat field corrections and subsequent photometry were performed in *AstroImageJ* (Collins et al., 2017). Corrections for light-travel time, unit distance, and solar phase angle were applied using ephemerides from the NASA Horizons app assuming a slope parameter G=0.23 typical for Koronis family members (Slivan, personal communication).

(2498) Tsesevich. Period determinations and lightcurves have been published by Fauerbach and Brown (2019) and Wilkin and Schechter (2022). We performed imaging observations at the Union College Observatory on two nights in September, 2022 with 240s exposure time, R filter and 2×2 binning. Significant light pollution was present due to nearby athletic facilities, and images from a third night had to be rejected. Magnitude values for Sep 24 were shifted relative to those of Sep 16 to obtain a self-consistent composite. Our resulting lightcurve is consistent with the period obtained from the previous apparition (Wilkin and Schechter, 2022), assuming that the lightcurve is doubly-periodic. The amplitude 0.26 mag was the same as in the 2021 apparition. We also examined ATLAS sparse survey data (Tonry et al., 2018) for 2022 at telescope T08 in the o filter (orange, 560-820 nm) folded at the same 2.8734-h period, which results in a similar lightcurve (not shown).

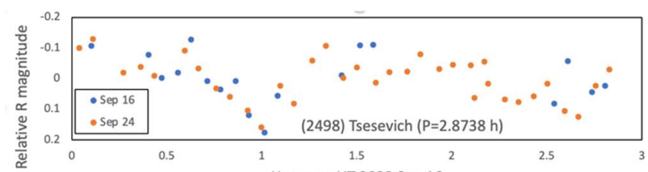

Figure 1. Lightcurve for (2498) Tsesevich.

(2742) Gibson. No previously published lightcurves for Gibson were found in the literature and no rotation period was listed on the NASA Horizons system. We obtained imaging observations of Gibson on two nights at the telescope Chi-4 operated by *Telescope.Live*. Exposures in color-separation Red filter were 300s and unbinned. Each individual night showed significant variation, but neither exhibited an unambiguous local extremum. A common comparison star was used for both nights to create a partial lightcurve (see Fig. 2), but these two nights were insufficient to establish a unique period. Additionally, a gradient of background across the images on Sep 06 suggests that the relative calibration of the two nights is slightly ambiguous.

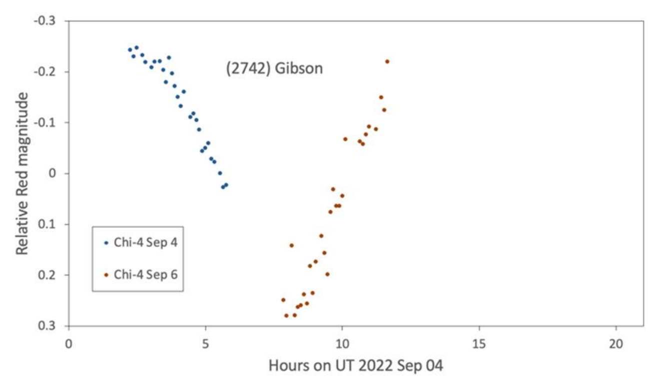

Figure 2. Partial lightcurve for (2742) Gibson from Chi-4 folded at P=20.60 h.

Name	Site	Telescope	Camera	Array	Filter	FOV(')	Scale ("/pix)
UCO	Schenectady, NY	0.50-m RC f/8.1	SBIG STXL-11002	2004×1336x9μm	R	30×20	0.93
Chi-4	Rio Hurtado, Chile	0.50-m RC f/6.8	FLI PL16803	4096×4096x9μm	Red	65×65	0.96

Table I. Telescopes and Cameras. RC=Ritchey-Chrétien; CDK = Planewave with f/4.5 focal reducer. UCO = Union College Observatory

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2498	Tsesevich	2022 09/16-09/24	4.0,0.5	2	1	2.8738	0.0002	0.26	0.04	MB-KOR
2742	Gibson	2022 09/04-09/06	3.2,4.0	334	-2	20.60	0.01	0.60	0.05	MB-KOR

Table II. Observing circumstances and results. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range. Grp is the asteroid family/group.

We supplemented our observations with sparse survey data from the ATLAS project in o filter on three telescopes, constrained in time between the two stationary points in 2022. We then shifted our Chi-4 magnitudes to produce a smooth composite with those of the ATLAS telescopes, including a small additional shift between the two nights on Chi-4. A search for consistent period in the range 9-100 h led to a best-fit, doubly-periodic lightcurve with period 20.60 ± 0.01 h (see Fig. 3). An alternate, singly-periodic solution with half of that period or a quadruply-periodic solution at double this period can be excluded, despite the nearly equal maxima, due to the large amplitude ~0.60 mag in Red (Harris et al., 2014).

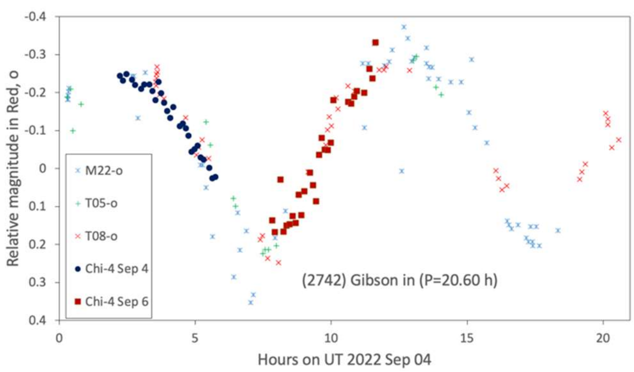

Figure 3. Composite lightcurve for (2472) Gibson.

Acknowledgements

We thank Dr. Stephen Slivan for helpful advice during the course of this study and for running his periodogram calculation for (2742). FPW received financial support from the Union College Faculty Research Grant. This work has also made use of data and services provided by the International Astronomical Union's Minor Planet Center; specifically, the brightnesses accompanying astrometry from the Asteroid Terrestrial-impact Last Alert System (ATLAS) survey observing program.

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COLLABORATIVE ASTEROID PHOTOMETRY FROM UAI: 2023 APRIL-JUNE

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Alessandro Coffano, Wladimiro Marinello
Osservatorio Serafino Zani (130), Lumezzane (BS), ITALY

Paolo Fini, Guido Betti
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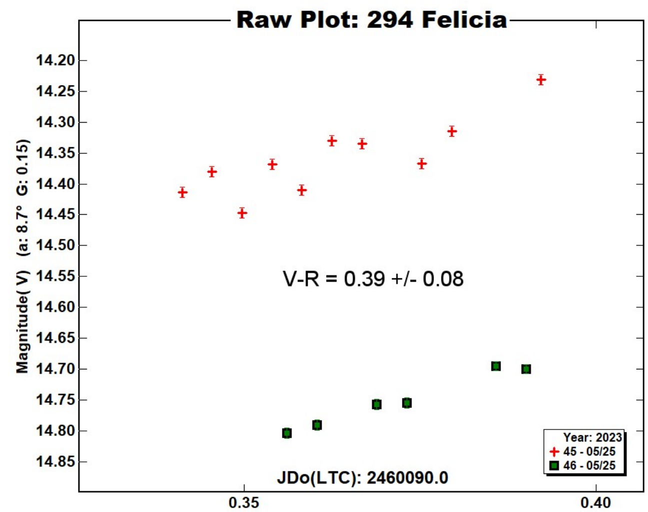
(Received: 2023 July 10)

Photometric observations of five asteroids were made in order to acquire lightcurves for shape/spin axis modeling. Synodic periods and lightcurve amplitudes were found for 1166 Sakuntala, 1929 Kollaa, 3443 Leetsungdao, and 2020 DB5. We also found color indices for 294 Felicia, 1166 Sakuntala, and 2020 DB5.

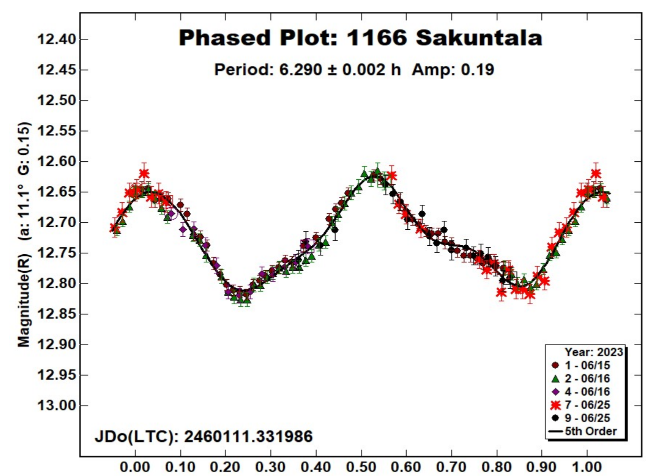
Collaborative asteroid photometry was done inside the Italian Amateur Astronomers Union (UAI; 2023) group. The targets were selected mainly in order to acquire lightcurves for shape/spin axis modeling. Table I shows the observing circumstances and results.

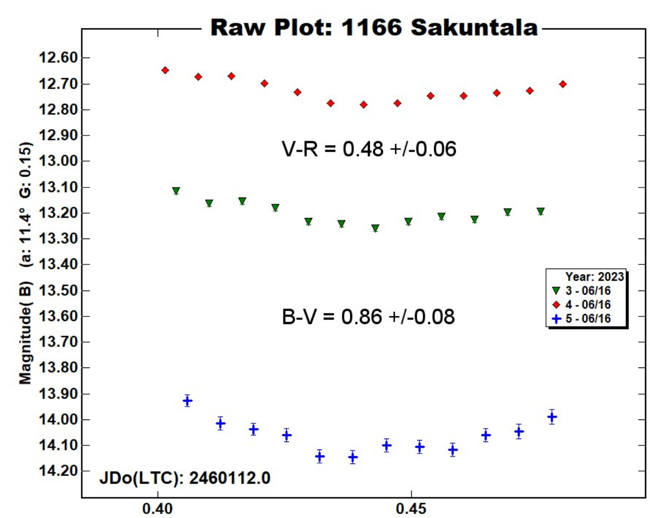
The CCD observations of five asteroids were made in 2023 April-June using the instrumentation described in the Table II. Lightcurve analysis was performed at the Balzaretto Observatory with *MPO Canopus* (Warner, 2021). All the images were calibrated with dark and flat frames and converted to standard magnitudes using solar-colored field stars from CMC15 and ATLAS catalogues, distributed with *MPO Canopus*. For brevity, the following citations to the asteroid lightcurve database (LCDB; Warner et al., 2009) will be summarized only as "LCDB".

294 Felicia is a low-albedo outer main-belt asteroid. Multiband photometry was made by P. Fini and G. Betti (L73) on 2023 May 25. We found V-R = 0.39 ± 0.08, which is close to a C-type asteroid (Shevchenko and Lupishko, 1998).

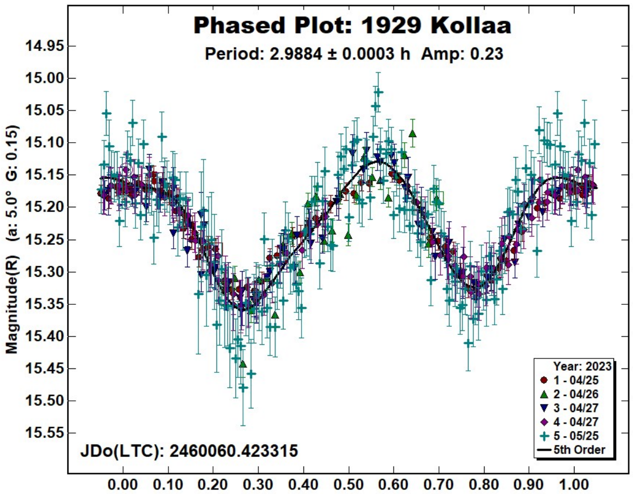


1166 Sakuntala is a medium-albedo middle main-belt asteroid. Collaborative observations were made over four nights. The period analysis shows a synodic period of P = 6.290 ± 0.002 h with an amplitude A = 0.19 ± 0.01 mag. The period is close to the previously published results in the LCDB. Multiband photometry was made by N. Montigiani and M. Mannucci (A57) on 2023 June 16. We found B-V = 0.86 ± 0.08 and V-R = 0.48 ± 0.06, which are consistent with a S-type asteroid (Shevchenko and Lupishko, 1998).

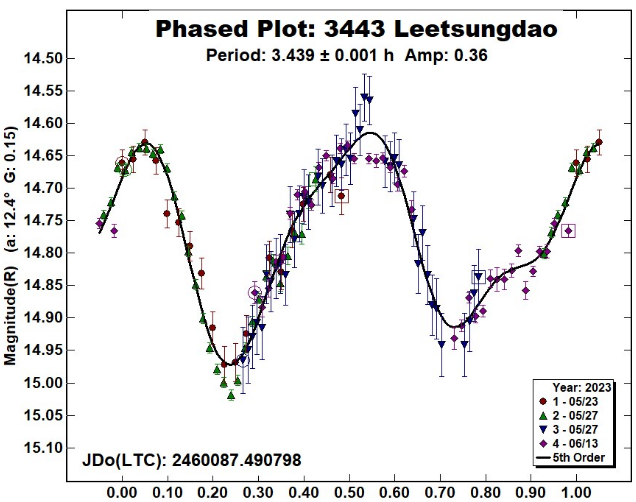




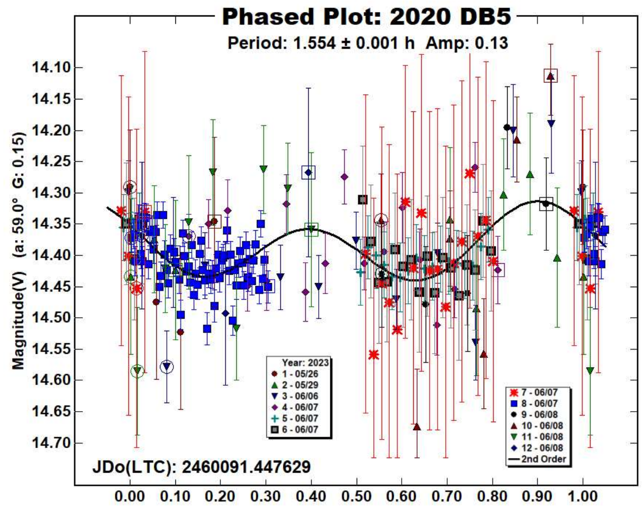
1929 Kollaa is a V-type (Bus and Binzel, 2002) inner main-belt asteroid. Collaborative observations were made over four nights. The period analysis shows a synodic period of *P* = 2.9884 ± 0.0003 h with an amplitude *A* = 0.23 ± 0.07 mag. The period is close to the previously published results in the LCDB.

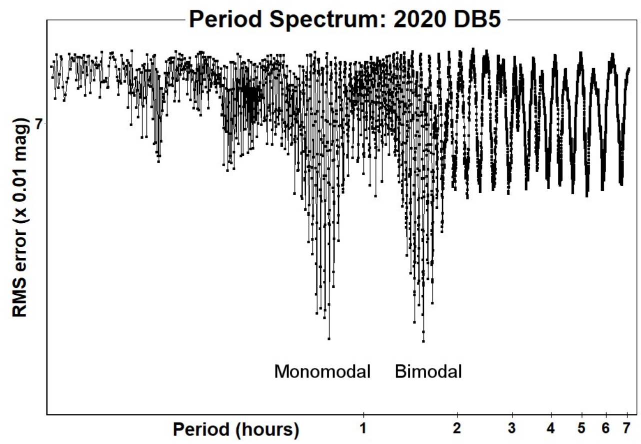


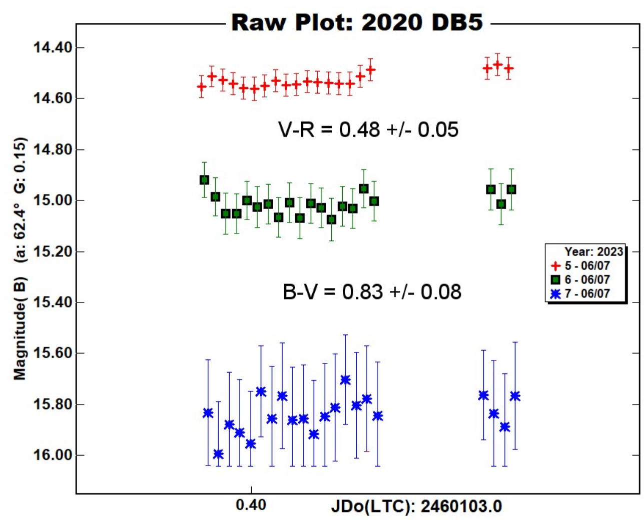
3443 Leetsungdao is a T-type (Bus and Binzel, 2002) inner main-belt asteroid. Collaborative observations were made over three nights. The period analysis shows a synodic period of *P* = 3.439 ± 0.001 h with an amplitude *A* = 0.36 ± 0.05 mag. The period is close to the previously published results in the LCDB.



2020 DB5 is an Amor Near-Earth asteroid. Collaborative observations were made over four nights, before its close approach to the Earth. We found a bimodal solution with a synodic period of *P* = 1.554 ± 0.001 h and an amplitude *A* = 0.13 ± 0.10 mag. For this asteroid no periods were found in the LCDB. Multiband photometry was done by P. Bacci and M. Maestripieri (104) on 2023 June 7. We found color indices of B-V = 0.83 ± 0.08 and V-R = 0.48 ± 0.05, which are close to a medium-albedo S-type asteroid (Shevchenko and Lupishko, 1998).







Number	Name	2023 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
294	Felicia	05/25	8.7	223	8					MB-O
1166	Sakuntala	06/15-06/25	11.0, 14.3	253	13	6.290	0.002	0.19	0.01	MB-M
1929	Kollaa	04/25-05/25	4.9, 17.1	209	5	2.9884	0.0003	0.23	0.07	MB-I
3443	Leetsungdao	05/23-06/13	12.7, 21.7	235	16	3.439	0.001	0.36	0.05	MB-I
	2020 DB5	05/26-06/08	58.9, 62.0	221	18	1.554	0.001	0.13	0.10	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)
HOB Astronomical Observatory (L63)	0.20-m SCT f/6.0	ATIK 383L+	C,V, Rc	3443(1), 2020 DB5(6)
Osservatorio Astronomico Nastro Verde (C82)	0.35-m SCT f/6.3	SBIG ST10XME (bin 2x2)	C	1929(1), 3443(2), 2020 DB5(1)
GAMP (104)	0.60-m NRT f/4.0	Apogee Alta	C,B, V,Rc	1929(2), 2020 DB5(1)
Astronomical Observatory, University of Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e(bin 2x2)	Rc	1166(2), 1929(1)
M57 (K38)	0.35-m RCT f/5.5	SBIG STT1603ME	V,Rc	1166(2)
Osservatorio Serafino Zani (130)	0.40-m RCT f/5.8	SBIG ST8 XME (bin 2x2)	C	1929(1)
Blessed Hermann Observatory (L73)	0.30-m SCT f/6.0	QHY 174MGPS (bin 2x2)	V,Rc	294(2)
Iota Scorpii(K78)	0.40-m RCT f/8.0	SBIG STXL-6303e (bin 2x2)	Rc	3443(1)
Osservatorio Astronomico Margherita Hack (A57)	0.35-m SCT f/8.3	SBIG ST10XME (bin 2x2)	B,V, Rc	1166(1)

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

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LIGHTCURVES, H-G CURVES AND COLOR INDICES FOR THREE MINOR PLANETS

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Photometric measurements were made for three main-belt asteroids based on CCD observations made from 2023 April through June. Phased lightcurves are presented, followed by phase-slope parameter analyses based on 30 nights of data. Three color indices were computed for each asteroid. All the lightcurve data have been submitted to the ALCDEF database.

CCD photometric observations of three main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe, AZ. Images were taken using a 0.32-m *f*/6.7 Modified Dall-Kirkham telescope and an SBIG STXL-6303 CCD camera. A 'clear' glass filter was used for lightcurve and phase-slope (H-G) parameter observations, and photometric B, V, R, and I filters were used on one night to compute color indices. Exposure time for all the images was 60 seconds. The image scale after 2×2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and period solution results. All of the images for these asteroids were obtained between 2023 April and June.

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

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2023). The 45′×30′ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of 0.5 < B-V < 0.95 to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. *MPO Canopus* plots instrumental vs. catalog magnitudes for solar-colored stars, which is useful for selecting comp stars of suitable color and brightness.

Since the goal of this effort was to determine H-G parameters, magnitudes were reduced to Johnson V. Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *MPO Canopus*. The ATLAS catalog derives magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required.

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

Asteroids were selected from the "Low Phase-Angle Opportunities" section in the *Minor Planet Bulletin* (Warner et al., 2023). These are bright asteroids with short periods and small amplitudes. The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All the new data for these asteroids can be found in the ALCDEF database.

H-G Parameters and Absolute Magnitudes

The H-G parameter is determined by plotting absolute magnitude against phase angle. This curve will be linear when the phase is larger than 7°, but bows upward at lower phase values due to the opposition effect. Fewer data points are required to define the linear portion of the curve. Each data point on an H-G curve represents a night of observations, after which the average magnitude was computed.

Determining average magnitude can be problematic for asteroids with rotation periods longer than the observing session. An asteroid with low orbital inclination is necessarily well away from opposition at large phase angles, and only available for observation for a portion of the night. High amplitudes with differing pairs of maxima and minima also introduce error into the determination of an average value. Viewing the night's data points on a phased lightcurve helps in locating time points to calculate average magnitude from a raw lightcurve.

Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
19	Fortuna	23/04/14-06/07	*15.7,5.0	245	1	7.44306	0.00018	0.23	0.03	MB-I
150	Nuwa	23/04/11-06/07	*11.7,6.9	238	1	8.13374	0.00019	0.17	0.02	MB-O
423	Diotima	23/04/11-06/07	*13.5,5.9	241	3	4.77575	0.00006	0.18	0.03	EOS

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).

Number	Name	H	H err	G	G err	B-V	B-V err	V-R	V-R err	R-I	R-I err
19	Fortuna	7.241	0.012	0.163	0.022	0.706	0.015	0.355	0.012	0.349	0.030
150	Nuwa	8.508	0.009	0.110	0.017	0.681	0.043	0.377	0.013	0.349	0.023
423	Diotima	7.531	0.011	0.160	0.020	0.664	0.019	0.368	0.013	0.332	0.016

Table II. Absolute magnitudes, phase-slope parameters, and color indices.

A tutorial and an associated spreadsheet created by Lorenzo Franco were instrumental in creating H-G curves. Using these tools, the author created a spreadsheet that computes average magnitude and the midpoint time for each night. These values are brought into the H-G Calculator utility in *MPO Canopus*. Input for the utility is average V magnitude with no H-G adjustment and mid-point time and date for the night. Knowing the asteroid's designation, the utility calculates absolute magnitude and phase, which are then plotted on the H-G curve. Values of *H* and *G* are reported in Table II.

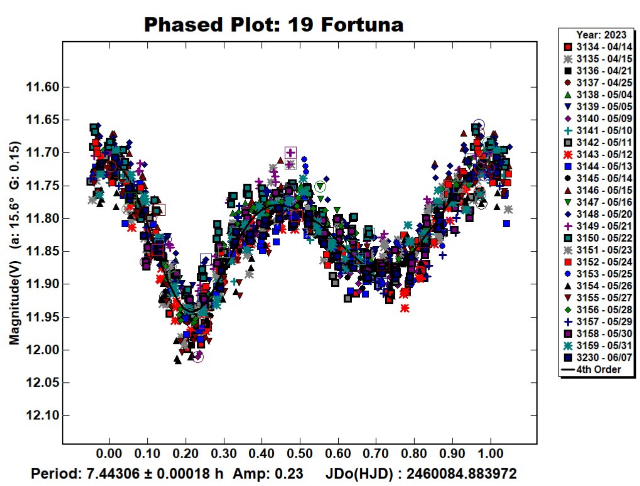
Color Indices

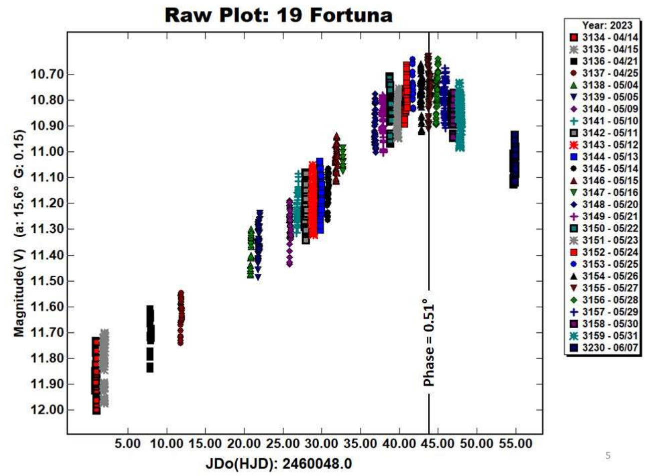
The method for computing color indices involved making a single full night of observations through photometric filters. Photometry is done in the usual fashion, producing sets of B, V, R, and I magnitudes for each visit. These magnitudes are subtracted to produce three color indices, B-V, V-R, and R-I. The averages and standard deviations of the color indices throughout the night are then calculated.

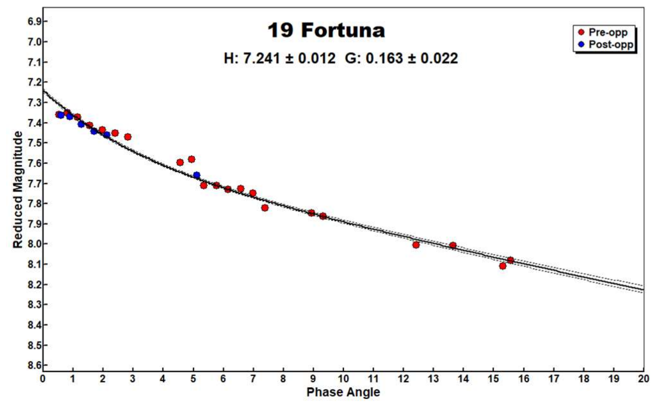
For each asteroid, a trio of images was taken consecutively in each filter, and the sets of magnitudes were binned. Each of the three asteroids in these observations had eight or nine visits throughout the night of 2023 June 5. Results are summarized in Table II. Published B-V color indices for the asteroids were found in the Planetary Data System site (Tedesco, 2020), and are compared to this work in the text below.

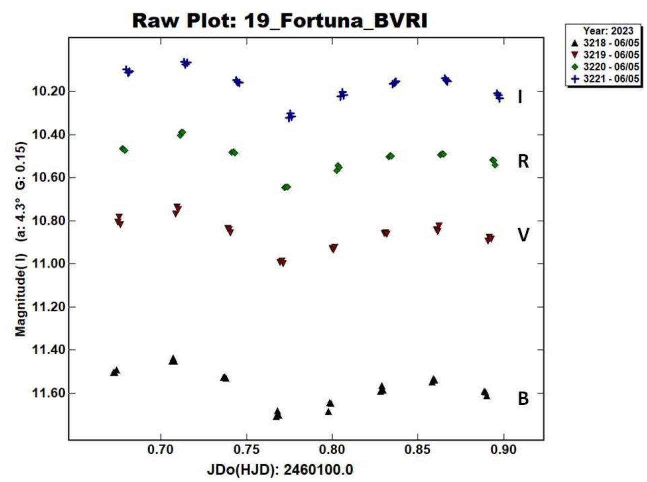
19 Fortuna is an inner main-belt asteroid, discovered in 1852 by John Russell Hind at London. Its rotation period is well-characterized, with the most recent result being from Vernazza et al. (2021), who computed 7.443224 ± 0.000005 h. Images were gathered on 27 nights in a 55-day interval, yielding 1417 data points. A period of 7.44306 ± 0.00018 h was calculated, agreeing with previous assessments. The amplitude of the lightcurve is 0.23 mag, with an RMS error on the fit of 0.030 mag.

Observations of this minor planet began on 2023 April 14, when the phase angle was -15.56°, reaching a minimum of 0.51° on May 27. Post-opposition data was gathered through June 7, when the phase angle reached 5.11° (a negative value is before opposition). A plot of all raw data with no H-G correction is provided, as well as the H-G curve. The computed value of *G* is 0.163 ± 0.022, in line with the LCDB level of 0.162 ± 0.03 (Pravec et al., 2012). Absolute magnitude, *H*, is 7.241 ± 0.012 mag, roughly agreeing with Pravec's 7.152 ± 0.02 mag.







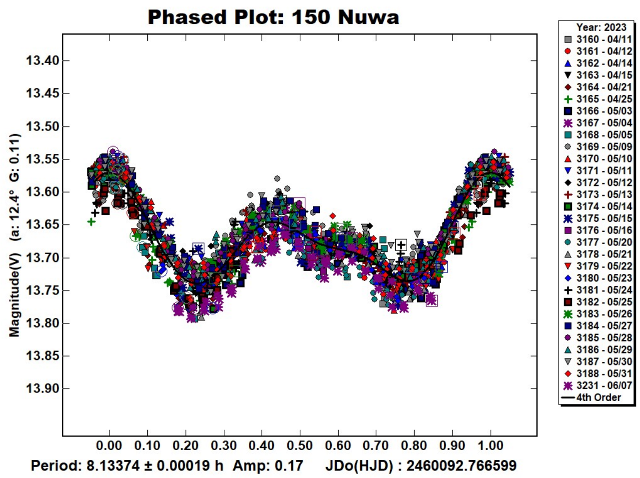


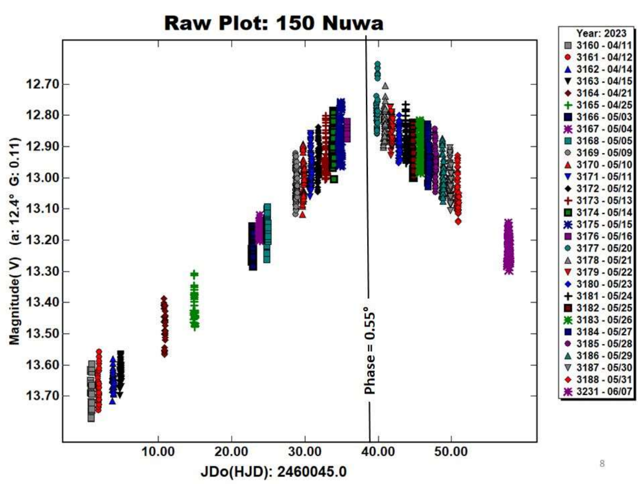
Tedesco shows B-V of 0.719 ± 0.014 mag. Eight visits of collecting sets of three points in the four filters were made during a 6-hour interval on 2023 June 5. They produced B-V of 0.706 ± 0.015 mag. The two other color indices are V-R = 0.355 ± 0.012 and R-I = 0.349 ± 0.030. These values are consistent with a carbonaceous (Type C or G) asteroid, as tabulated by Shevchenko and Lupishko (1998).

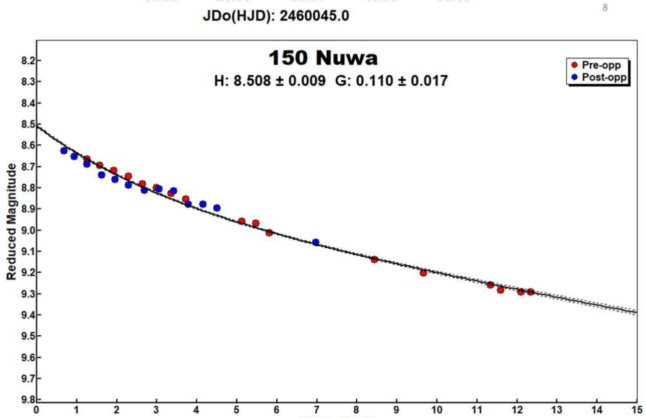
150 Nuwa is an outer main-belt asteroid, which was discovered by James Craig Watson in 1875 at Ann Arbor. The most recent calculation of the well-known rotation period is that of Hanus et al. (2016), who published a sidereal period of 8.13456 ± 0.000005 h. A total of 1625 images were taken in 30 nights, producing a period of 8.13374 ± 0.00019 h, in good agreement with Hanus' and other results. The amplitude is 0.17 ± 0.023 mag.

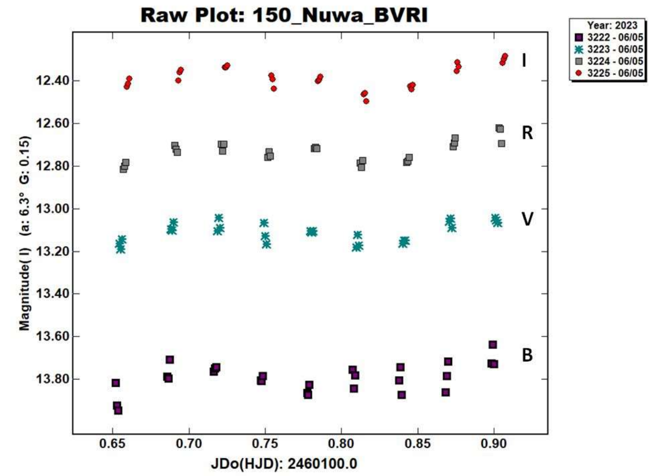
150 Nuwa was observed between 2023 April 11 and June 7, when the phase angle varied from -12.34° and 6.98°, reaching a minimum of 0.55° on May 19. Most *G* values reported in the LCDB appear to be simply the default value of 0.15, but Nugent et al. (2016) published *G* = 0.12. The result of this analysis is *G* = 0.110 ± 0.017. Nugent shows *H* = 8.46 mag, while these 2023 observations produce a result of *H* = 8.508 ± 0.009 mag.

Analysis of observed from nine visits resulted in B-V = 0.681 ± 0.043 mag, Tedesco's result is B-V = 0.706 ± 0.065. This is also in line with a Type C asteroid. V-R is 0.377 ± 0.013 and R-I is 0.349 ± 0.023.

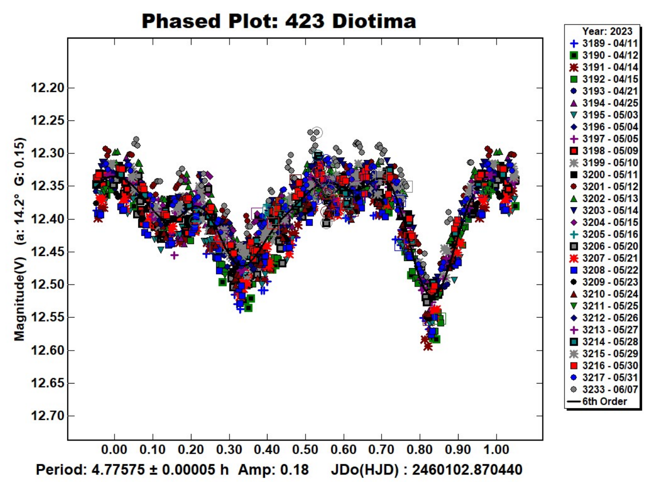


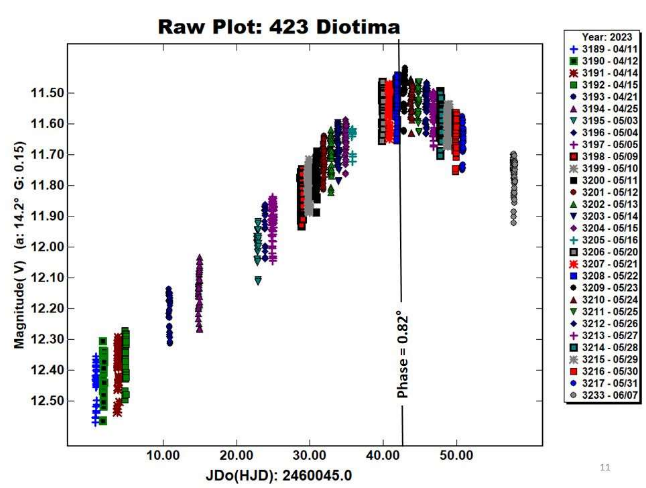




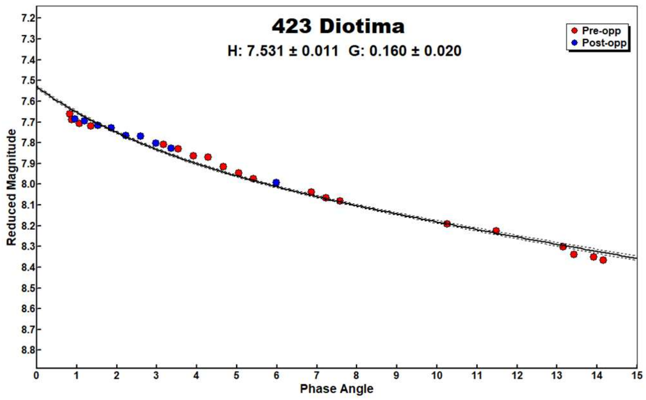


423 Diotima belongs to the Eos family. It was discovered by Auguste Charlois in 1896 from Nice. Hanus et al. (2018) published a sidereal period of 4.775377 ± 0.000002 h. During 30 nights, 1662 images were taken. The synodic period solution is 4.77575 ± 0.00006 h, agreeing with previous values. The amplitude of the lightcurve is 0.18 mag, and the RMS error on the fit is 0.029 mag.

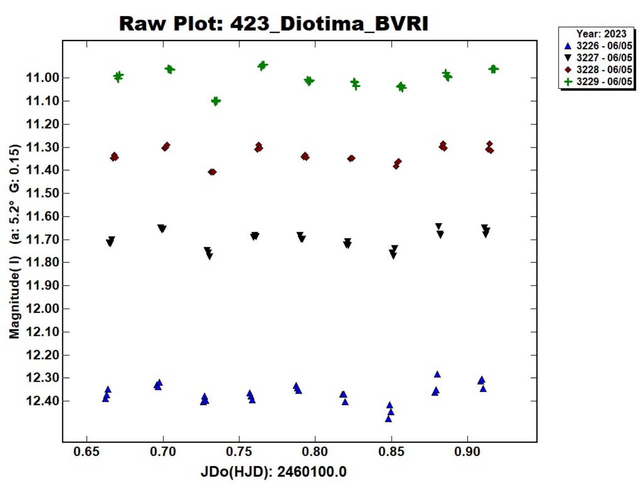




423 Diotima was also observed from 2023 April 11 through June 7. Phase angle ranged from -14.16° to 5.98° during this interval, with a minimum of 0.82° on May 23. The LCDB shows a wide range of values of *G*. Nugent et al. (2015) published *G* = 0.12 and *H* = 7.23 mag. The phase-slope parameter, *G*, from this analysis is 0.160 ± 0.020. Absolute magnitude, *H*, is 7.531 ± 0.011 mag, which is several tenths of a magnitude fainter than values in the LCDB.



423 Diotima was also visited nine times on 2023 June 7. A B-V color index of 0.664 ± 0.019 mag was computed, which compares favorably with Tedesco's 0.668 ± 0.011 mag. Color indices for V-R and R-I are 0.368 ± 0.013 mag and 0.332 ± 0.016 mag. The color indices again correlate well with a Type C asteroid.



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LIGHTCURVE ANALYSIS FOR SEVENTEEN MAIN-BELT AND TWO MARS-CROSSING ASTEROIDS

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Photometric observations of seventeen main-belt asteroids and two Mars-crossers were obtained between 2014 and 2019. We derived the following rotational periods: 174 Phaedra, 5.7396 ± 0.0029 h; 218 Bianca, 6.3380 ± 0.0005 h; 267 Tirza, 7.662 ± 0.003 h; 375 Ursula, 16.89839 ± 0.00024 h; 398 Admete, 20.991 ± 0.002 h; 1013 Tombecka, 6.04933 ± 0.00037 h; 1135 Colchis, 23.416 ± 0.007 h; 1795 Woltjer, 13.2574 ± 0.0034 h; 2078 Nanking, 6.4599 ± 0.0001 h; 2947 Kippenhahn, 10.952 ± 0.001 h; 3637 O'Meara, 5.7967 ± 0.0008 h; 3977 Maxine, 3.10 ± 0.01 h; 3999 Aristarchus, 12.6087 ± 0.0108 h; 4775 Hansen, 3.12349± 0.00004 h; 6729 Emiko, 3.1335 ± 0.0005 h; 6979 Shigefumi, 11.9455 ± 0.0023 h; (7774) 1992 UU2, 3.86752 ± 0.00017 h; 9956 Castellaz, 2.3903 ± 0.0017 h; and (28892) 2000 LZ2, 10.787 ± 0.003 h.

We report on the photometric analysis results for seventeen main-belt and two Mars-crosser asteroids by Asociación Valenciana de Astronomía (AVA). The data were obtained over several years, starting in 2014. We present graphic results of data analysis, mainly lightcurves, with the plot phased to a given period. We managed to obtain a number of accurate and complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

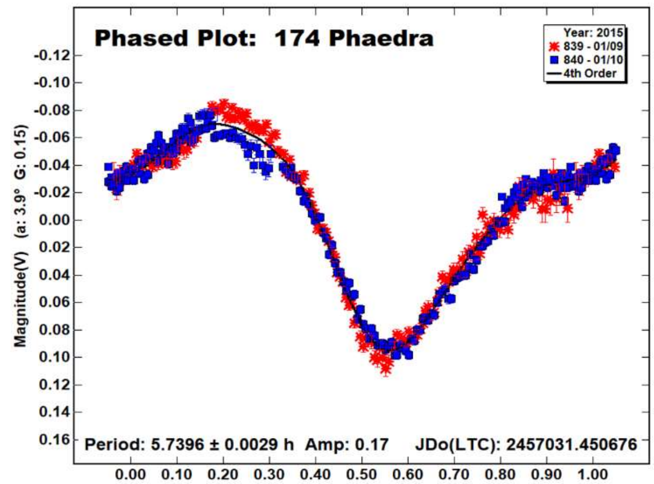
Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME

Table I. List of instruments used for the observations.

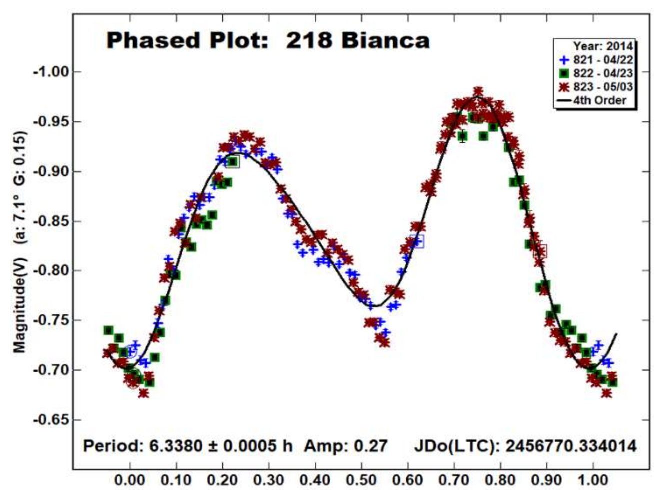
We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website (*http://www.minorplanet.info/call.html)* and the Minor Planet Center (*http://www.minorplanet.net*). The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results.

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. The comparison stars were restricted to near solar-color to minimize color dependencies, especially at larger air masses. The lightcurves show 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.

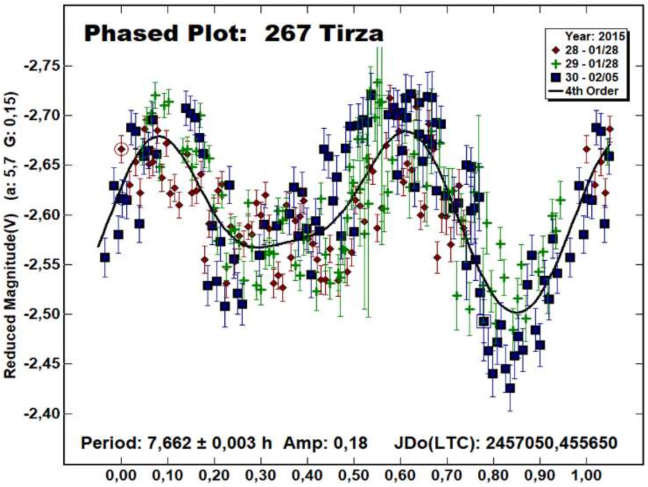
174 Phaedra. This outer main-belt asteroid was discovered on 1877 September 2 by J.C. Watson at Ann Arbor Observatory. We made observations on 2015 Jan 9 and 10. We derived a rotation period of 5.7396 ± 0.003 h and an amplitude of 0.17 mag. This is not consistent with the previous result of 5.75025 h from Ďurech (2006), Marciniak et al. (2011) and Hanus et al. (2011).



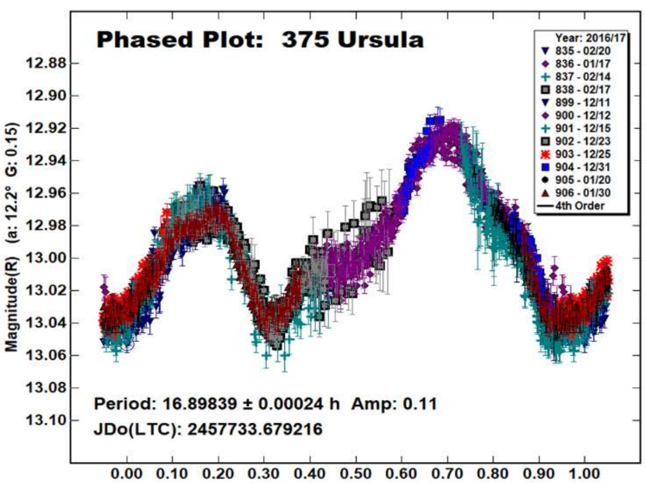
218 Bianca. This Flora group member was discovered on 1880 Sep 4 by J. Palisa at Pula. We made observations from 2014 April 22 to May 3. From our data we derive a rotation period of 6.3380 ± 0.0005 h and an amplitude of 0.27 mag. We agree with Kryszczynska et al. (1996), Ďurech et al. (2007), and Ďurech et al. (2011) who reported a period close to 6.337 h.



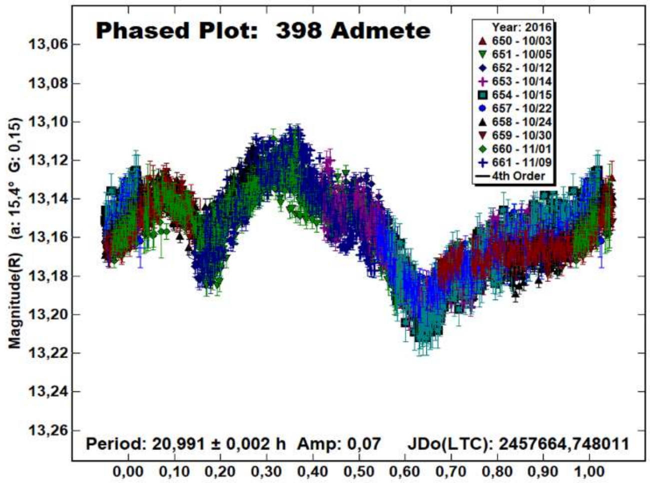
267 Tirza. This middle main-belt asteroid was discovered on 1887 May 27 by K.A. Charlois at Nice. We made observations on 2015 Jan 28 to Feb 5. From our data we derive a rotation period of 7.662 ± 0.003 h and an amplitude of 0.18 mag. This is consistent with the previous result from Ďurech et al. (2020), who got a 7.653 h period, and Behrend (2004web; 2006web), 7.658 h



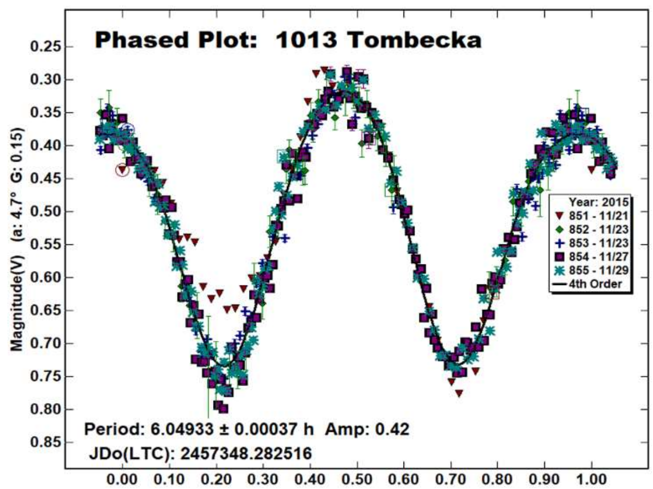
375 Ursula. This outer main-belt asteroid was discovered on 1893 Sep 18 by A. Charlois at Nice. We made observations on 2017 Jan 17 to Feb 17. From our data, we derive a rotation period of 16.89839 ± 0.00024 h and an amplitude of 0.14 mag. We joined data from Pilcher in the ALCDEF database (*https://alcdef.org*) covering 2016 Dec 11 through 2017 Feb 20 with ours to improve the quality of the result. From this data set we derive a rotation period of 16.8984 ± 0.0004 h and an amplitude of 0.11 mag This is consistent with Ďurech et al. (2020, 16.8937 h), Pilcher (2017b, 16.899 h), and Franco et al. (2021, 16.900 h).



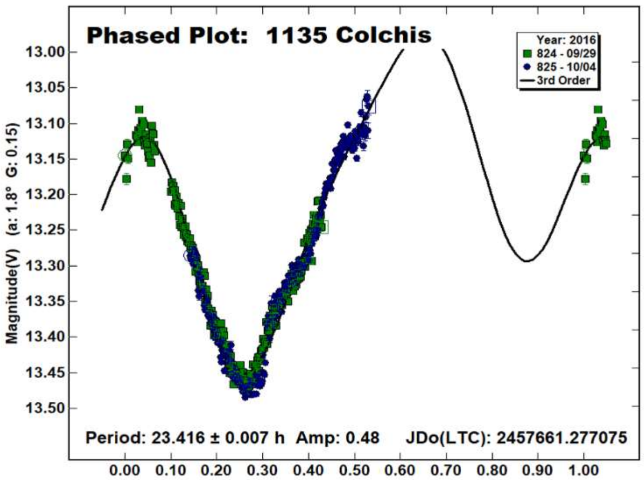
398 Admete. This inner main-belt asteroid was discovered on 1894 Dec 28 by A. Charlois at Nice. We made observations on 2016 Oct 3 to Nov 9. From our data, we derive a rotation period of 20.991 ± 0.0002 h and an amplitude of 0.07 mag. This agrees with the results from with Pilcher (2017a) who reported a period of 20.998 h based on data with a mid-date of 2016 Oct 10 and a period of 21.010 h based on data with a mid-date of 2016 Oct 25.



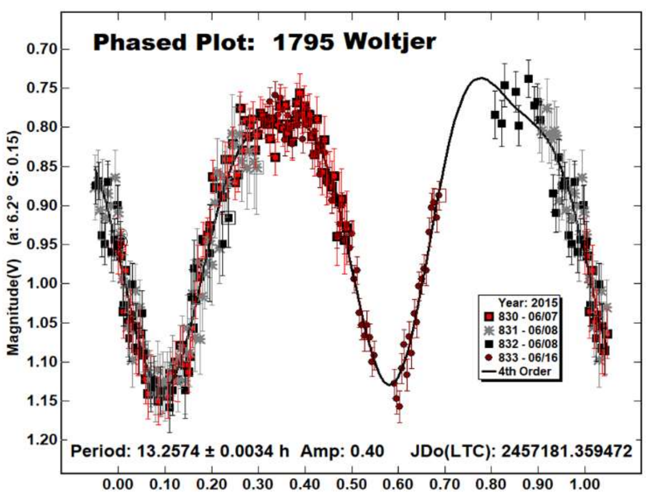
1013 Tombecka. This middle main-belt asteroid was discovered on 1924 Jan 27 by B. Jekhovsky at Algiers. We made observations on 2015 Nov 21-29. From our data we derive a rotation period of 6.04933 ± 0.00037 h and an amplitude of 0.42 mag. There are several results in LCDB consistent with 6.049 h, for example, Ďurech et al. (2018, 6.05017 h) and Hanus et al. (2018, 6.05017 h).



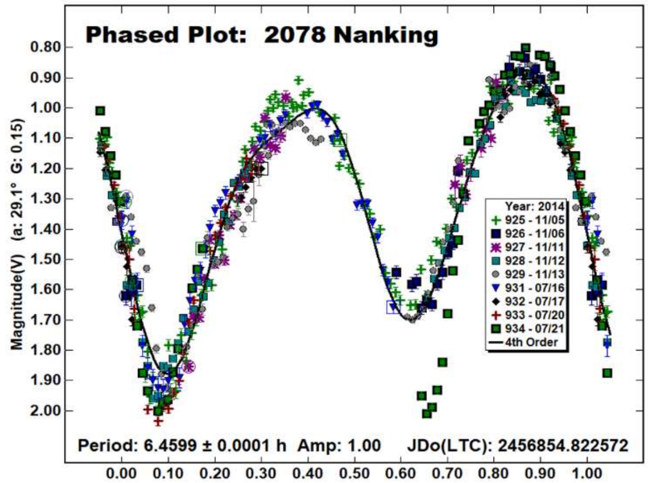
1135 Colchis. This middle main-belt asteroid was discovered on 1929 Oct 3 by G. N. Neujmin at the Crimea-Simeis Observatory. We made observations on 2016 Sep 29 to Oct 4. Data analysis found a rotation period of 23.416 ± 0.007 h and an amplitude of 0.48 mag. Behrend (2016web) and Stephens and Malcolm (2001) found 24.47 h, Hanus et al. (2016) found a period of 23.483 h, and Ďurech et al. (2016) found a period of 23.4827 h.



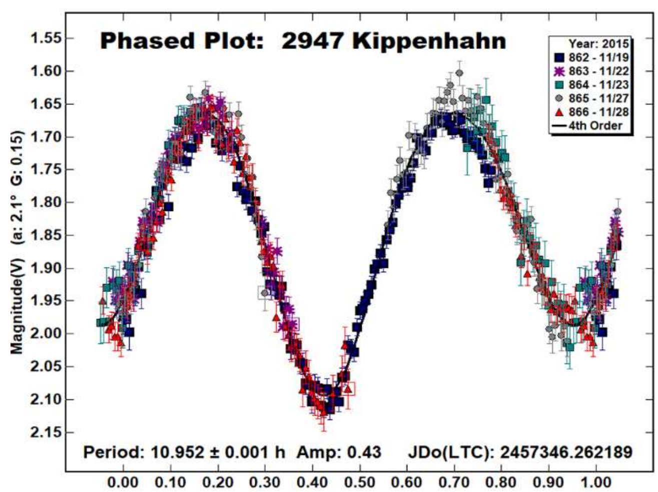
1795 Woltjer. This Dora family member (Nesvorny, 2015; Nesvorny et al., 2015) was discovered on 1960 Sep 24 by PLS at Palomar. We made observations on 2015 Jun 7-16. From our data, we derive a rotation period of 13.2574 ± 0.0034 h and an amplitude of 0.4 mag. Garcerán et al. (2016) found a different result with the same data, 12.102 h. We note that different periods are given in the lightcurve and the text. We confirm now a 13.2574 h period.



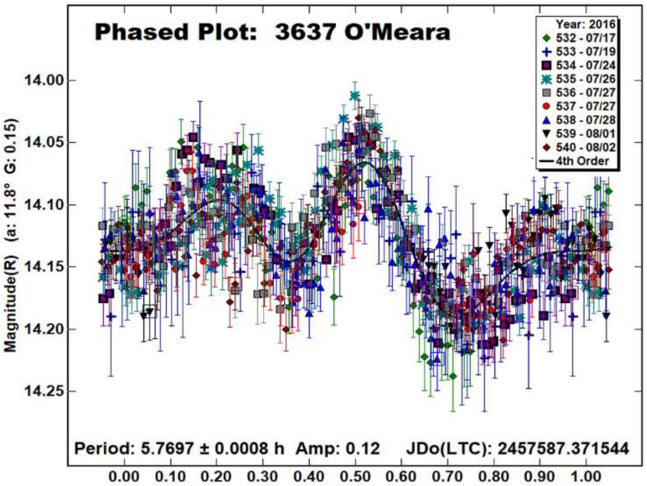
2078 Nanking. This Mars-crosser asteroid was discovered on 1975 Jan 12 at the Purple Mountain Obs. We made observations on 2014 Nov 5-13. From our data we derive a rotation period of 6.460 ± 0.001 h and amplitude of 0.96 mag. We found data in the ALCDEF database from Warner covering 2014 Jul 15-22 and joined them with ours to improve the quality of the result. From this data set we derive a rotation period of 6.4599 ± 0.00001 h and amplitude of 1.00 mag. Warner (2015) found a period of 6.459 h and Pal et al. (2020) reported 6.46122 h; these are consistent with our analysis.



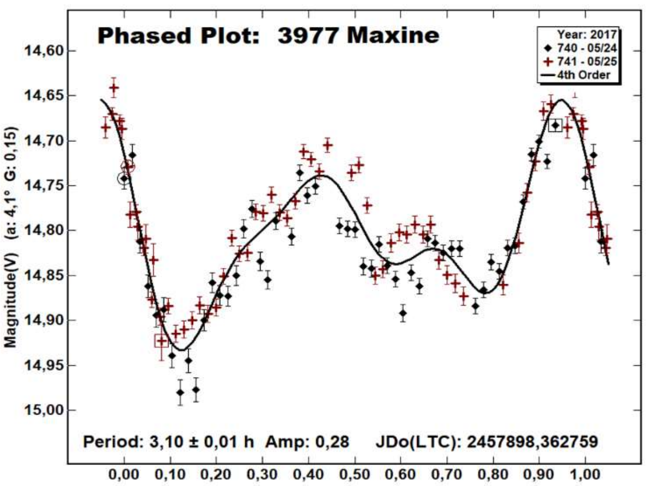
2947 Kippenhahn. This inner main-belt asteroid was discovered on 1955 Aug 22 by I. van Houten-Groeneveld at Heidelberg. We made observations on 2015 Nov 19-28. From our data we derive a rotation period of 10.952 ± 0.001 h and an amplitude of 0.43 mag. Ďurech et al. (2018; 2020) found, respectively, periods of 10.95528 and10.95526 h. Aznar Macias et al. (2016) found 10.43 h and Chyrony et al. (2011) found 10.5 h.



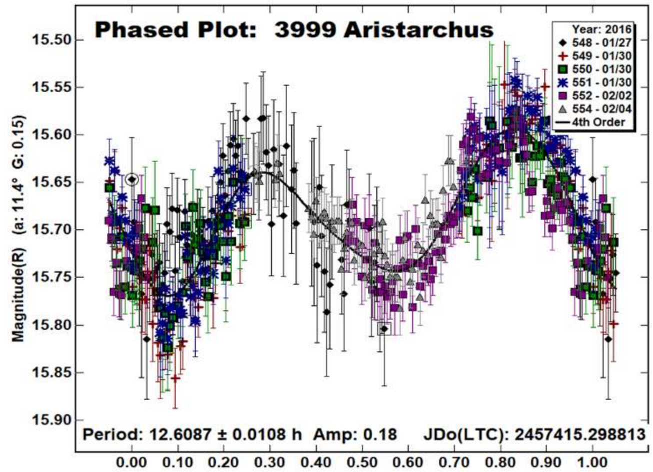
3637 O'Meara. This middle main-belt asteroid was discovered on 1984 Oct 23 by B.A. Skiff at Anderson Mesa Observatory. We made observations on 2016 Jul 7 to Aug 2. From our data we derive a rotation period of 5.7967 ± 0.00008 h and an amplitude of 0.12 mag. Consistent with our results are those from Polakis (2020, 5.751 h) and Pal et al. (2020, 5.77146 h). Results from Behrend (2008web, 5.49 h; 2018web, 7.710 h) are more divergent.



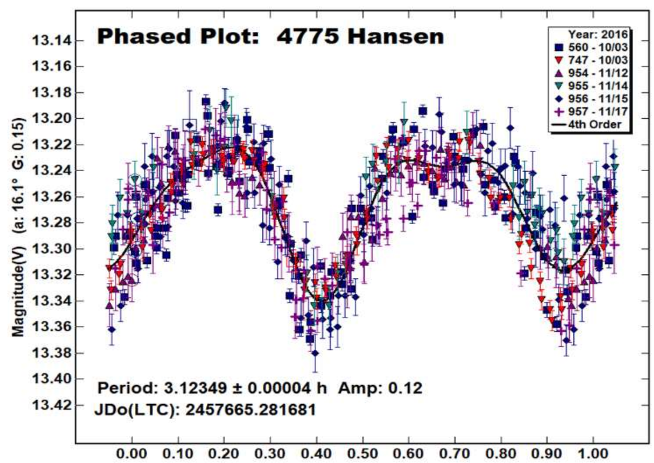
3977 Maxine. This Eunomia family member (Nesvorny, 2015; Nesvorny at al., 2015) was discovered on 1983 Jun 14 by C.S. Shoemaker and E.C. Shoemaker at Palomar Observatory in USA. We made observations on 2017 May 24-25. From our data we derive a rotation period of 3.10 ± 0.01 h and an amplitude of 0.28 mag. Franco et al. (2014) and Benishek (2023) both found a period of 3.081 h.



3999 Aristarchus. This inner main-belt asteroid was discovered on 1989 Jan 5 by T. Kojima at Chiyoda. We made observations on 2016 Jan 27 to Feb 4. From our data, we derive a rotation period of 12.6087 ± 0.0108 h and an amplitude of 0.18 mag. Ditteon et al. (2010) found a period of 12.58 h.

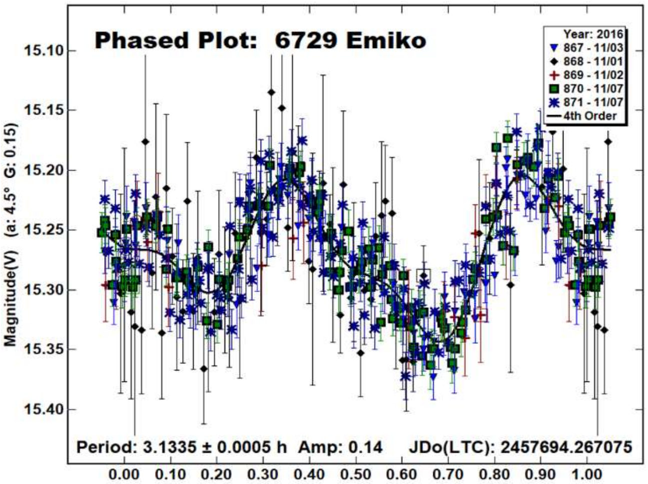


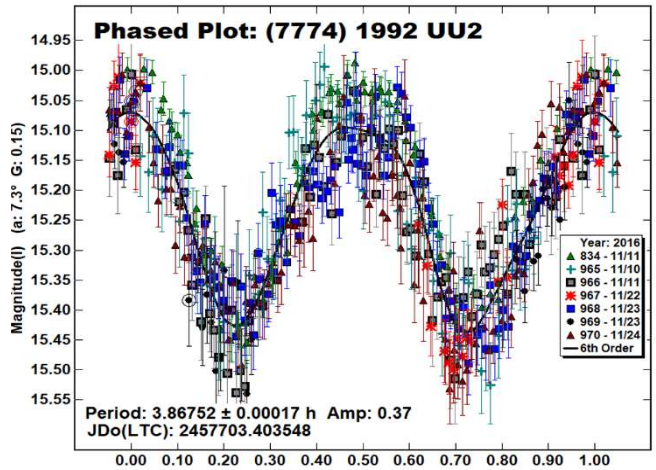
4775 Hansen. This Mars-crosser asteroid was discovered on 1927 Oct 3 by M.F. Wolf at Heidelberg Observatory. We made observations on 2016 Oct 3 and 4. From our data we derive a rotation period of 3.12349 ± 0.00004 h and an amplitude of 0.12 mag.



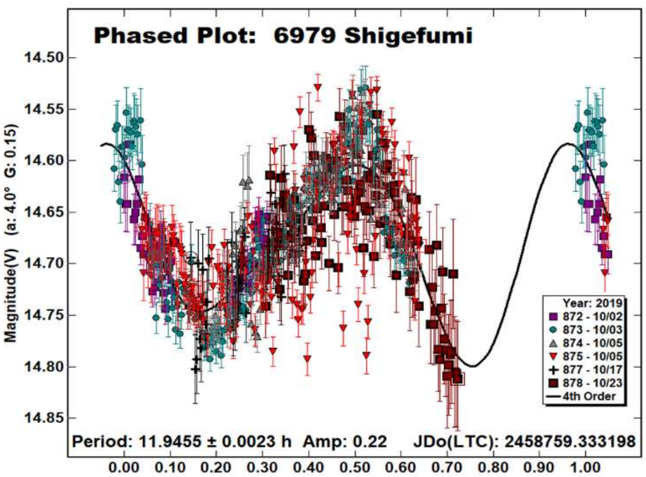
Pravec et al. (2016web) found a period of 3.1185h; Warner (2017) found 3.124 h, and Sada et al. (2017) reported 3.1182 h using data with a mid-date of 2016 Aug 20 and 3.1182 h using data with a mid-date of 2016 Oct 7. We found data from Warner in the ALCDEF database covering 2016 Nov 11-17. We joined them with ours to improve the quality of the result. From this data set we derive P = 3.12349 ± 0.00004 h and A = 1.12 mag

6729 Emiko. This middle main-belt asteroid was discovered on 1991 Nov 4 by S. Otomo at Kiyosato Observatory. We made observations on 2016 Nov 3-7. From our data we derive a rotation period of 3.1335 ± 0.0005 h and an amplitude of 0.14 mag. Behrend (2016web) reported 3.13 h and Benishek (2022) found 3.14 h.



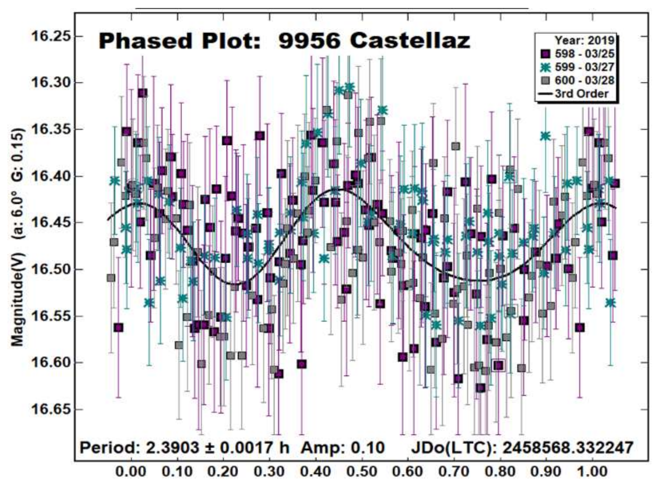


6979 Shigefumi. This inner main-belt asteroid was discovered on 1993 Sep 12 by K. Endate and K. Katanabe at Kitami. We made observations on 2019 Oct 2-23. From our data we derive a rotation period of 11.9455 ± 0.0023 h and an amplitude of 0.22 mag. Ďurech et al. (2018) found a period of 12.10795 h.

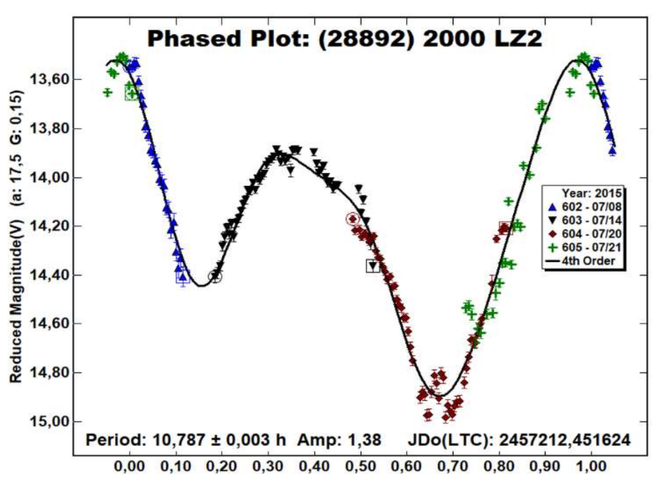


(7774) 1992 UU2. This inner main-belt asteroid was discovered on 1992 Oct 19 by K. Endate and K. Katanabe at Kitami. We made observations on 2016 Nov 10. From our data we derive a rotation period of 3.86752 ± 0.00017 h and an amplitude of 0.42 mag. Other results are from Krotz et al. (2010, 3.87 h), Foylan (2017, 3.868 h), Aznar (2017, 3.869 h), and Ďurech et al. (2020, 3.867221 h). Data from Foylan in the ALCDEF database (2016 Nov 10-24) were joined with ours to improve the result. From this data set we derive $P = 3.86752 \pm 0.00017$ h and $A = 0.37$ mag.

9956 Castellaz. This inner main-belt asteroid was discovered on 1991 Oct 5 by L.D. Schmadel and F. Börngen at Tautenburg Observatory. We made observations on 2019 March 25-28. From our data we derive a rotation period of 2.390 ± 0.002 h and an amplitude of 0.1 mag. There were no previous rotation period results in the LCDB.



(28892) 2000 LZ2. This inner main-belt asteroid was discovered on 2000 at LINEAR, Socorro. We made observations from 2015 Jul 8-21. From our data we derive $P = 10.787 \pm 0.003$ h and $A = 1.38$ mag. Pravec et al. (2015web) found $P = 11.2575$ h



Number	Name	20yy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
174	Phaedra	15/01/09-01/10	369	4.0, 4.2	103	10	5.7396	0.0029	0.17	0.01	MB-O
218	Bianca	14/04/22-05/03	203	7.1, 9.2	208	14	6.3380	0.0005	0.27	0.01	MB-M
267	Tirza	15/01/28-02/05	268	6.6, 8.8	112	5	7.662	0.003	0.18	0.03	MB-M
375	Ursula	17/01/04-02/20	175	4.4,11.9	113	13	16.89839	0.00024	0.11	0.01	MB-O
	(Pilcher)	16/12/11-17/02/20									
398	Admete	16/10/03-11/09	3986	15.4, 7.5	38	12	20.991	0.002	0.07	0.01	MB-M
1013	Tombecka	15/11/21-11/29	454	4.7, 7.9	52	7	6.04933	0.00037	0.42	0.02	MB-M
1135	Colchis	16/09/29-10/04	475	1.7, 1.5	8	2	23.416	0.007	0.48	0.05	MB-M
1795	Woltjer	15/06/07-06/16	259	5.9,19.9	253	9	13.2574	0.0034	0.40	0.03	MC
2078	Nanking	14/11/05-11/13	430	29.1,37.1	22	27	6.4599	0.0001	1.00	0.02	MB-I
	(Warner)	14/07/15-07/22									
2947	Kippenhahn	15/11/19-11/28	452	2.1, 5.3	55	3	10.952	0.001	0.43	0.01	MB-I
3637	O'Meara	16/07/17-08/02	714	11.6,15.1	289	19	5.7697	0.0008	0.12	0.02	MB-M
3977	Maxine	17/05/24-05/25	109	4.0, 4.3	240	7	3.10	0.01	0.28	0.02	MB-M
3999	Aristarchus	16/01/27-02/04	499	10.9,14.7	107	0	12.6087	0.0108	0.18	0.03	MB-I
4775	Hansen	16/10/03-10/04	463	15.7,29.5	13	12	3.12349	0.00004	0.12	0.01	MC
	(Warner)	16/11/12-11/17									
6729	Emiko	16/11/03-11/07	395	4.5, 5.3	40	8	3.1335	0.0005	0.14	0.02	MB-M
6979	Shigefumi	19/10/02-10/23	660	4.3, 9.3	14	6	11.9455	0.0023	0.22	0.03	MB-M
7774	1992 UU2	16/11/10	524	7.9, 2.3	59	-3	3.86752	0.00017	0.37	0.02	MB-I
	(Foylan)	16/11/10-11/24									
9956	Castellaz	19/03/25-03/28	272	5.4, 7.2	175	0	2.3903	0.0017	0.1	0.03	MB-I
28892	2000 LZ2	15/07/08-07/21	168	17.7,15.1	307	19	10.787	0.003	1.38	0.02	MB-I

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). MB-I/O: Main-belt inner/outer; MC: Mars-crosser.

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LIGHTCURVES AND SYNODIC ROTATION PERIODS FOR 23 ASTEROIDS FROM SOPOT ASTRONOMICAL OBSERVATORY: 2022 OCTOBER – 2023 JULY

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Lightcurve and synodic rotation period results were derived using photometric data for 23 asteroids obtained at the Sopot Astronomical Observatory in the time span 2022 October – 2023 July.

Photometric observations of 23 asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2022 October through 2023 July in order to determine the asteroids' synodic rotation periods. For this purpose, two 0.35-m *f*/6.3 Meade LX200GPS Schmidt-Cassegrain telescopes were employed. The telescopes are equipped with a SBIG ST-8 XME and a SBIG ST-10 XME CCD cameras. The exposures were unfiltered and unguided for all targets. Both cameras were operated in 2×2 binning mode, which produces image scales of 1.66 arcsec/pixel and 1.25 arcsec/pixel for ST-8 XME and ST-10 XME cameras, respectively. Prior to measurements, all images were corrected using dark and flat field frames.

Photometric reduction was conducted using *MPO Canopus* (Warner, 2018). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq B\text{-}V \leq 0.9$) was performed using the Comparison Star Selector (CSS) utility. This helped ensure a satisfactory quality level of night-to-night zero-point calibrations and correlation of the measurements within the standard magnitude framework. Field comparison stars were calibrated using standard Cousins R magnitudes derived from the Carlsberg Meridian Catalog 15 (VizieR, 2023) Sloan r' magnitudes using the formula: $R = r' - 0.22$ in all cases presented in this paper. In some instances, small zero-point adjustments were necessary in order to achieve the best match between individual data sets in terms of achieving the most favorable statistical indicators of Fourier fit goodness.

Lightcurve construction and period analysis was performed using *Perfindia* custom-made software developed in the R statistical programming language (R Core Team, 2020) by the author of this paper. The essence of its algorithm is reflected in finding the most favorable solution for rotational period by minimizing the *residual standard error* of the lightcurve Fourier fit.

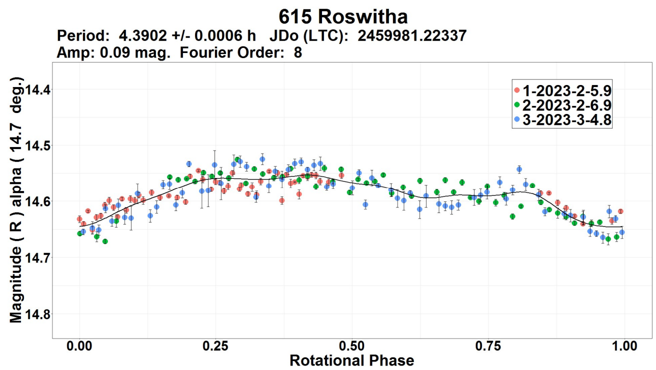
The lightcurve plots presented in this paper show so-called 2% error for rotational periods, i.e., an error that would cause the last data point in a combined data set by date order to be shifted by 2% (Warner, 2012) and represented by the following formula:

$$\Delta P = (0.02 \cdot P^2) / T$$

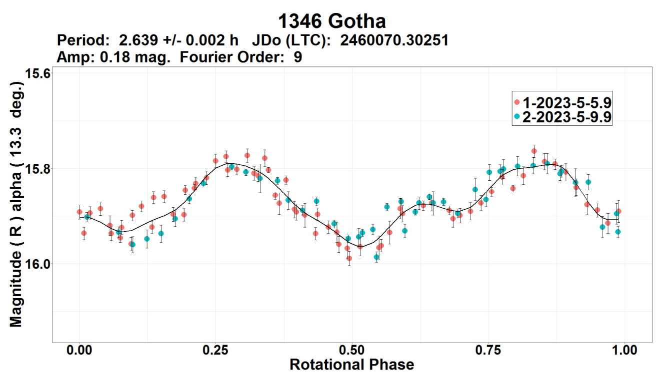
where P and T are the rotational period and the total time span of observations, respectively. Both of these quantities must be expressed in the same units.

Table I gives the observing circumstances and results.

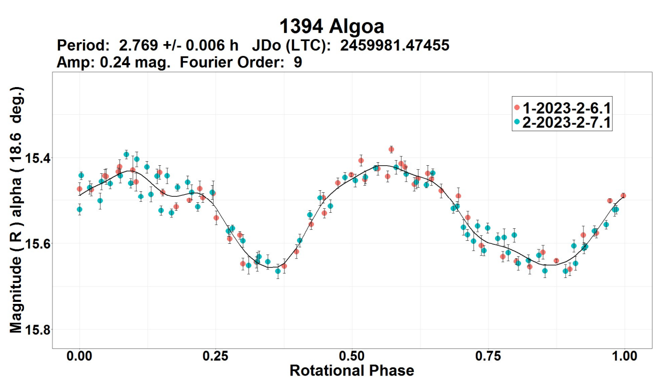
615 Roswitha. A low-amplitude (0.09 mag) rotational lightcurve obtained over three nights spanning nearly a month from early 2023 February to early 2023 March shows no substantial change in shape during that time. The SAO observations indicate a fairly unambiguous solution for a synodic rotation period of $P = 4.3902 \pm 0.0006$ h, which is quite close to the two previously known period determinations found in the Asteroid Lightcurve Database (LCDB; Warner et al., 2009): 4.422 h by Shevchenko et al. (2008) and 4.42 h by Behrend (2021web).



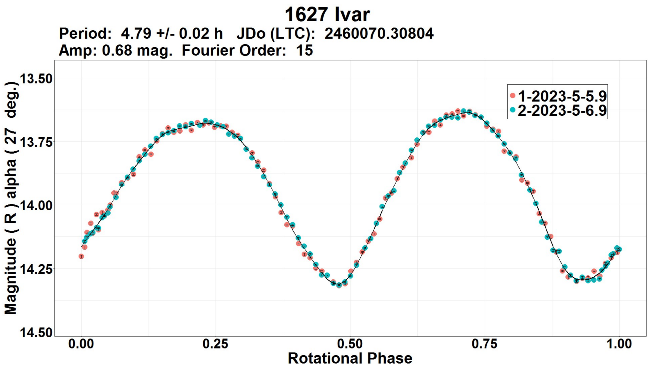
1346 Gotha. A large number of previous rotation period determination results from the LCDB, such as the following: 2.64067 h by Behrend (2011web), Waszczak et al. (2015, 2.640 h), Aznar Macias (2017, 2.642 h), Benishek (2022a, 2.640 h) match well with the bimodal period of $P = 2.639 \pm 0.002$ h, found from the 2023 May SAO observations obtained over two nights.



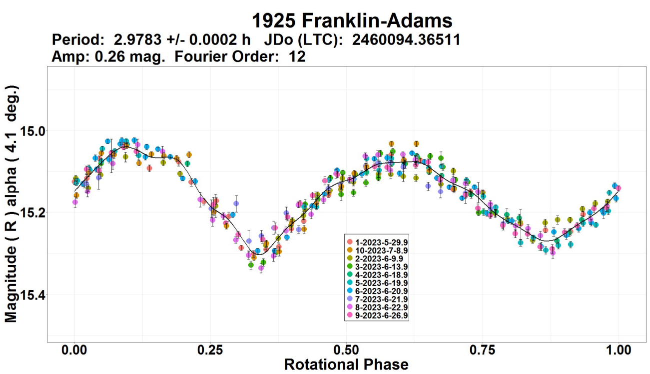
1394 Algoa. Observations conducted over two consecutive nights in 2023 July show an unequivocal bimodal period of $P = 2.769 \pm 0.006$ h, statistically equal to virtually all previous results listed in the LCDB, some of which are as follows: Hills (2012, 2.768 h), Klinglesmith et al. (2013, 2.768 h), Behrend (2020web, 2.76829 h).



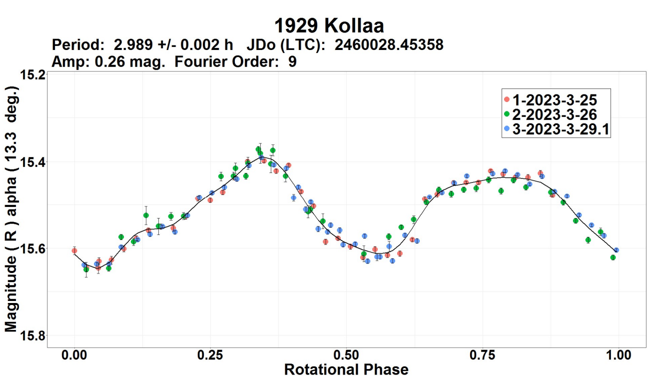
1627 Ivar. A dense photometric dataset obtained over two consecutive nights in 2023 May shows an unambiguous large-amplitude (0.68 mag.) bimodal rotation period solution of $P = 4.79 \pm 0.02$ h, a value in excellent agreement with 20 synodic and 3 sidereal previous rotation period values for this NEA ranging between 4.7947 an 4.801 hours and determined in the time span from 1985 to 2020 (LCDB; Warner et al., 2009).



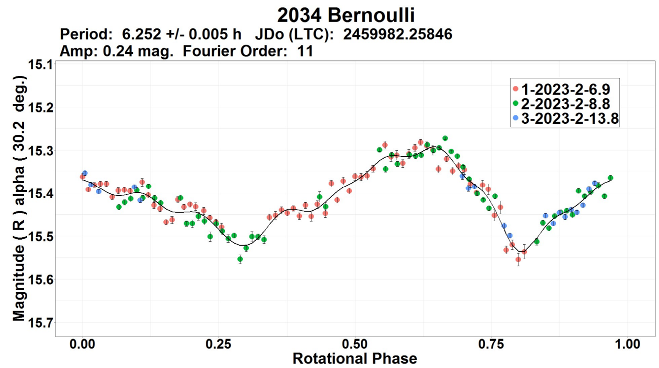
1925 Franklin-Adams. A bimodal solution for period of $P = 2.9783 \pm 0.0002$ h was found from a dense combined dataset acquired at SAO over 10 nights from late 2023 May through early July. The obtained result is well consistent with the prior period determinations by Warner (2013a, 2.978 h), Waszczak et al. (2015, 2.979 h) and a sidereal period result by Hanuš et al. (2016, 2.978301 h).



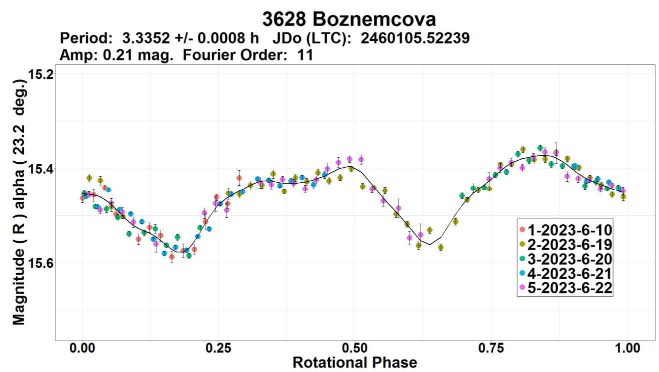
1929 Kollaa. Observations of this V-type asteroid from late 2023 March carried out at SAO over three nights yielded a bimodal period result of $P = 2.989 \pm 0.002$ h, which is well consistent with previous findings listed in the LCDB: 2.9887 h (Behrend, 2008web), 2.982 h (Benishek, 2022b).



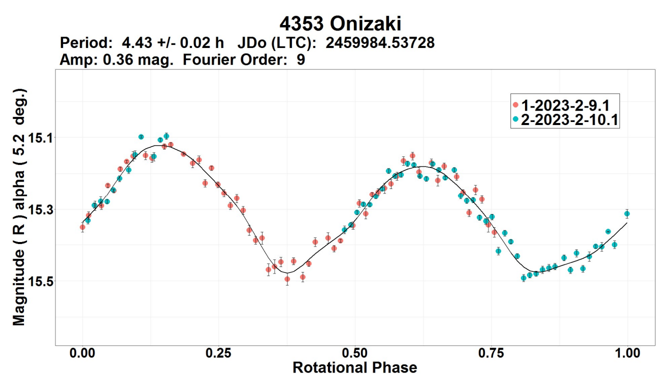
2034 Bernoulli. Data collected on three nights in early 2023 February yielded a bimodal solution for a period of $P = 6.252 \pm 0.005$ h. This value does not differ much from the previously determined fairly uniform results by Alkema (2013, 6.248 h), McNeill et al. (2019, 6.245 h), Pal et al. (2020, 6.24919 h), and Benishek (2021, 6.249 h).



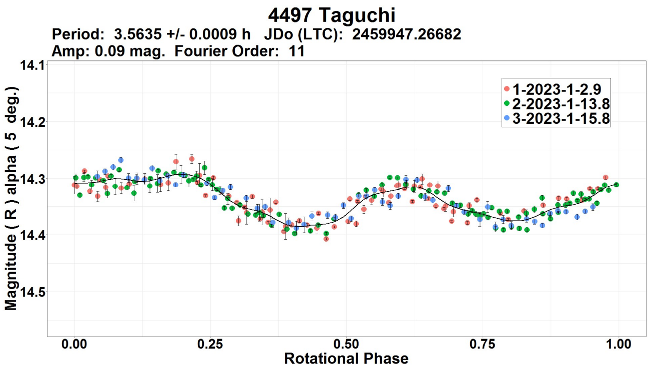
3628 Boznemcova. The only prior rotation period determination from Warner (2008, 3.335410 h) matches well the bimodal result ($P = 3.3352 \pm 0.0008$ h) found from the 2023 June SAO data collected on five nights.



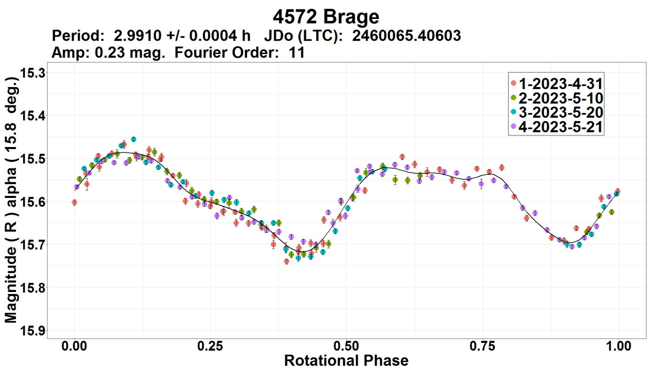
4353 Onizaki. An unambiguous bimodal period ($P = 4.43 \pm 0.02$ h) was derived from the data obtained on two consecutive nights in 2023 February. Several previously determined periods listed in the LCDB are also in the range of 4.429 h to 4.49 h.



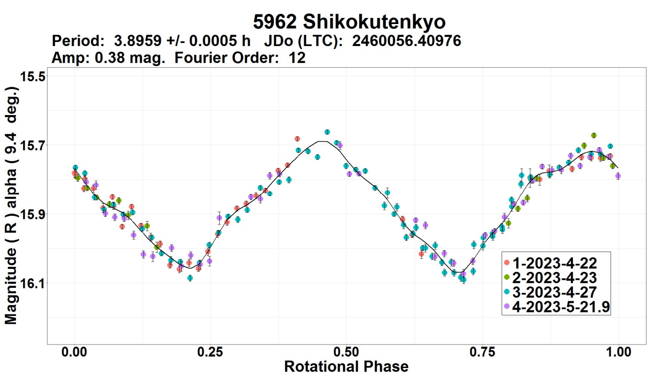
4497 Taguchi. Period result ($P = 3.5635 \pm 0.0009$ h) established from the 2023 January data obtained over three nights is consistent with the vast majority of previous period determinations, some of which are as follows: 3.563 h (Almeida et al., 2004), 3.567 h (Behrend, 2012web), 3.563 h (Warner, 2013b), 3.5639 h (Pal et al., 2020).



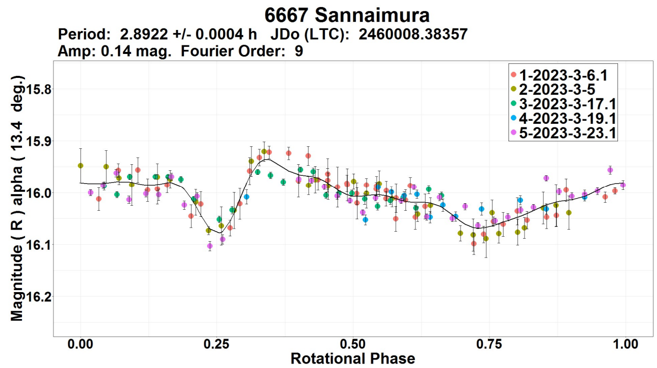
4572 Brage. The only prior rotation period result from Behrend (2015, 2.99105 h) is virtually identical to the bimodal period solution derived from the 2023 April-May SAO data ($P = 2.9910 \pm 0.0004$ h).



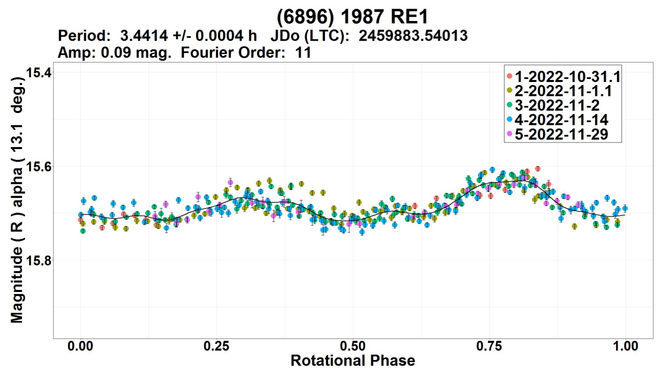
5962 Shikokutenkyo. There is no information on previous rotation period determinations for this asteroid in the LCDB. Period analysis performed on the dense combined dataset from four nights in 2023 April - May indicates an unequivocal period solution of $P = 3.8959 \pm 0.0005$ h, associated with a rather large amplitude (0.38 mag.) bimodal lightcurve at relatively low solar phase angles.



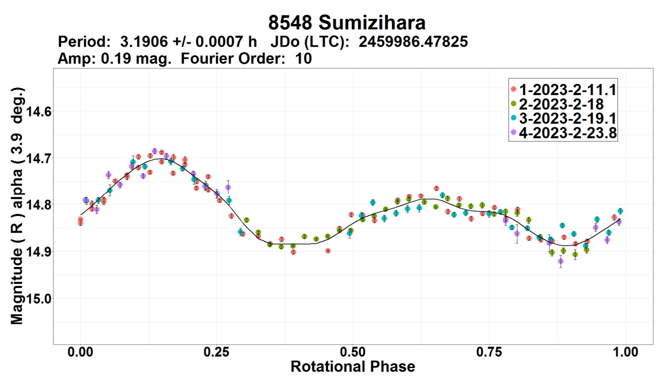
6667 Sannaimura. The only prior rotation period result by Pal et al. (2020, 2.89282 h) is almost identical to the statistically most favorable period of $P = 2.8922 \pm 0.0004$ h, obtained from the analysis conducted on the SAO photometric data obtained on five nights in 2023 March.



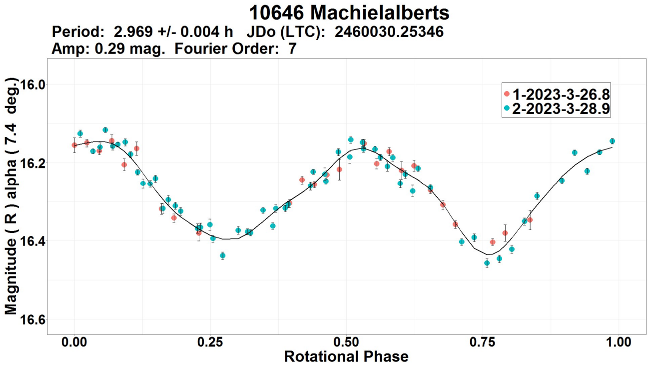
(6896) 1987 RE1. There are no previous rotation period results present in the LCDB. Data collected in 2022 October-November over five nights indicate a period of $P = 3.4414 \pm 0.0004$ h as the most favorable solution.



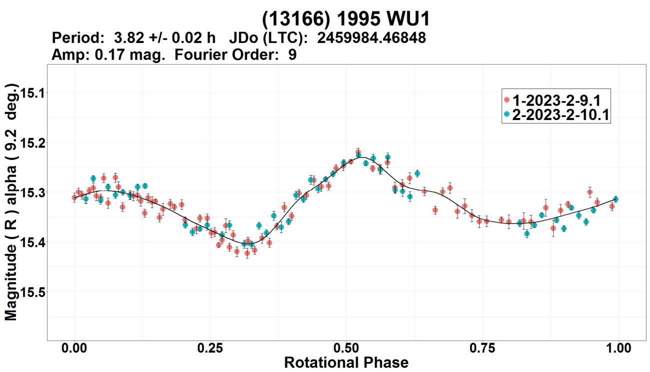
8548 Sumizihara. Observations of this asteroid carried out in early 2023 January (Benishek, 2023) were continued during 2023 February and led to a bimodal solution for a rotation period of $P = 3.1906 \pm 0.0007$ h, close to the one obtained from the 2023 January data (3.187 h). The new result is also in line with all previous period determinations cited in the LCDB, which are in the range between 3.187 and 3.195 hours.



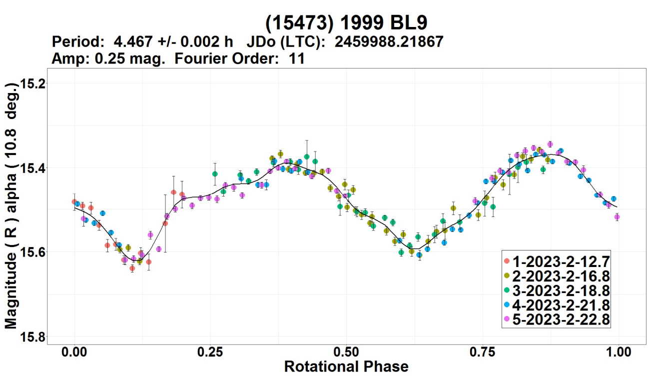
10646 Machielalberts. Waszczak et al. (2015) found a value of 3.058 h for a rotation period. A bimodal solution of $P = 2.969 \pm 0.004$ h was determined from the SAO data taken over two nights in 2023 March.



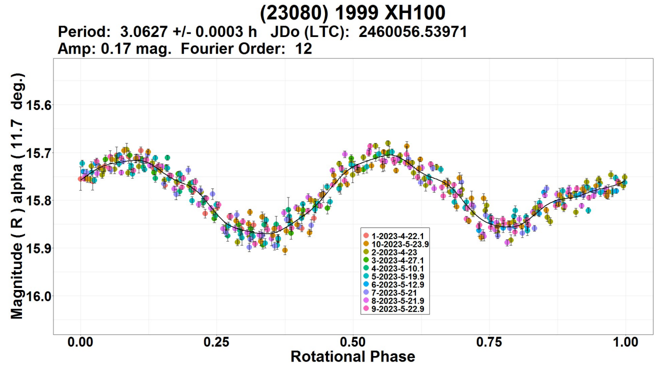
(13166) 1995 WU1. Data obtained in 2023 February led to a bimodal period solution of $P = 3.82 \pm 0.02$ h. The previously found values are in good accordance with the newly established result: 3.8123 h (Pravec, 2008web), 3.8101 h (Pravec, 2010web), 3.810 h (Waszczak et al., 2015), 3.8104 h (Pravec, 2019web).



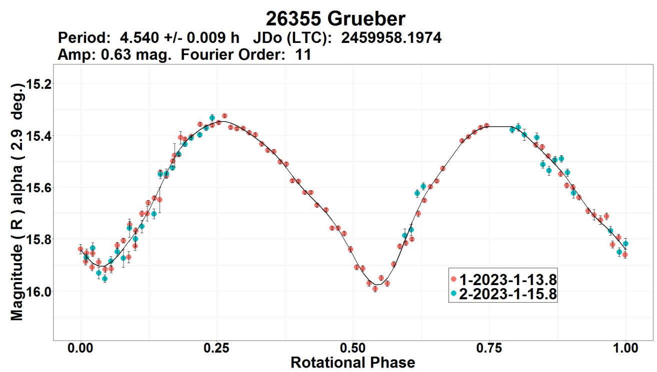
(15473) 1999 BL9. A high concordance is apparent between the only previously rotation period determination by Pal et al. (2020, 4.46844 h) and the bimodal result found from the 2023 February SAO data ($P = 4.467 \pm 0.002$ h).



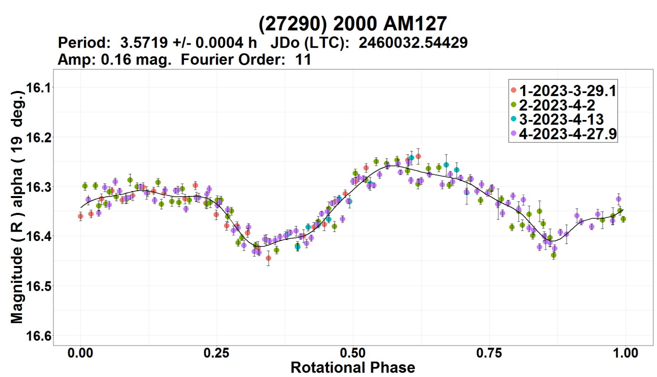
(23080) 1999 XH100. Similar to the previous case, the bimodal period solution of $P = 3.0627 \pm 0.0003$ h derived from SAO data collected over 10 nights in 2023 April-May shows an exact match (within the period error bounds) with the only previous result by Pal et al. (2020, 3.06273 h).



26355 Grueber. Data from two nights in 2023 January at low solar phase angles show a fairly high-amplitude (0.63 mag.) bimodal lightcurve phased to a period of $P = 4.540 \pm 0.009$ h as a unique solution. This result is in very good agreement with the previous results by Fauerbach and Fauerbach (2019, 4.539 h), Behrend (2020, 4.541 h), as well as a sidereal value determined by Ďurech et al. (2019, 4.540231 h).



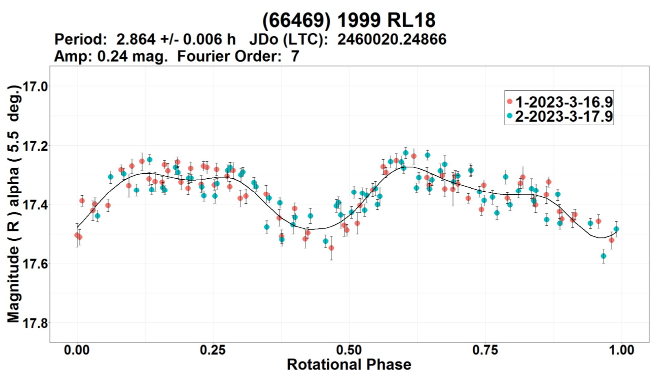
(27290) 2000 AM127. No rotation period determination results were previously known. An equivocal bimodal period solution of $P = 3.5719 \pm 0.0004$ h was found from the dense combined dataset acquired over four nights in 2023 March - April.



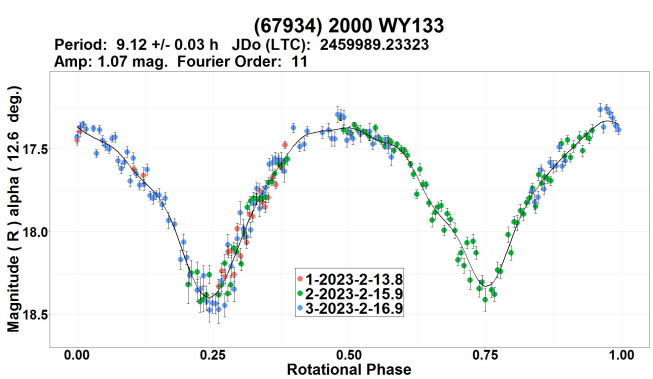
(66469) 1999 RL18. Pal et al. (2020) found a period of 2.86509 h. A very close value to this previous one ($P = 2.864 \pm 0.006$ h) was found from the 2023 March SAO data obtained on two consecutive nights.

Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
615	Roswitha	23/02/05-23/03/04	14.7,19.4	97	3	4.3902	0.0006	0.09	0.03	MB-M
1346	Gotha	23/05/05-23/05/09	13.3,14.4	190	9	2.639	0.002	0.18	0.03	EUN
1394	Algoa	23/02/05-23/02/07	18.6,18.3	182	0	2.769	0.006	0.24	0.02	MB-I
1627	Ivar	23/05/05-23/05/07	27.0,27.4	194	13	4.79	0.02	0.68	0.01	NEA
1925	Franklin-Adams	23/05/29-23/07/08	*4.1,15.2	253	6	2.9783	0.0002	0.26	0.02	MB-I
1929	Kollaa	23/03/24-23/03/29	13.3,11.5	208	7	2.989	0.002	0.26	0.02	V
2034	Bernoulli	23/02/06-23/02/13	30.2,31.0	84	11	6.252	0.005	0.24	0.02	MB-I
3628	Boznemcova	23/06/10-23/06/22	23.2,19.6	299	7	3.3352	0.0008	0.21	0.02	MB-I
4353	Onizaki	23/02/09-23/02/10	5.2, 5.2	142	11	4.43	0.02	0.36	0.03	MB-I
4497	Taguchi	23/01/02-23/01/15	*5.0, 4.3	109	4	3.5635	0.0009	0.09	0.02	MB-I
4572	Brage	23/04/30-23/05/21	15.8, 9.5	248	13	2.9910	0.0004	0.23	0.02	MB-I
5962	Shikokutenkyo	23/04/21-23/05/22	*9.4, 7.8	228	9	3.8959	0.0005	0.38	0.03	EUN
6667	Sannaimura	23/03/04-23/03/23	14.0, 4.9	189	2	2.8922	0.0004	0.14	0.04	MB-I
6896	1987 RE1	22/10/31-22/11/29	*13.1,8.4	56	7	3.4414	0.0004	0.09	0.02	MB-I
8548	Sumizihara	23/02/10-23/02/23	*3.9, 4.5	148	1	3.1906	0.0007	0.19	0.02	MB-I
10646	Machielalberts	23/03/26-23/03/29	7.4, 8.6	173	-1	2.969	0.004	0.29	0.03	MB-I
13166	1995 WU1	23/02/08-23/02/10	9.2, 9.0	147	16	3.82	0.02	0.17	0.02	MB-I
15473	1999 BL9	23/02/12-23/02/22	10.8,13.7	131	-16	4.467	0.002	0.25	0.02	MB-I
23080	1999 XH100	23/04/22-23/05/24	-11.7, 7.9	231	10	3.0627	0.0003	0.17	0.02	MB-M
26355	Grueber	23/01/13-23/01/15	2.9, 3.7	109	5	4.540	0.009	0.63	0.03	MB-I
27290	2000 AM127	23/03/29-23/04/28	19.0,11.1	219	16	3.5719	0.0004	0.16	0.02	MB-I
66469	1999 RL18	23/03/16-23/03/18	5.5, 6.1	165	-4	2.864	0.006	0.24	0.05	MAR
67934	2000 WY133	23/02/13-23/02/16	12.6,14.0	119	-6	9.12	0.03	1.07	0.06	EUN

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



(67934) 2000 WY133. A Eunomia family member with no previously determined rotation period. A bimodal lightcurve with an extremely high amplitude of over one magnitude indicating an elongated shape and a rotation period of $P = 9.12 \pm 0.03$ h results from the 2023 February data gathered on three nights.



Acknowledgements

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LIGHTCURVES OF THIRTEEN ASTEROIDS

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We present lightcurves and synodic rotation periods for thirteen asteroids measured in the first half of 2023.

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 15-80 nearby comparison ("comp") stars selected from the ATLAS refcat2 catalog (Tonry et al., 2018). Custom diagnostic plots and the abundance of comp stars 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 magnitudes, on Sloan r' (SR) catalog basis, for one target asteroid. These magnitudes are corrected for instrument transforms, sky extinction, and image-to-image ("cirrus") fluctuations and thus represent magnitudes at the top of earth's atmosphere. These magnitudes are imported directly into *MPO Canopus* software (Warner, 2021) where they are adjusted for distances and phase-angle dependence, fit by Fourier analysis including identifying and ruling out of aliases, and plotted.

Phase-angle dependence is corrected with a H-G model, using the *G* value minimizing best-fit RMS error across all nights' data; when we cannot estimate an asteroid's *G* value, usually due to a campaign's 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 session herein, other than by estimating *G*.

Lightcurve Results

Thirteen asteroids were observed from New Mexico Skies observatory at 2310 meters elevation in southern New Mexico. Images before May 24 were acquired and autoguided using a 0.35-meter SCT reduced to *f*/7.7 and an SBIG STXL-6303E CCD camera cooled to -35 C fitted with an Exoplanet/Blue Blocker (BB) filter (Astrodon). Images after May 24 were acquired, without autoguiding, using a 0.50-meter PlaneWave OTA and an SBIG AC4040M CMOS camera cooled to -15 C fitted with a GG495 yellow filter (Schott). A PlaneWave L-500 served as OTA mount.

The equipment was operated remotely via *ACP* software (DC-3 Dreams, version 8.3), 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 150 seconds (before May 24) or 90 seconds (after May 24) to ensure suitable comp-star photometry, and to a maximum of 900 seconds (before May 24) or 480 seconds (after May 24).

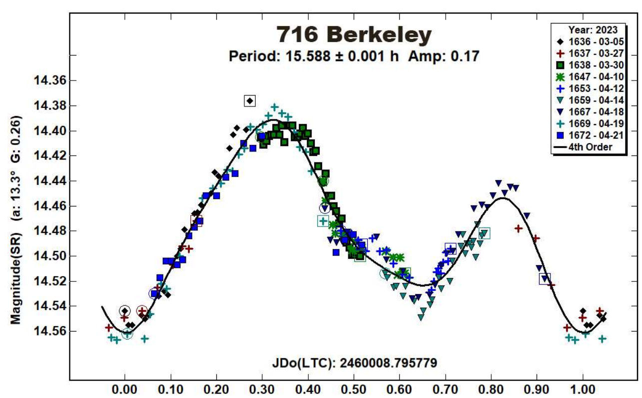
FITS images were plate-solved by *PinPoint* (DC-3 Dreams) or *TheSkyX* (Software Bisque) and were calibrated using temperature-matched, median-averaged dark images and recent flat images of a flux-adjustable flat panel. Target asteroids were identified in *Astrometrica* (Herbert Raab). All photometric images were visually inspected; the author excluded images with poor tracking, excessive interference by cloud or moon, or having stars, satellite tracks, cosmic ray 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.

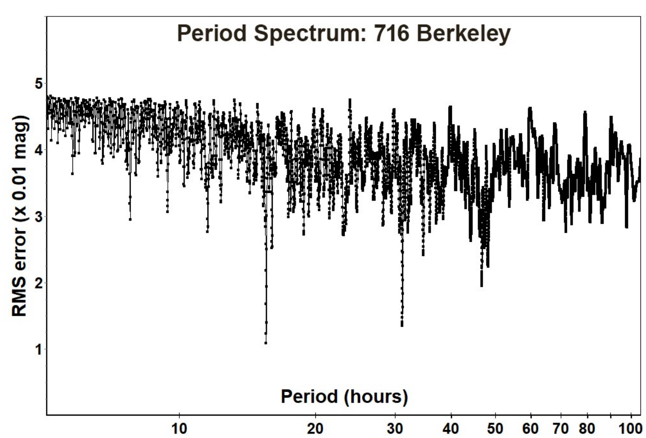
The BB and GG495 yellow filters allow for modest first-order transforms to yield magnitudes in the standard Sloan r' (SR) passband. In our hands, using these filters rather than a clear filter or no filter improves night-to-night reproducibility to a degree outweighing loss of signal-to-noise ratio from loss of flux.

Comparison stars from the ATLAS refcat2 catalog were selected only if they had a distance of at least 15 arcseconds from image boundaries and from other catalogued flux sources, no catalog VARIABLE flag, SR magnitude within [-1, +2] of the target asteroid's SR magnitude on that night (except that very faint asteroids used comp stars with 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 work, "period" refers to an asteroid's synodic rotation period, "SR" denotes the Sloan r' passband, and "mmag" denotes millimagnitudes (0.001 magnitude). The *G* value given in the lightcurve plot is that which optimized the Fourier fit.

716 Berkeley. Nine nights of observations of this outer main-belt asteroid support a synodic rotation period of 15.588 ± 0.001 h, agreeing with two previous reports of 15.55 h (Garlitz, 2011web) and 15.46 h (Polakis, 2021) but differing from two others: > 17 h (Lagerkvist, 1978) and 34.3 h (Behrend, 2018web). The RMS error of our Fourier fit is 11 mmag. The lightcurve is clearly bimodal and the period spectrum appears unambiguous.



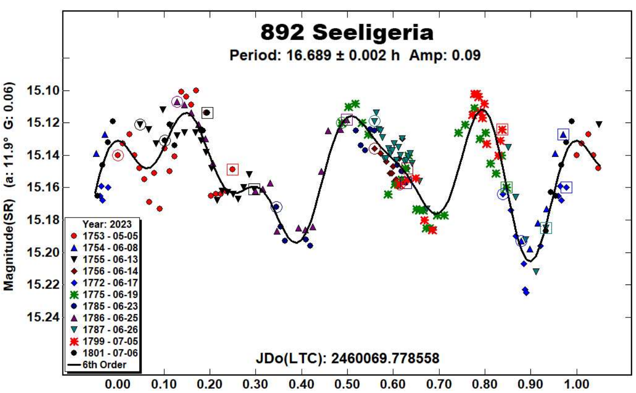


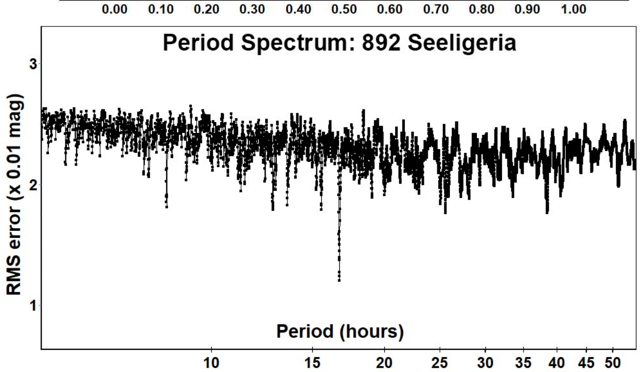
Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
716	Berkeley	2023 03/05-04/21	*13.4,8.4	194	8	15.588	0.001	0.17	0.03	MB-O
892	Seeligeria	2023 05/05-07/06	*12.0,10.9	257	24	16.689	0.002	0.09	0.03	MB-O
907	Rhoda	2023 05/06-06/19	16.2,22.6	192	8	22.467	0.003	0.27	0.02	MB-O
920	Rogeria	2023 02/01-05/31	*7.6,23.4	145	-9	12.250	0.001	0.35	0.05	MB-M
926	Imhilde	2023 01/30-04/22	7.9,21.1	126	19	25.977	0.002	0.31	0.04	IMH
931	Whittemora	2023 04/21-06/10	*9.0,6.0	241	10	19.177	0.001	0.21	0.03	MB-O
1015	Christa	2023 04/16-05/03	11.1,6.9	240	10	11.223	0.002	0.15	0.03	MB-O
1393	Sofala	2023 02/05-04/17	*20.3,12.5	183	7	162.672	0.062	0.49	0.04	MB-I
1465	Autonoma	2023 05/29-07/05	*6.7,14.2	253	12	4.882	0.001	0.11	0.03	MB-O
1937	Locarno	2023 04/16-06/14	*9.7,20.9	221	9	110.910	0.050	0.24	0.05	MB-I
2356	Hirons	2023 04/21-06/24	*7.6,14.8	228	12	41.858	0.006	0.15	0.03	MB-O
3099	Hergenrother	2023 03/04-04/24	*9.8,17.7	177	11	25.663	0.003	0.14	0.03	MB-O
3784	Chopin	2023 04/13-07/06	*15.8,15.7	244	8	10.503	0.001	0.21	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 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 2009a).

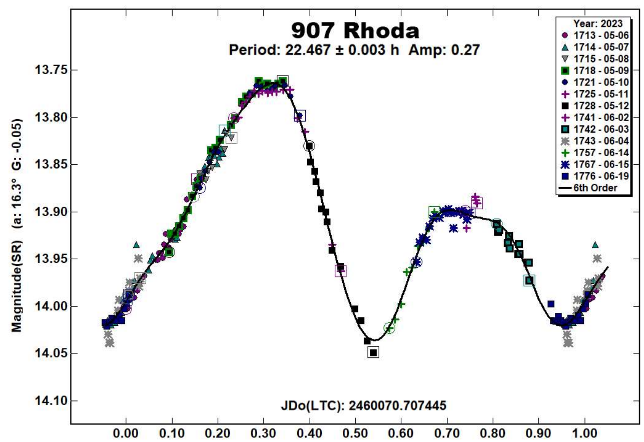
892 Seeligeria. For this outer main-belt asteroid, we find a complex lightcurve shape yielding only one suitable period solution of 16.689 ± 0.002 h, in agreement with most previous reports: 16.7 h (Behrend, 2007web; 2017web), 16.695 h (Behrend, 2020web), 16.6924 h (Ďurech et al., 2020), and 16.693 h (Colazo et al., 2023) but differing from 15.78 h (Shipley et al., 2008) and 8.395 h (Polakis, 2020). Colazo found a lightcurve shape remarkably similar to ours, whereas the incompleteness of Shipley's phase coverage proved problematic for such a complex lightcurve shape. Polakis' result is simply half of ours, which may result from the target's smaller amplitude during that observation period. Our Fourier fit RMS error is 12 mmag.

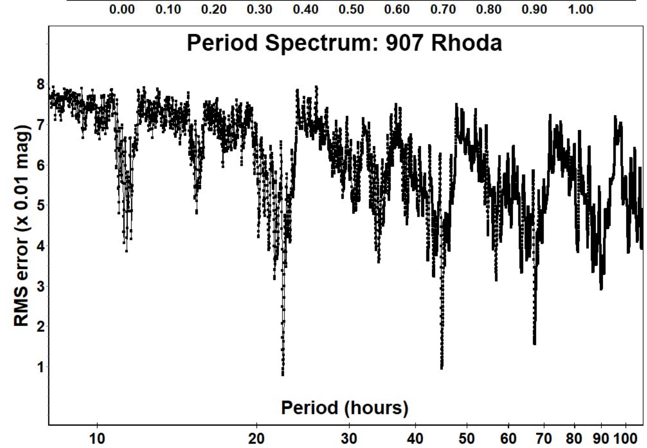
However complex the lightcurve, the period spectrum affords only one acceptable period solution.





907 Rhoda. Our period estimate of 22.467 ± 0.003 h agrees well with three previous reports; 22.44 h (Warner, 2004b), 22.46 h (Marciniak et al., 2014), and 22.4 h (Behrend, 2018web); it differs from one recent survey result of 42.6307 h (Pál et al., 2020), an alias by ½ period per day. The lightcurve is clearly bimodal. Our Fourier fit RMS error is 8 mmag. The period spectrum's most significant signals are limited to multiples of our period estimate.

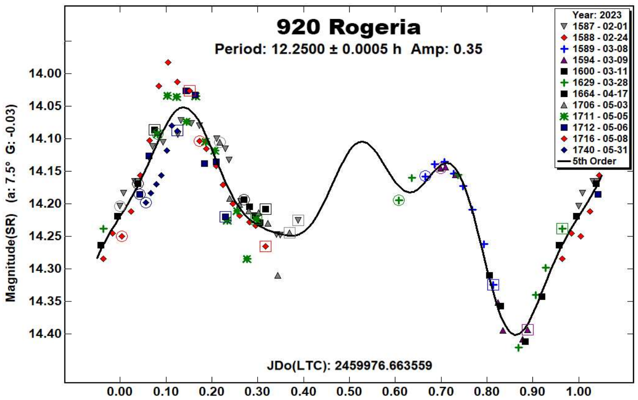


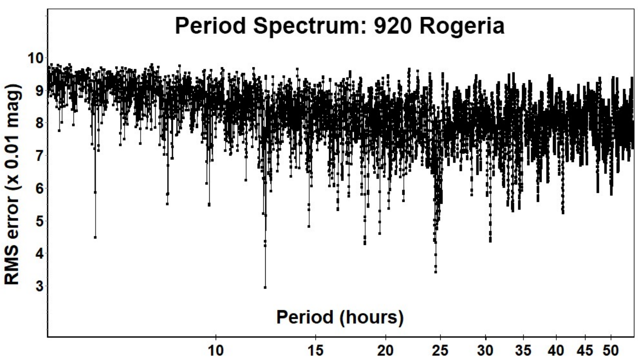


920 Rogeria. For this middle main-belt asteroid, our period estimate of 12.2500 ± 0.0005 h agrees well with two previous reports: 12.244 h (Polakis, 2018) and 12.2358 h (Pál et al., 2020), and fairly well with another of 12.5749 h (Hanuš et al., 2013) but differs from two web reports of 9.05 h (Behrend, 2012web) and 8.09 h (Pravec et al., 2012web). The 8.09 h estimate is an alias of our estimate by one period per day. Our Fourier fit RMS error is 30 mmag.

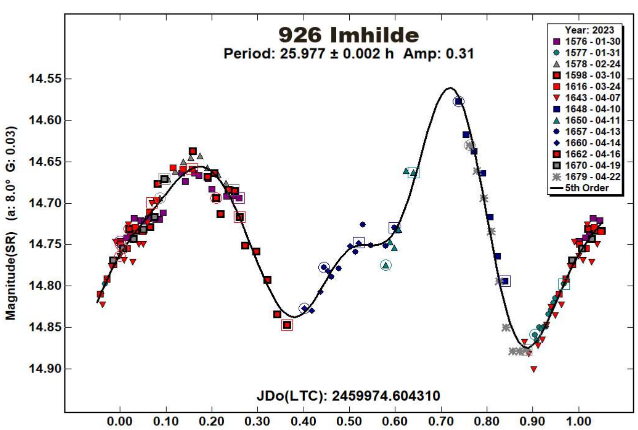
Despite 12 nights' observations over 17 weeks, our lightcurve phase coverage suffers a gap of about 20%; even so, the lightcurve is clearly bimodal. Indeed, our lightcurve observations match quite closely the shape of Polakis' 2017 lightcurve (Polakis, 2018).

Periods of 8.09 h and 9.05 h do appear as minor signals in our period spectrum, but the present period estimate dominates.

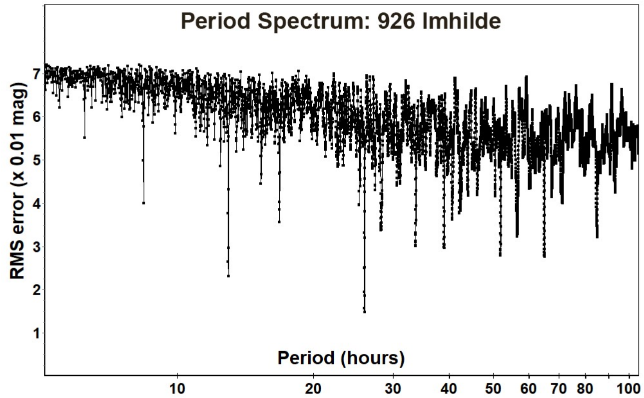




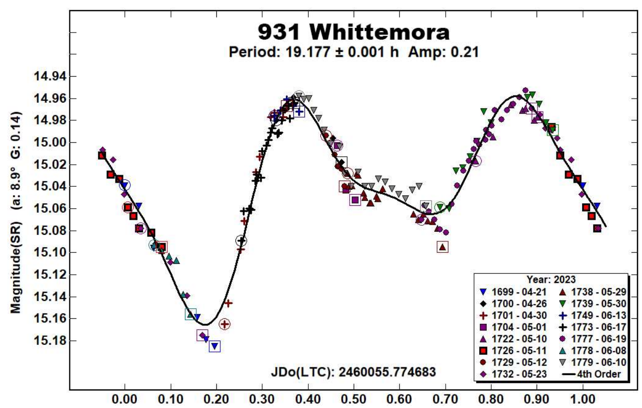
926 Imhilde. Observations of this asteroid, for which the Imhilde asteroid family is named, yield a period estimate of 25.977 ± 0.002 h, in close agreement with two previous reports: 26.1 h (Warner, 2004a) and 25.9775 h (Ďurech et al., 2020) and in rougher agreement with 26.8 h (Warner, 2011) and 25.1244 h (Pál et al., 2020). Our Fourier fit RMS error is 15 mmag.

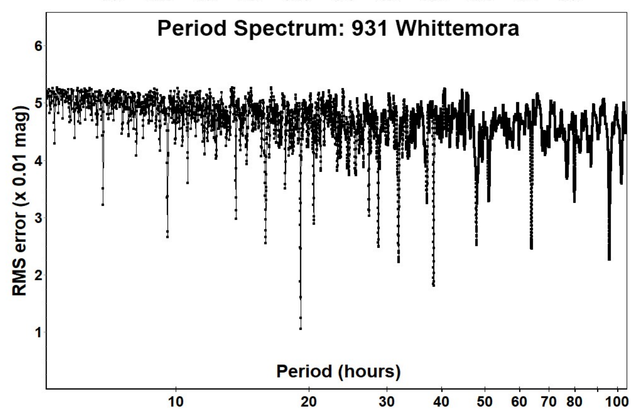


Period solutions of 26.8 h and 25.1244 h are absent from the major signals of our period spectrum.

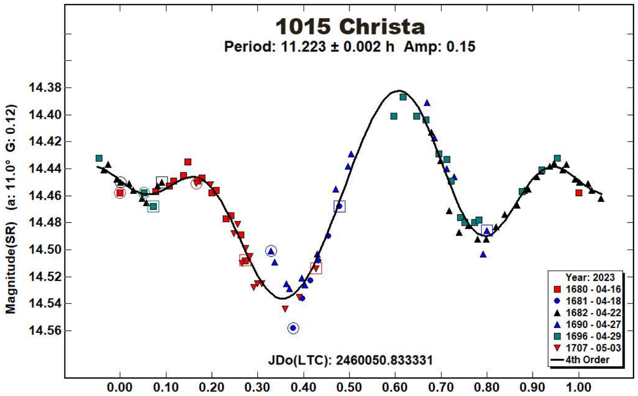


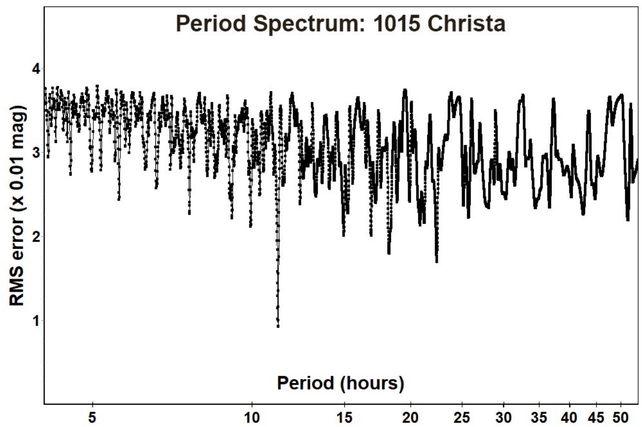
931 Whittemora. We estimate the synodic period for this outer main-belt asteroid as 19.177 ± 0.001 h, in acceptable agreement with all three known previous reports: 19.20 h (Menke, 2005), >16 h (Behrend, 2006web), and 19.199 h (Behrend, 2016web). The lightcurve shape resembles that given by Menke, except that ours shows a much sharper minimum brightness. Our Fourier fit RMS error is 10 mmag. Our proposed period and its double dominate the period spectrum.





1015 Christa. We estimate for this outer main-belt asteroid a period of 11.223 ± 0.002 h, which agrees the previous reports of 11.230 h (Warner, 2009b) and 11.23 h (Colazo et al., 2020) but differs from one earlier estimate of 12.189 h (Behrend, 2005web), the latter being an alias of 11.223 h by 1 period per 6 days. Our lightcurve is roughly bimodal and resembles Warner's lightcurve shape as well as a time-reversal of Colazo's lightcurve shape. Our Fourier fit RMS error is 9 mmag.

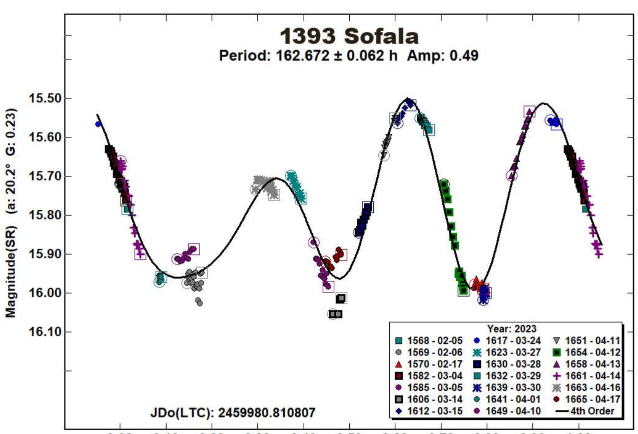


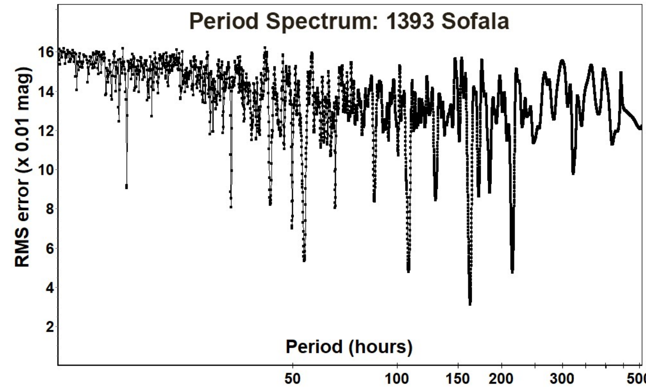


1393 Sofala. Previous reports offer three very different period estimates: 7.8 h (Behrend, 2008web), 16.5931 h (Hanuš et al., 2013), and 108.2590 h (Waszczak et al., 2015) for this inner main-belt asteroid, which is little wonder given the unusual trimodal lightcurve shape that we report here. Settling on a solution with confidence required 20 nights of observation over 10 weeks (10.5 period cycles); in the end, we report a period of 162.672 ± 0.062 h, a relatively large amplitude, and a Fourier fit RMS error of 31 mmag.

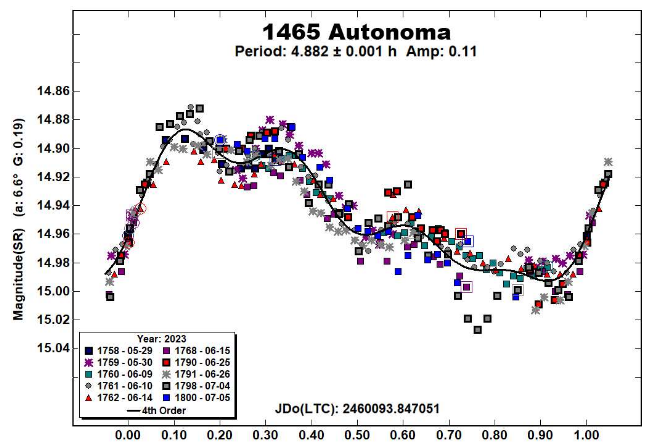
The previous estimate of 16.5931 h represents an alias of 1/3 of our estimate (monomodal interpretation) by almost exactly 1 period per day. The previous estimate of 108.2590 h is close to 2/3 of our estimate (bimodal interpretation).

The period spectrum is dominated by our period estimate, with the next three largest signals at multiples of 1/3 that estimate.

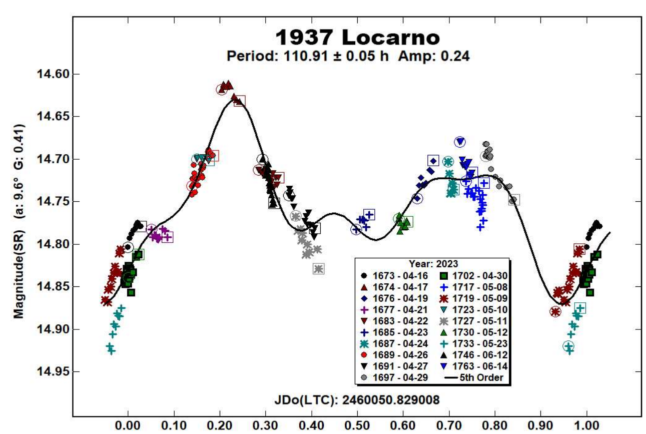


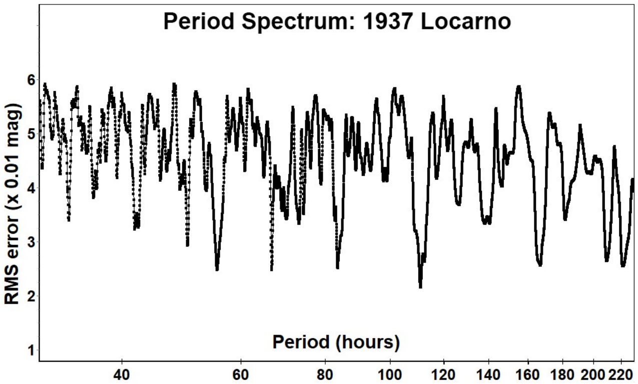


1465 Autonoma. Our period estimate of 4.882 ± 0.001 h for this outer main-belt asteroid agrees with most previous reports, e.g., 4.88 h (Brinsfield, 2008), 4.886 h (Fauvaud and Fauvaud, 2013), and 4.882 h (Ditteon et al., 2018) but differs from 11.94897 h (Ďurech et al., 2019) and 6.11 h (Yeh et al., 2020). The survey-based estimate of 6.11 h is an alias of 4.882 h by 1 period per day and its lightcurve plot shows numerous observation outliers. Our lightcurve shape is monomodal, and our Fourier fit RMS error is 11 mmag.



1937 Locarno. With our period estimate of 110.91 ± 0.05 h, we generally confirm the sole known previous report, 107.2 h (Behrend, 2019web) when the latter is interpreted as bimodal. Our lightcurve is bimodal as well, and the observations exhibit systematic night-to-night variations that are too large to be caused by differing sets of comp stars, possibly indicating a mild effect of precession (non-principal-axis rotation, or “tumbling”). Our Fourier fit RMS error is 21 mmag.

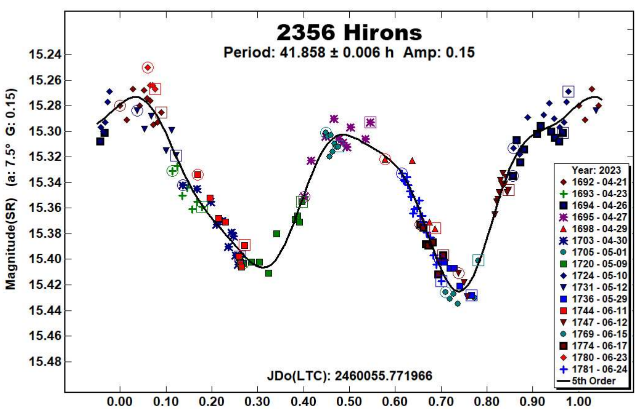


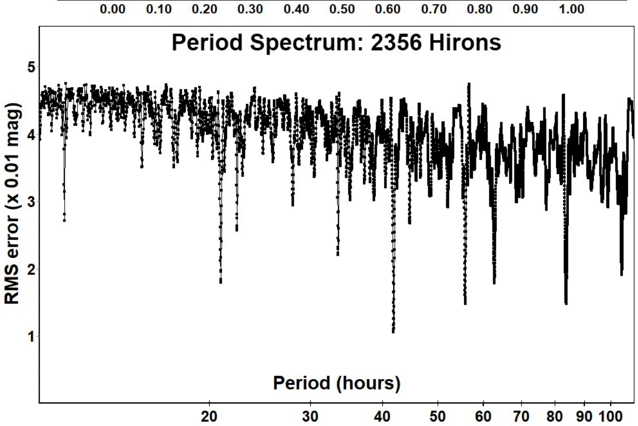


Our observations include only one night near brightness maximum, and our period spectrum shows numerous signals in addition to the main solution of 110.91 h. So, this asteroid merits re-examination with special attention to the brightness maximum and/or to the sharp brightening just prior. 2024 and 2026 apparitions favor the Northern Hemisphere.

2356 Hirons. Our period estimate of 41.858 ± 0.006 h for this outer main-belt asteroid differs from the known reports of 21.782 h (Waszczak et al., 2015) and 38.3 h (Behrend, 2020web). Our lightcurve is built from 17 nights' observations and is clearly bimodal. Our Fourier fit RMS error is 11 mmag.

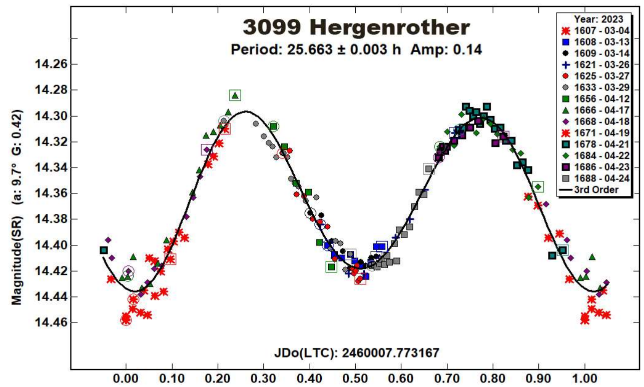
We can interpret neither previously reported period as an alias, simple fraction, or multiple of our estimate, and neither appears as a major signal in our period spectrum.

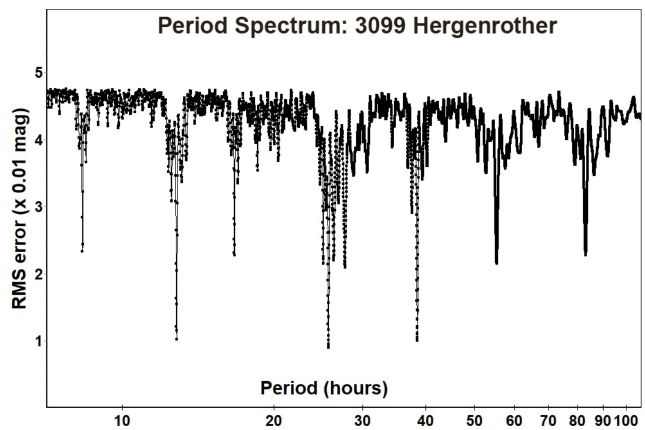




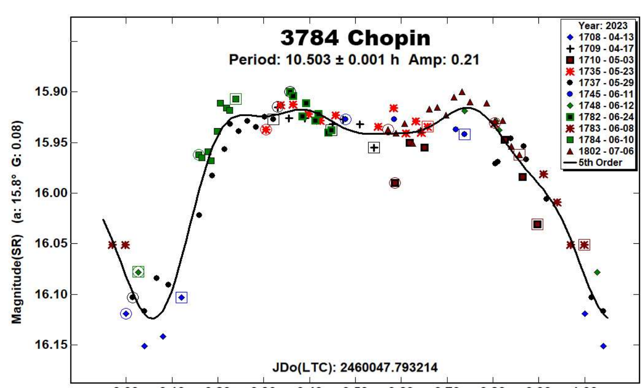
3099 Hergenrother. Our period estimate of 25.663 ± 0.003 h for this outer main-belt asteroid matches two recent reports: 25.58 h (Skiff et al., 2019) and 25.6991 h (Pál et al., 2020) more closely than it does with the 24.266 h from Behrend (2008web). Our lightcurve is bimodal and resembles the shape found by Skiff, though at only half its amplitude. Our Fourier fit RMS error is 9 mmag.

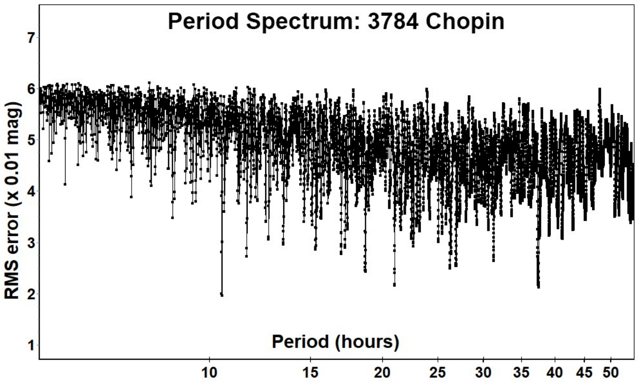
The period spectrum's major signals appear at half, one, and three-halves of our period estimate.





3784 Chopin. We report a rotational period of 10.503 ± 0.001 h taken as monomodal, though the amplitude and shape allow for a bimodal interpretation as well, which would agree with one previous report (20.9902 h; Pál et al., 2020) while still differing from one other (12.72 h; Behrend, 2006web). Our Fourier fit RMS error is 18 mmag.





Neither the split-halves plot (not shown) nor period spectrum helps much in deciding between monomodal and bimodal interpretations. This asteroid merits observation at upcoming apparitions, which unfortunately will be fainter in magnitude than was that of 2023.

Acknowledgements

The author thanks all contributors to the ATLAS paper (Tonry et al. 2018) for providing openly and without cost the ATLAS refcat2 catalog release. This current work also makes extensive use of the python language interpreter and of several supporting packages (notably: astropy, ccdproc, ephem, matplotlib, pandas, photutils, requests, skyfield, and statsmodels), all made available openly and without cost. Thanks also to Jim Seargeant for finding and helping secure the 0.5-m OTA.

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ROTATION PERIOD AND LIGHTCURVE DETERMINATION FOR FOURTEEN MINOR PLANETS

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Photometric measurements of fourteen main-belt asteroids were conducted from 2023 February through 2023 May. Phased lightcurves and rotation periods for each one are presented here. Eight of the asteroids have no prior published period solutions. All lightcurve data has been submitted to the ALCDEF database.

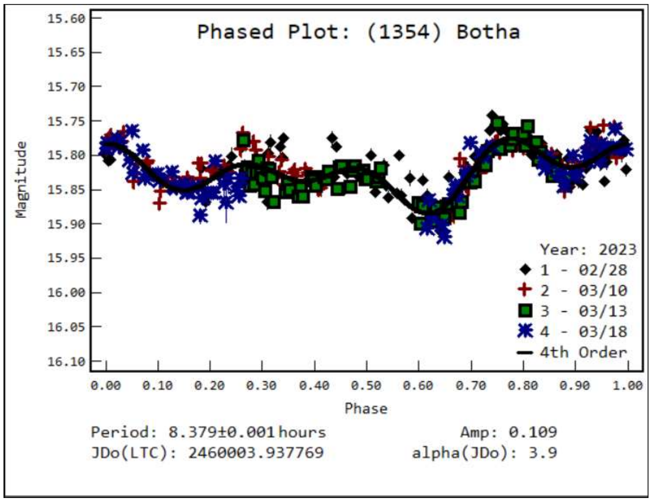
CMOS and CCD observations of fourteen main-belt asteroids were performed at NAC Observatory (MPC U98) in Benson, AZ. Images were taken using a 0.35m f/7.2 Corrected Dall-Kirkham telescope. Some images were captured using a Moravian C5A-100M CMOS camera featuring a Sony IMX-461 sensor. Images were captured at a scale of 1.21 arc seconds per pixel after binning 4×4. In 2023 March the CMOS camera was decommissioned in favor of a SBIG CCD47-10 CCD camera. It utilizes a back-illuminated Teledyne E2V CCD47-10 AIMO sensor and is operated at 1×1 binning with a scale of 1.05 arc seconds per pixel. Table I shows observing circumstances and results. All images for these observations were obtained between 2023 February and 2023 May.

Data reduction and period analysis were done using *Tycho* (Parrott, 2023). The CMOS sensor provided a 58'×44' field of view, enabling the use of the same field center for three to four consecutive nights. The CCD camera provides an 18'×18' field of view. The asteroid and five or more comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B\text{-}V < 0.95$ to correspond with color ranges of asteroids.

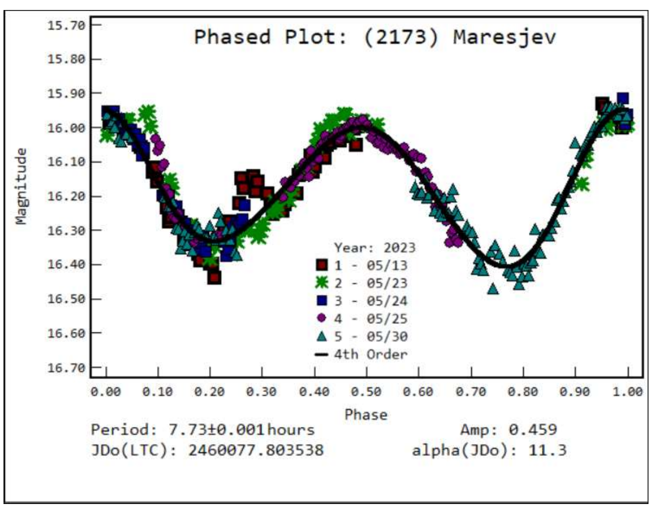
Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into Tycho. The ATLAS catalog derives Sloan *griz* magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color indices allowed the separate nightly runs to be linked often with no zero-point offset required. The measuring aperture diameter was set to value equal to the average FWHM of the session data set multiplied by four. The same size aperture 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, 2011a), either for having uncertain periods or no reported period at all. In this set of observations, eight of the fourteen asteroids had no previous period analysis listed. 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.

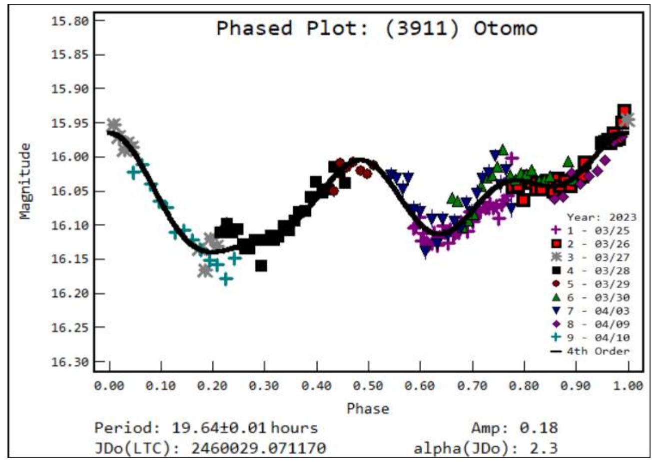
1354 Botha was discovered by C. Jackson at Johannesburg in April 1935. It is an outer main belt asteroid with a semi-major axis of 3.12 AU orbiting the sun in 5 years, 6 months. A previously reported period of 4 hours and amplitude 0.21 mag (Behrend, 2003web) was reported from observations made in September 2003. Over the course of four nights 334 observations were made and used to calculate a rotation period of 8.379 ± 0.001 hours and amplitude of 0.109 ± 0.019 mag., disagreeing with Behrend's result.



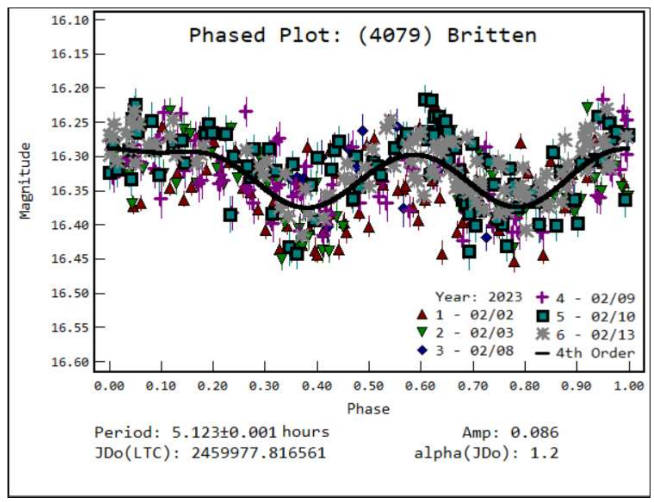
2173 Maresjev was discovered at the Crimean Astrophysical Observatory in 1974 by L. V. Zhuravleva. Two period solutions were found in the LCDB. The earliest reported period by Shipley et al (2008) is 11.6 ± 0.1h; Durech et al (2020) reported a period of 7.72956 ± 0.00003 h. A light curve was constructed from 390 data points obtained during five nights in 2023 May. The calculated period of 7.730 ± 0.001 h agrees with the period published by Durech. The amplitude of the lightcurve is 0.459 ± 0.037 mag.



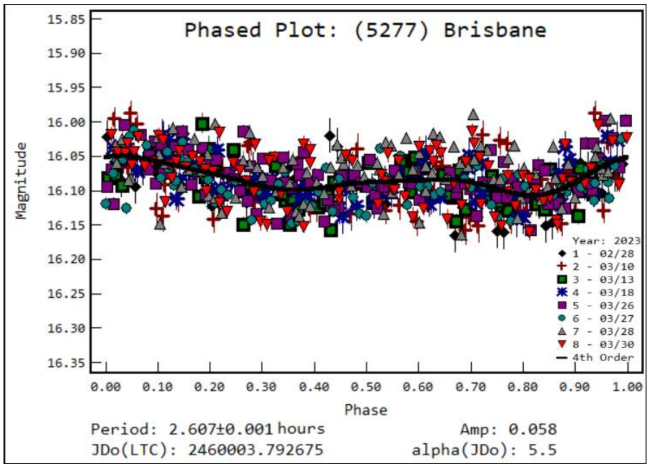
3911 Otomo is the first minor planet observed at this observatory since installing a back illuminated CCD camera in place of the CMOS sensor. The LCDB lists a single previously reported period of 10.6 ± 0.06 hours by Behrend (2014web). The Behrend observations note that the result is provisional with an unreliable period. Over a period of 9 nights 464 data points were obtained and binned in sets of 3 with a maximum time difference of 3 minutes. This data produced a light curve with a rotation period of 19.64 ± 0.01 hours and an amplitude of 0.18 ± 0.018 magnitude, disagreeing with Behrend's previous result.

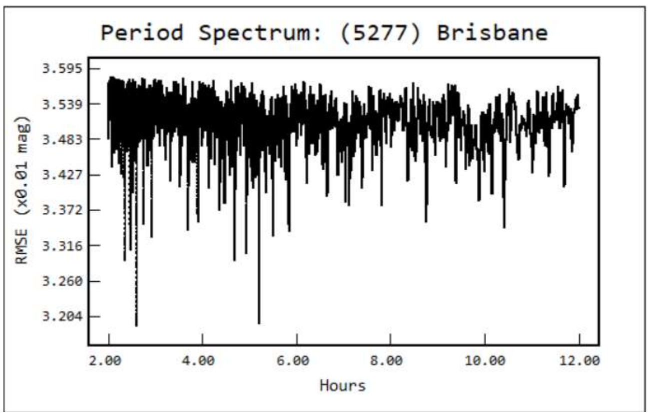


4079 Britten is a Themis family asteroid, discovered by E. Bowell at Flagstaff in 1983. No published period was found in the LCDB. During a six-night interval, 551 images were obtained for calculation of the rotation period. Upon further inspection 69 of the images were not used because of interference from field stars. A rotation period of 5.123 ± 0.001 hours was calculated from remaining data. The amplitude is 0.086 mag., and the RMS error on the fit is 0.040 mag.

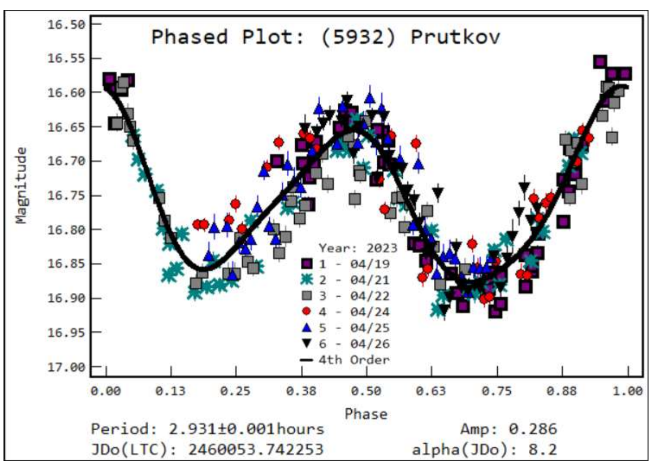


5277 Brisbane is an inner main belt asteroid discovered by R.H. McNaught at Siding Spring in 1988. No periods are shown in the LCDB. During the first four nights of observation, 261 images were gathered with the CMOS camera prior to its decommissioning. The four subsequent nights of observations were done with the newly installed CCD camera contributing an additional 384 images. Using a custom G value of 0.24 noted in the asteroid's entry in the LCDB produced a better fit between sessions as the phase angle changed significantly during the window of observations. The period search yielded a result of 2.607 ± 0.001 h with an amplitude of 0.058 mag. The RMS error on the fit is 0.032 mag.

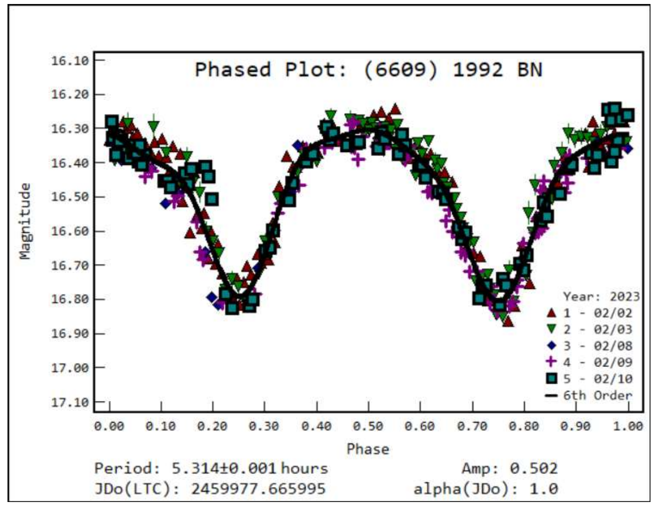




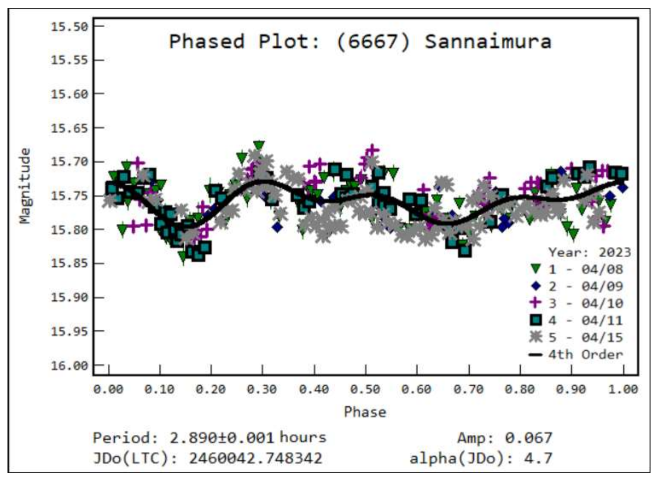
5932 Prutkov is a main belt asteroid without a listed period in the LCDB. In 2023 April, during six nights observing, 254 images were taken. Subsequent analysis produced a period solution of 2.931 ± 0.001 h. The amplitude is 0.286 mag., and the RMS error on the fit is 0.037 mag.



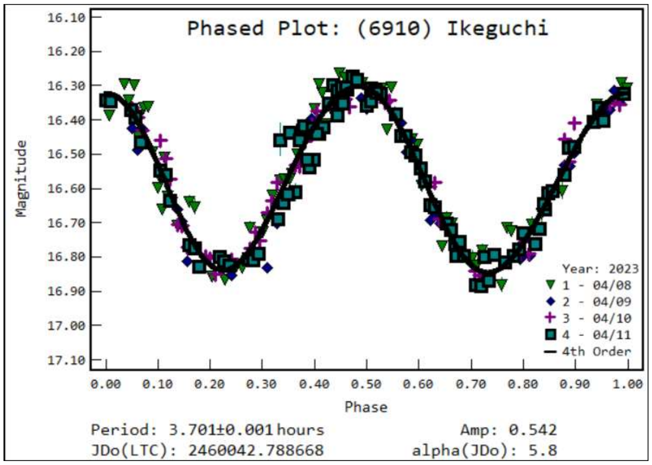
6609 1992 BN is an Eos-family asteroid, discovered at Kushiro in 1940. No published period was found in a search of the LCDB. Observing five nights over a nine-night interval, 391 images were obtained, yielding a rotation period of 5.314 ± 0.001 h. The amplitude is 0.502 mag., and the RMS error on the fit is 0.045 mag.



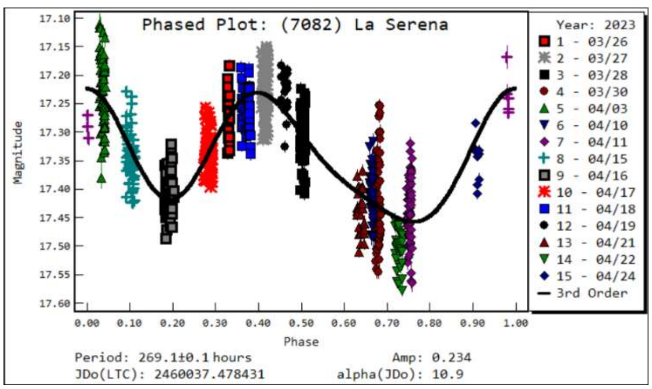
6667 Sannaimura was discovered in 1994 Y. Kushida and O. Muramatsu at the Yatsugatake South Base Observatory. A period solution by Pál et al (2020) of 2.89282 ± 0.00005 h is listed in the LCDB. A total of 323 data points obtained during five nights were used to calculate a period solution of 2.890 ± 0.001 h, agreeing with Pál. The amplitude of the lightcurve is 0.067 ± 0.026 mag.

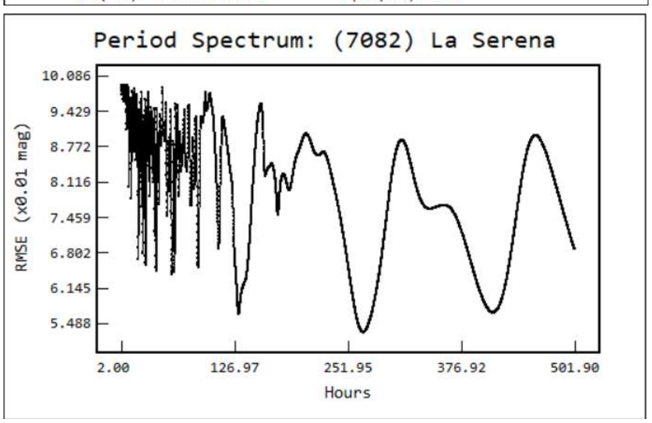


6910 Ikeguchi is an Eos-family asteroid, discovered at Kiyosato by S. Otomo and O. Muramatsu in 1991. There are no published periods listed in the LCDB. 241 total images were taken and measured on four consecutive nights in April 2023. Plotting the measurements yielded a nearly symmetrical bimodal curve with a period of 3.701 ± 0.001 hours and an amplitude of 0.542 magnitude. The RMS error on the fit is 0.043 magnitude.

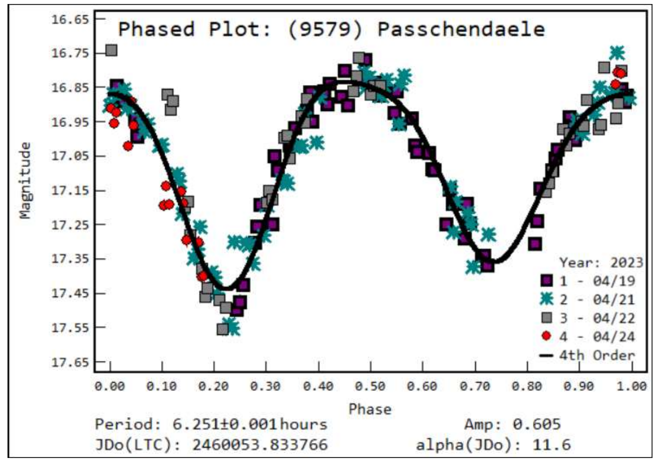


7082 La Serena was discovered in 1987 by E.W. Elst and G. Pizarro at the European Southern Observatory. There are no reported period solutions for this minor planet in the LCDB. In a one-month period, 743 total observations were made over sixteen separate sessions to get full coverage of the period of this slow rotator. Analysis of the observations produced a period of 269.1 ± 0.1 h with an amplitude of 0.234 ± 0.05 mag.

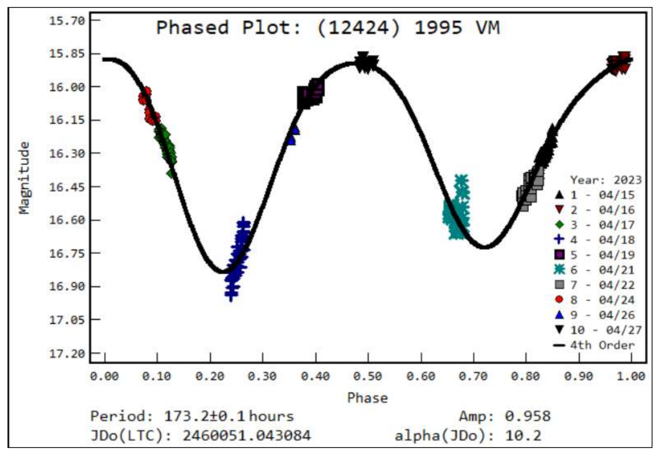




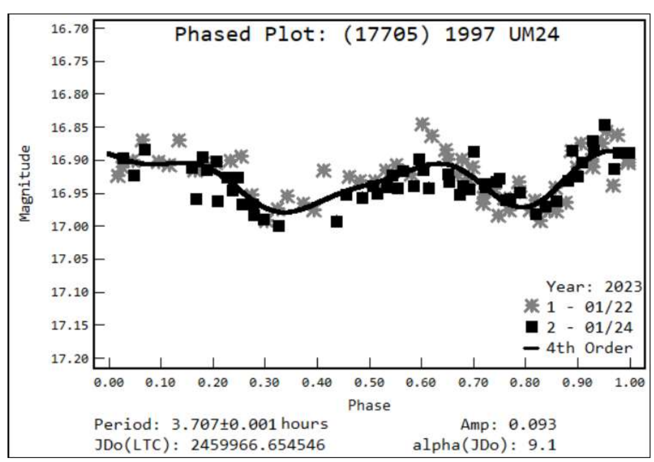
9579 Passchendaele is a Hertha-family asteroid, discovered at the European Southern Observatory by E.W. Elst in 1989. During a four-night interval, 186 images were obtained, establishing a rotation period of 6.251 ± 0.001 h. No published period was found in the LCDB. The amplitude is 0.605 mag., and the RMS error on the fit is 0.059 mag.



12424 1995 VM was discovered in 1994 by T. Kobayashi at Oizumi. Two period solutions are listed the LCDB; Waszczak et al. (2015), 173.772 ± 0.6533 h, and Pál et al (2020), 176.94 ± 0.05 h. A total of 293 data points obtained over ten nights were used to calculate a period solution of 173.2 ± 0.1 h, agreeing with Waszczak and Pál. The amplitude of the lightcurve is 0.958 ± 0.037 mag.

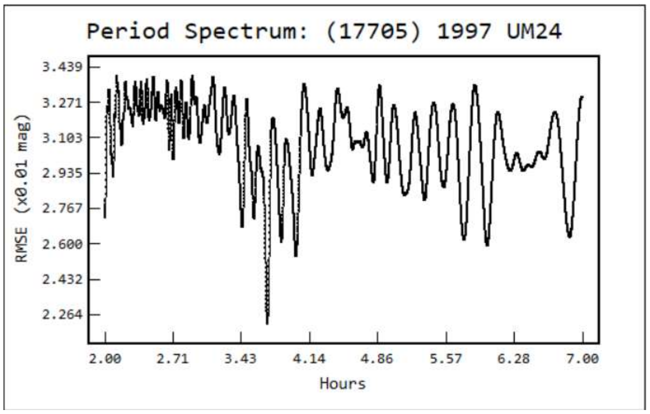


17705 1997 UM24 was discovered in 1997 by the Beijing Schmidt CCD Asteroid Program at Xinglong. No period solutions were found in the LCDB. A total of 114 data points obtained during two consecutive nights were used to calculate a period solution of 3.707 ± 0.001 h. The amplitude of the lightcurve is 0.093 ± 0.023 mag.

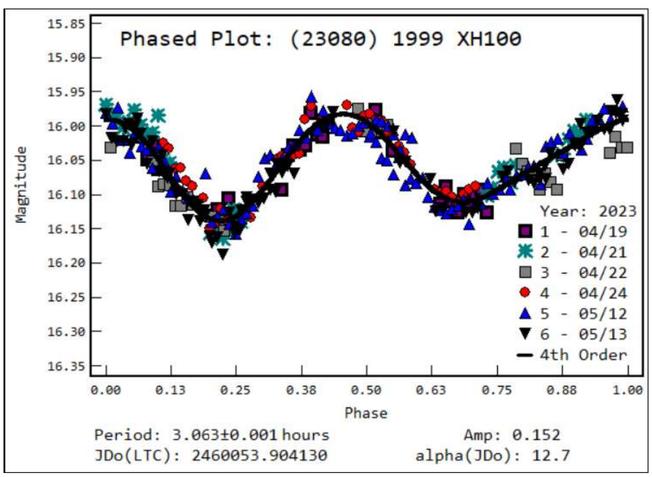


Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1354	Botha	2023 02/28-03/18	3.9,9.25	149	5	8.379	0.001	0.109	0.019	MB-O
2173	Maresjev	2023 05/13-05/30	11.2,7.8	258	17	7.730	0.001	0.459	0.037	MB-O
3911	Otomo	2023 03/25-04/10	*2.4,4.5	188	-4	19.64	0.01	0.18	0.018	Eos
4079	Britten	2023 02/02-02/13	3.6,5.2	131	3	5.123	0.001	0.086	0.04	Themis
5277	Brisbane	2023 02/28-03/30	5.5,18.6	157	-8	2.607	0.001	0.058	0.032	MB-I
5932	Prutkov	2023 04/19-04/26	8.2,11.2	193	3	2.931	0.001	0.286	0.037	MB-M
6609	1992 BN	2023 02/02-02/10	1.1, 3.6	131	3	5.314	0.001	0.502	0.045	Eos
6667	Sannaimura	2023 04/08-04/15	4.7,8.3	191	3	2.890	0.001	0.067	0.026	MB-I
6910	Ikeguchi	2023 04/08-04/11	5.8,6.9	184	-4	3.701	0.001	0.542	0.043	Eos
7082	La Serena	2023 03/26-04/25	12.6,7.4	217	18	269.1	0.1	0.234	0.05	MB-O
9579	Passchendaele	2023 04/19-04/24	11.5,13.9	189	-2	6.251	0.001	0.605	0.059	Herth
12424	1995 VM	2023 04/15-04/27	10.6,5.5	223	7	173.2	0.1	0.958	0.037	Eun
17705	1997 UM24	2023 01/22-01/23	9.1,10	107	9	3.707	0.001	0.093	0.023	Vesta
23080	1999 XH100	2023 04/19-05/13	12.7,7.6	230	10	3.063	0.001	0.152	0.019	MB-M

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



<u>23080 1999 XH100</u> was discovered in December 1999 by LINEAR at Socorro. In the LCDB Pál et al (2020) reported a period solution of 3.06273 ± 0.0005 h. CCD observations by the author in 2023 April and May provided 325 measurements and a calculated period of 3.063 ± 0.001 h. This measurement is in agreement with Pál's result. The amplitude of the lightcurve is 0.152 ± 0.019 mag.



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LIGHTCURVE ANALYSIS FOR FOUR NEAR-EARTH ASTEROIDS OBSERVED APRIL-JUNE 2023

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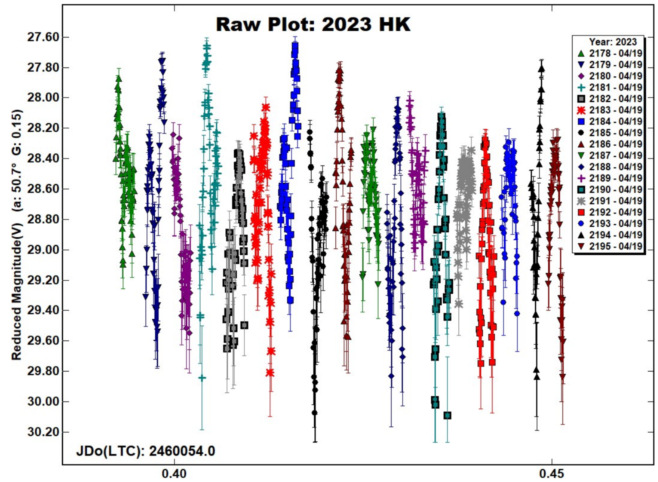
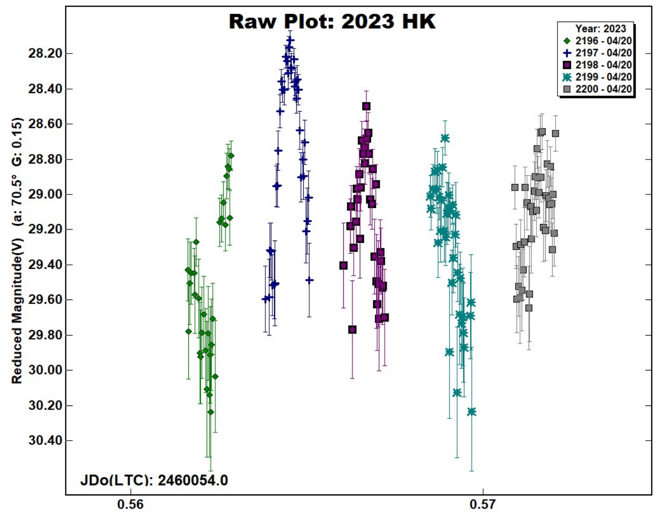
Lightcurves and amplitudes for four small near-Earth asteroids observed from Great Shefford Observatory during close approaches between April and June 2023 are reported. All are fast rotators with dominant periods shorter than 10 minutes and two are identified as having tumbling rotation.

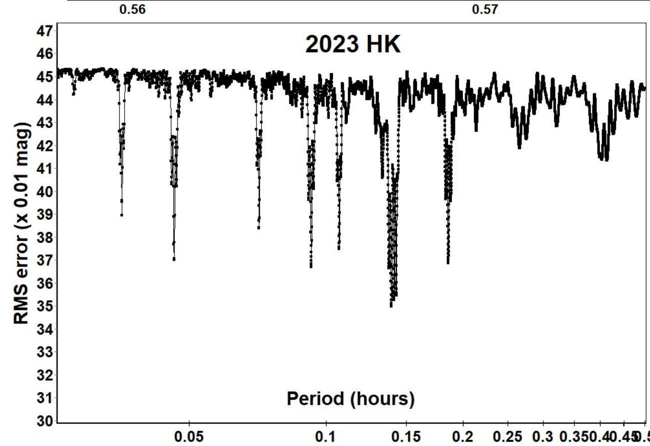
Photometric observations of near-Earth asteroids during close approaches to Earth between April and June 2023 were made at Great Shefford Observatory using a 0.40-m Schmidt-Cassegrain and Apogee Alta U47+ CCD camera. All observations were made unfiltered and with the telescope operating with a focal reducer at f/6. The 1K×1K, 13-micron CCD was binned 2×2 resulting in an image scale of 2.16 arc seconds/pixel. All the images were calibrated with dark and flat frames and *Astrometrica* (Raab, 2018) was used to measure photometry using APASS Johnson V band data from the UCAC4 catalogue (Zacharias et al., 2013). *MPO Canopus* (Warner, 2022), 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, 2023) or from wider searches unless otherwise noted. All size estimates are calculated using H values from the Small-Body Database Lookup (JPL, 2023), using an assumed albedo for NEAs of 0.2 (LCDB readme.pdf file) and are therefore uncertain and offered for relative comparison only.

2023 HK. This Apollo (H = 27.2, est. size 11 m) was discovered by the Mt. Lemmon Survey on 2023 Apr 16.3 UTC four days before an approach to within 0.9 Lunar Distances (LD) from Earth (Carcano et al., 2023). It was observed for 1.4 hours starting 2023 Apr. 19.89 UTC, then 2.6 hours later for an additional 15 minutes. Its apparent speed increased from 220 to 440 arcsec/min and exposures were limited to 2.4 s, reducing to 1 s to keep trailing of the target within the measurement aperture of *Astrometrica*. Large brightness variations are apparent in the raw plots from the two observing periods and irregularly spaced maxima and minima can be seen in timescales of a few minutes, with an amplitude of at least 1.5 magnitudes. It is apparent that the rotation is likely to be tumbling and a period spectrum shows a number of potential solutions. A simple reduction, assuming principal axis rotation (PAR) gives a very unsatisfactory trimodal lightcurve with period 0.13905 ± 0.00005 h and amplitude of 1.0 magnitudes. Tumbling, or non-principal axis (NPA) rotation solutions derived using the *MPO Canopus* Dual Period Analysis function are also unsatisfactory, an example pair of lightcurves from one NPA solution is given, labelled P1 and P2 and displays obvious systematic trends in both curves.



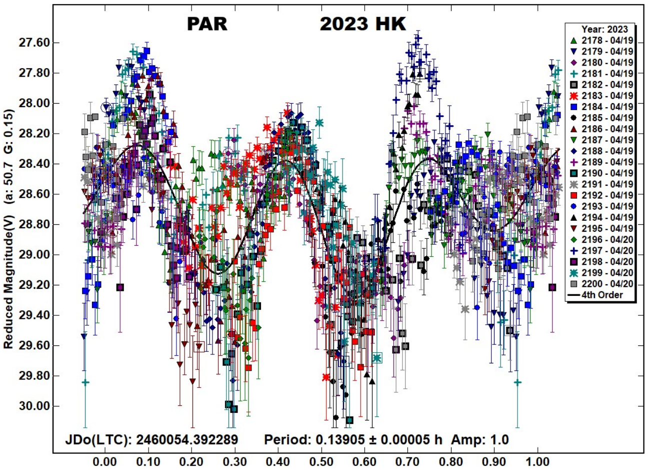


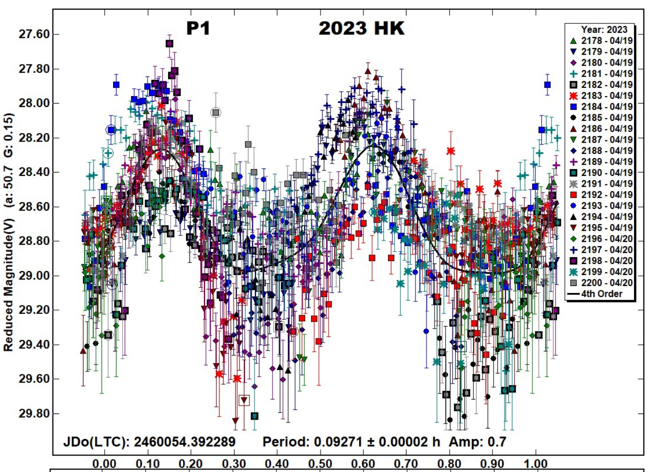


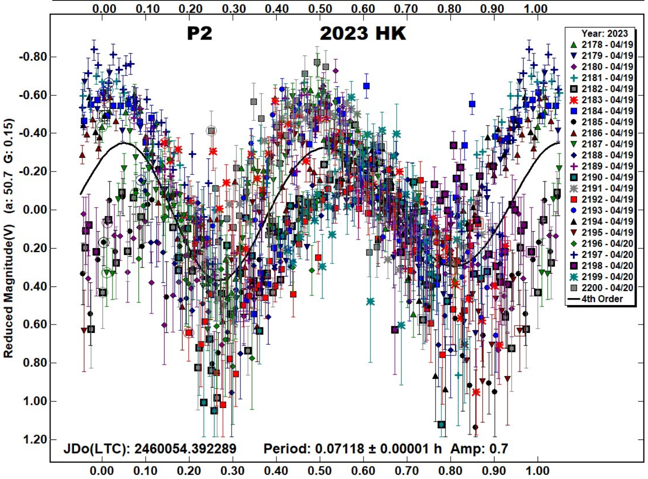
2023 HK is tumbling, and in a very excited state; there are high amplitudes also in linear combinations of the main frequencies (whichever they actually are). There are several significant periods in the data, but it is unclear which of them are real frequencies of the tumbler and which are linear combinations of the real frequencies. The candidate periods are:

0.0562 h (or half that)
0.0712 h (or half that)
0.0927 h (or half that)
0.2658 h (or half that)

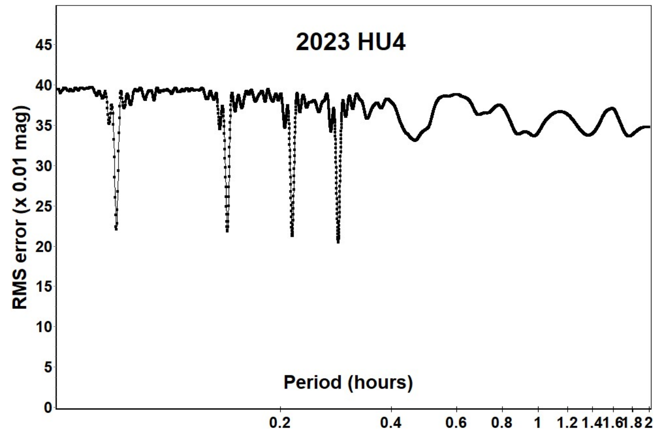
On the scale defined in Pravec et al. (2005) it is expected to be rated as PAR = -2 (NPA rotation detected based on deviations from a single period but the second period is not resolved) with periods in the range from 0.028 to 0.266 h (Petr Pravec, personal communication). The full amplitude suggested by the NPA solutions is ~1.5 magnitudes.



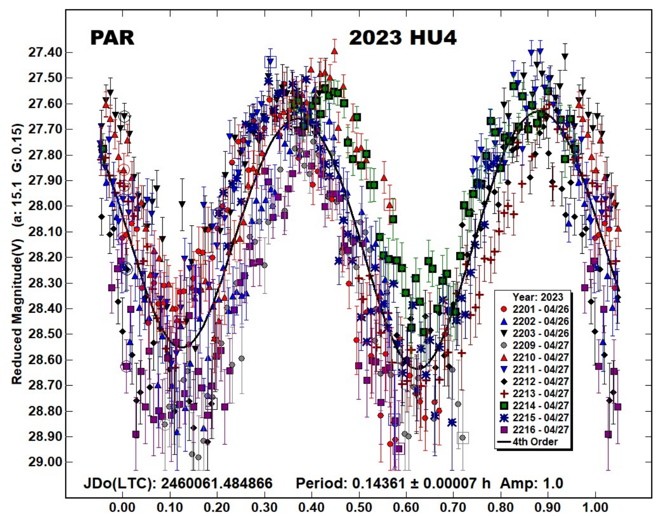




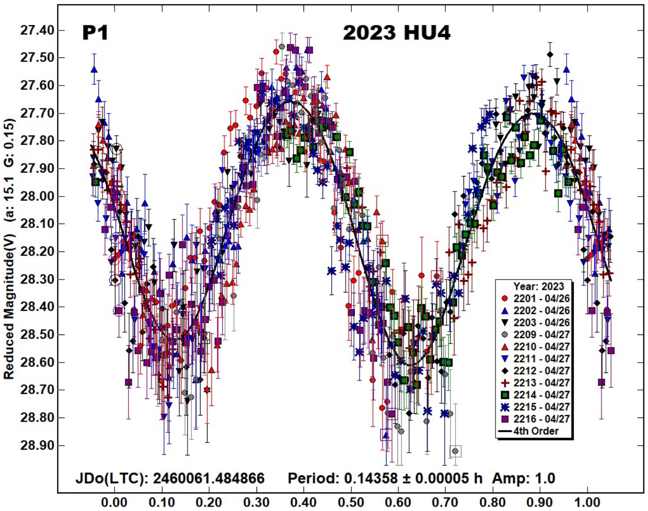
2023 HU4. The Catalina Sky Survey discovered this small Apollo (H = 26.8, est. size 13 m) on 2023 Apr. 25.2 UTC, 2 days before an approach to 1.4 LD (Bacci et al., 2023a). It was observed for 21 minutes starting on 2023 Apr. 26.98 UTC, then 40 minutes later observed for a further 56 minutes. During that time, it was 1.5 LD from Earth, its apparent speed accelerated from 132 to 145 arcsec/min. and exposures were kept between 3.6 and 3.9 s. A period spectrum indicates a number of potential solutions at multiples of 0.07 h.

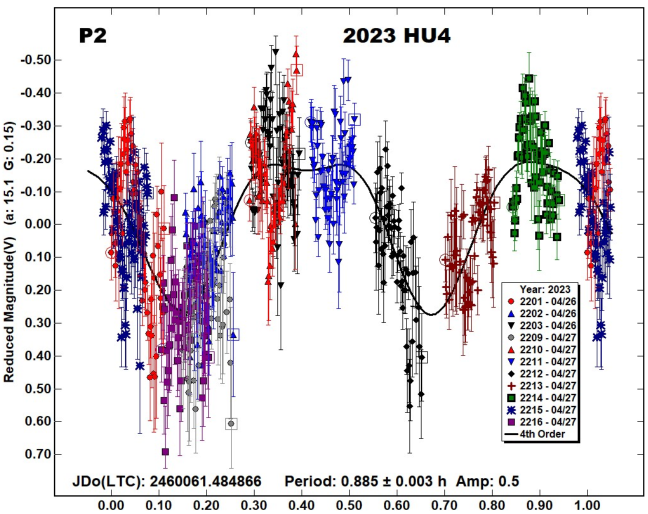


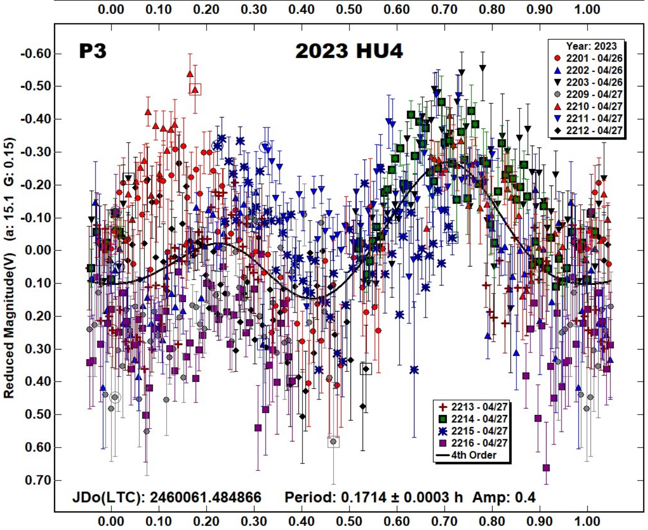
Initial analysis in *MPO Canopus* shows a strong 1 magnitude amplitude lightcurve with a period of 0.14361 ±0.00007 h, but some indications of systematic trends in the data points can be seen in the plot labelled PAR.



The *MPO Canopus* Dual Period Analysis function was used to check whether tumbling motion could be detected and the best fit was obtained with the dominant main period of 0.14358 ± 0.00005 h and a secondary period of 0.885 ± 0.003 h, see plots labelled P1 and P2. However, another solution, with somewhat larger residuals was also obtained, again identifying the same dominant P1 period, but with a secondary period of 0.1714 ± 0.0003 h, see plot labelled P3. It is noted that the frequencies of these candidate solutions are related, i.e., 1/P1 - 1/P2 = 1/P3. The dominant P1 period is well determined but the second period is ambiguous, either of the P2 or P3 periods are possible. However, it is expected that on the scale defined in Pravec et al. (2005) this may still be rated as PAR = -3, (NPA rotation reliably detected with the two periods resolved. There may be some ambiguities in one or both periods) (Petr Pravec, personal communication). The full amplitude suggested by the NPA solutions is 1.3 magnitudes.



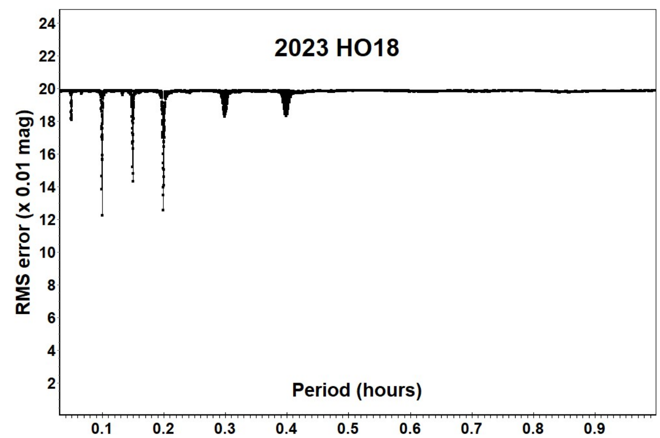


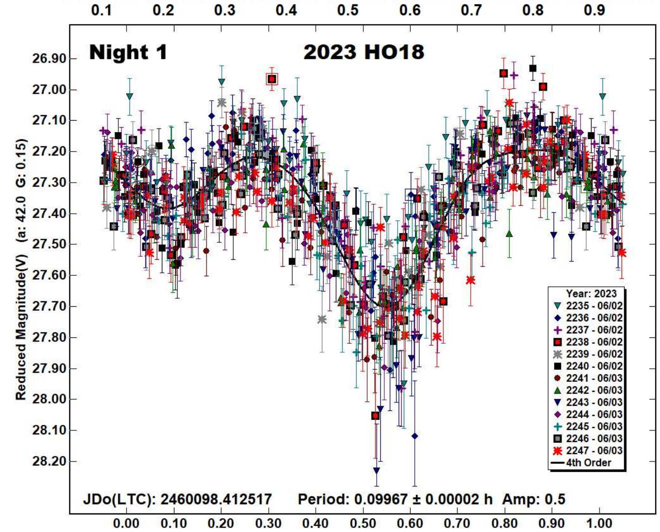


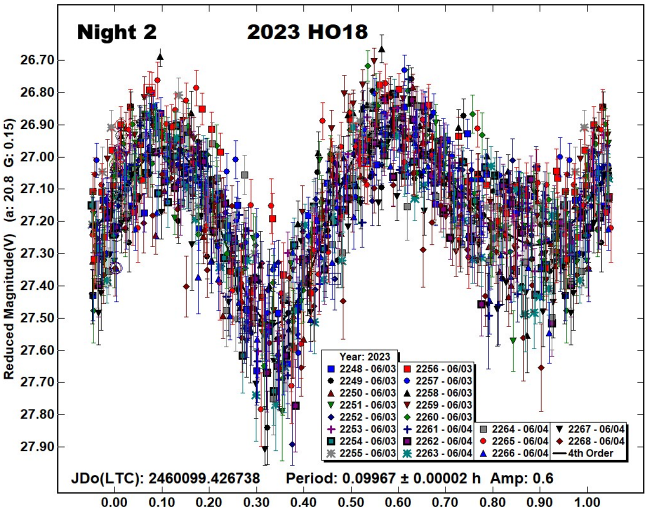
2023 HO18. With H = 25.5 and an est. diameter of 24 m this Apollo is the largest of the objects reported here. It was discovered by the Mt. Lemmon Survey on 2023 Apr. 22.4 UTC at magnitude 22, and a close approach to 1.2 LD occurred more than a month later on 2023 June 4.7 UTC (Bacci et al., 2023b). It was observed for 4.0 h starting on 2023 June 2.91 UTC and again for 2.7 h starting on 2023 June 3.93 UTC. On the first night it was at a distance of 2.2 LD and 1.4 LD on the second with the apparent speed increasing from 36 to 92 arcsec/min. Exposures were reduced from 14 to 5.7 s as the speed increased. A period spectrum shows a minimum at 0.04984 h and at multiples of ×2, 3, 4, 6 and 8 of that value. Separate best fit solutions from the two nights give very similar bimodal lightcurves:

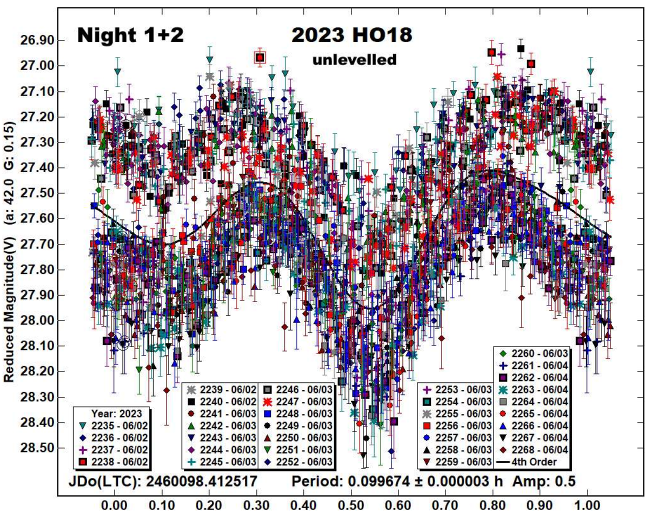
Night 1: Period 0.09967 ± 0.00002 h, amplitude 0.5
Night 2: Period 0.09967 ± 0.00002 h, amplitude 0.6

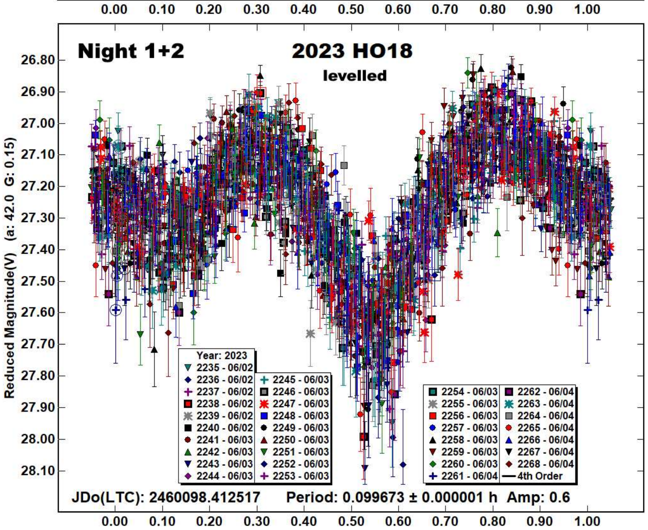
However, combining both nights with an assumed value of G = 0.15 in the H-G system results in a zero-point difference of ~0.4 magnitudes between the two nights as shown in the plot labelled Night 1+2 unlevelled. The phase angle reduced from 41.8° to 39.5° on Night 1, further reducing from 20.3° to 17.1° on Night 2. The observed magnitude of 2023 HO18 did not brighten as much as the H-G photometric model using G = 0.15 would predict for the changing phase angle. Attempts to solve for a value of G were unsuccessful, even with values of G ≫ 1. The plot labelled Night1+2 levelled was made by adjusting the zero points of the 34 individual sessions in *MPO Canopus* to minimise the overall scatter of the lightcurve, the average adjustment between the two nights was 0.44 mag, with the zero-point adjustments within the Night 1 sessions having an RMS of 0.041 and the adjustments for Night 2 an RMS of 0.047. The levelled lightcurve results in a period of 0.099673 ± 0.000001 h and amplitude 0.6 and indicates that 34 rotations were observed on Night 1 and 27 on Night 2.



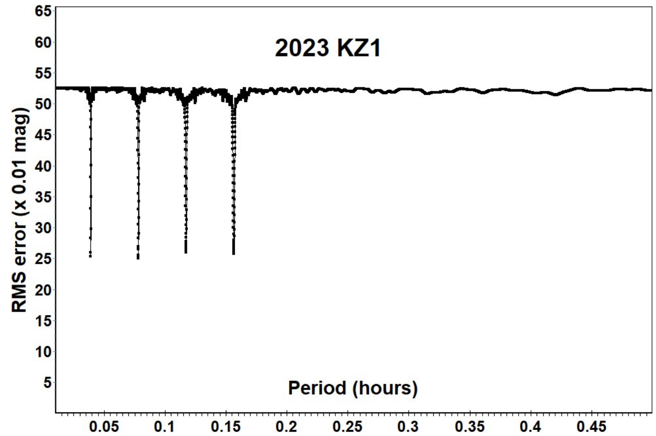


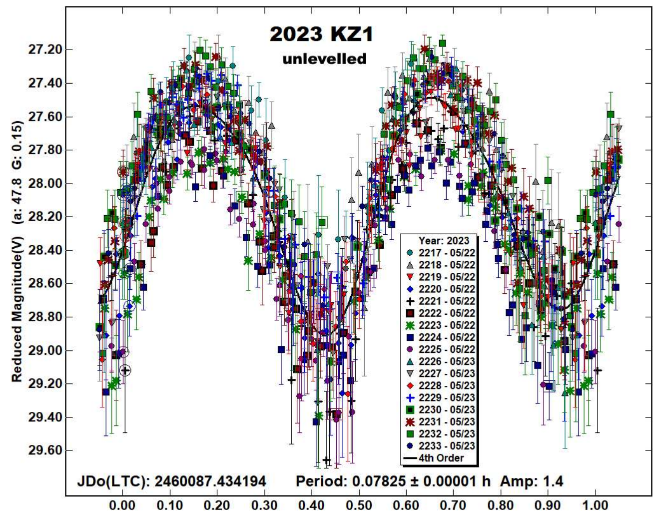




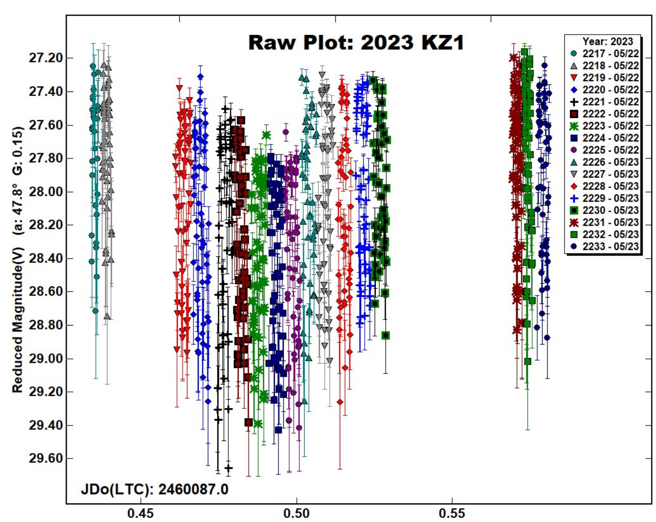


2023 KZ1. Another small Apollo, with H = 26.3, est. dia. 17 m, was discovered by the Catalina Sky Survey on 2023 May 22.4 UTC (Bacci et al., 2023c). It passed Earth at 1.0 LD on 2023 May 23.65 UTC and was under observation for 2.7 h over a 3.5 h period starting at 2023 May 22.93 UTC when it was at 2 LD. The apparent speed increased from 78 to 115 arcsec/min and exposure lengths were kept between 2 and 6 seconds throughout. A period spectrum shows a well-defined set of minima, with the best fit at 0.078 h producing a bimodal lightcurve with amplitude 1.4, shown in the plot labelled 2023 KZ1 unlevelled.





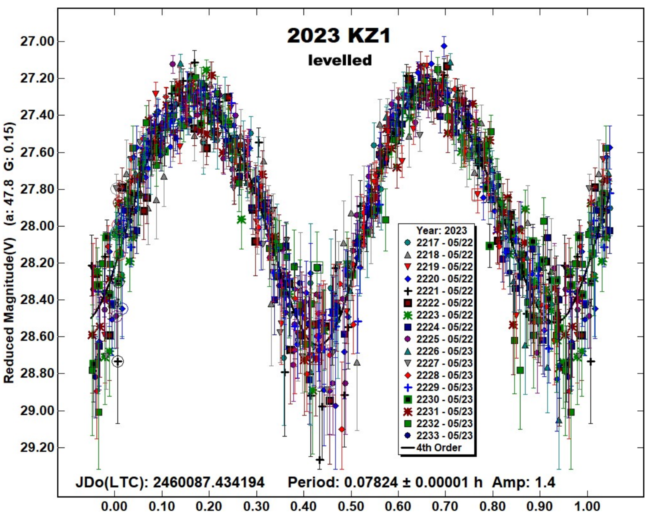
There are some trends in the data points that indicate there may be some tumbling motion present and further analysis with the *MPO Canopus* Dual Period function indicated a possible long secondary period. This variation can be seen in the raw plot, with one apparent minimum during the 3.5 h it was being observed.



Number	Name	Integration times	Max intg/Pd	Min a/b	Pts	Flds
	2023 HK	1-2.4	0.004	1.6*	1065	23
	2023 HU4	3.6-3.9	0.008	2.4	660	11
	2023 HO18	5.7-12.6	0.035	1.3	1828	34
	2023 KZ1	2-6.2	0.022	1.7*	864	17

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°.

However, the span of observations is not long enough to determine whether this is real tumbling motion or an effect of the changing aspect or conditions during the period of observation and so it is expected that 2023 KZ1 may be rated as PAR = -1 (NPA rotation possible, i.e., deviations from a single period are seen, but not conclusively) on the scale defined in Pravec et al. (2005). A lightcurve removing the apparent long-period variations by adjusting the zero-points of the 17 individual sessions to minimise the RMS residual of the fit is labelled 2023 KZ1 levelled and gives the period as 0.07824 ± 0.00001 h with amplitude 1.4 and indicates 34 rotations were observed.



Acknowledgements

The author would like to thank Petr Pravec for his ongoing assistance with the analysis of tumbling minor planets.

The author also gratefully acknowledges a Gene Shoemaker NEO Grant from the Planetary Society (2005) and a Ridley Grant from the British Astronomical Association (2005), both of which facilitated upgrades to observatory equipment used in this study.

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Number	Name	2023 mm/ dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E	PAR	H
	2023 HK	04/19-04/20	50.5-72.3	208	31	0.09271	0.00002	0.7	0.4	-2	27.2
						0.07118	0.00001	0.7	0.4		
	2023 HU4	04/26-04/27	15.0-11.8	209	0	0.14358	0.00005	1.0	0.2	-3	26.8
						0.885	0.003	0.5	0.2		
						0.1714	0.0003	0.4	0.2		
	2023 HO18	06/02-06/04	41.8-17.1	244	12	0.099673	0.000001	0.6	0.2		25.5
	2023 KZ1	05/22-05/23	47.7-42.2	243	23	0.07824	0.00001	1.4	0.2	-1	26.3

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. LPAB and BPAB 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, 2023).

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LIGHTCURVES AND COLORS OF FOUR SMALL NEAR-EARTH ASTEROIDS: 2020 BV14, 2023 HH3, 2023 HT3, 2023 KQ

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Photometric observations of four small, potentially fast-rotating near-Earth asteroids (NEAs) were conducted in April and May 2023. Lightcurves for three NEAs and BVRI colors for all four NEAs are reported. A relative reflectance was computed and compared with observed asteroid spectra (from SMASS and SMASSII) for each asteroid. Also, the comparison was performed with lab spectra of meteorites from the Brown University Reflectance Experiment Laboratory.

We used the Vatican Observatory's Vatican Advanced Technology Telescope (VATT), an f/1.0 telescope with a primary mirror of 1.8-m in diameter and a 0.38-m f/0.9 secondary mirror with MPC code 290 located at Mount Graham in southeastern Arizona. We used VATT4k, a CCD camera with 4064×4064 15×15 µm pixels. The data were binned two by two to reduce readout time to 30 seconds and yield a plate scale of 0.375 arcsec/pixel. VATT4K covers the visible spectrum (300-1000 nm) and has a quantum efficiency that peaks at 450 nm.

For each observing run, we took around 200 bias images and 15 dome-flat images in each filter (B, V, R, and I). The IRAF imred, ccdred, zerocombine, and flatcombine packages (Tody, 1986) were used to create a master bias and master flat in each filter. Asteroid observations were tracked at the rate of each asteroid. On each night, standard stars were observed to find a photometric zero point and extinction coefficient for each filter. We used the IRAF ccdphot, digiphot, and apphot packages for the photometry reduction. The aperture was set to twice the FWHM (Hergenrother et al., 2009; Kikwaya et al., 2019, 2022). A circular ring with a 15-pixel radius and width of 10 pixels was set to measure the sky background. We used the following filter sequence: V-R-I-B-V to get the lightcurve and colors (Fedorets et al., 2017; Tricarico, 2017; Schunova-Lilly et al., 2017). To ensure the entire lightcurve is covered, we took several V images at the sequence's beginning and end. The number of B, V, and R images is usually a third of V images. We used ALC, Petr Pravec's Asteroid Lightcurve software, to determine the lightcurve and rotation period. For colors, we computed the color indexes V-R, B-V, and V-I. To estimate the taxonomy of the object, we compared them with two-color plots (V-R versus B-V and V-R versus V-I) (Yoshida et al., 2004; Zellner et al., 1985). We computed the relative reflectance of the object

Object	yyyy mm/dd	Phase	Delta (AU)	r (AU)	H	a	e	i	Bpab	Lpab	Grp
2020 BV14	2023 04/21	25.0	0.051	1.051	23.43	2.101	0.521	2.773	197.944	6.023	Apollo
2023 HH3	2023 04/24	35.4	0.014	1.016	27.14	2.251	0.606	6.477	196.107	-6.072	Apollo
2023 HT3	2023 04/24	36.5	0.048	1.044	24.05	0.814	0.330	25.739	195.991	10.077	Aten
2023 KQ	2023 05/22	24.2	0.034	1.043	24.91	0.857	0.225	10.403	227.638	-2.218	Aten

Table I: Object name, date of observation, phase angle, delta (distance to the Earth in AU), r (distance to the Sun in AU), absolute magnitude, semi-major axis, eccentricity, inclination, Bpab, Lpab, and Grp (group the object belongs to) are reported.

Object	Period (hours)	Amp(mag)	B-V	V-R	V-I	Tax. Class
2020 BV14	0.17460+/-0.00006	0.346+/-0.055	0.781+/-0.029	0.441+/-0.031	0.826+/-0.026	X-complex (Xe,K,T)
2023 HH3	-----	-----	0.773+/-0.083	0.439+/-0.039	0.716+/-0.021	C-Complex (C,Cg)
2023 HT3	0.08167+/-0.00001	0.250+/-0.053	0.716+/-0.048	0.395+/-0.059	0.809+/-0.095	X-complex (Xc,X,Xk)
2023 KQ	0.70+/-0.01	0.195+/-0.041	0.859+/-0.039	0.450+/-0.043	0.808+/-0.044	S-Complex (Sq,Sr)

Table II: Periods of 3 NEAs and colors and Taxonomy classes of all 4 NEAs are reported.

normalized to V (Holmberg et al., 2006) and compared it using the chi-squared method with the observed asteroid spectra in the database (Popescu et al., 2012, Popescu et al. 2016) to refine the taxonomy classification as defined by Bus and Binzel (Bus and Binzel 2002a, 2002b). We also compared it with the laboratory spectra from the Brown University Reflectance Experiment Laboratory (RELAB) that extend into the near infrared. For our analysis, we are only interested in the visible part of these spectra. Table I lists the absolute magnitude and the orbital information of our objects. Lightcurve and color results are reported in Table II.

2020 BV14. The Mount Lemmon Survey discovered this Apollo asteroid on 2020 January 29 UT. In 2023, it passed 0.046 au from Earth on April 16. On April 21, we collected 128 images in V. With H=23.4, 2020 BV14 is a fast rotator with a rotation period of 0.17460 ± 0.00006 h and amplitude of 0.35 ± 0.06 mag (Fig. 1). Images were also taken in BVRI to compute the following color indices: B-V = 0.781 ± 0.029, V-R = 0.441 ± 0.031, and V-I = 0.826 ± 0.026.

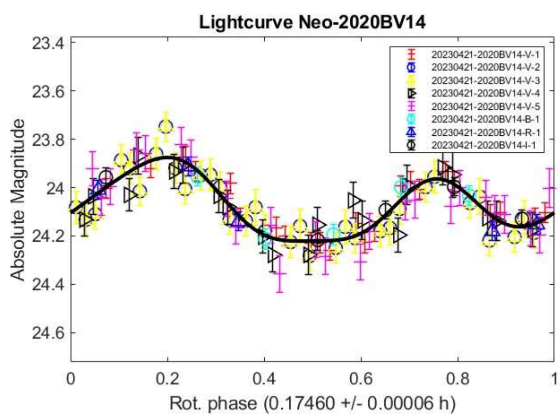

Fig. 1. Lightcurve of 2020 BV14 phased to a period of 0.17460 ± 0.00006 h.

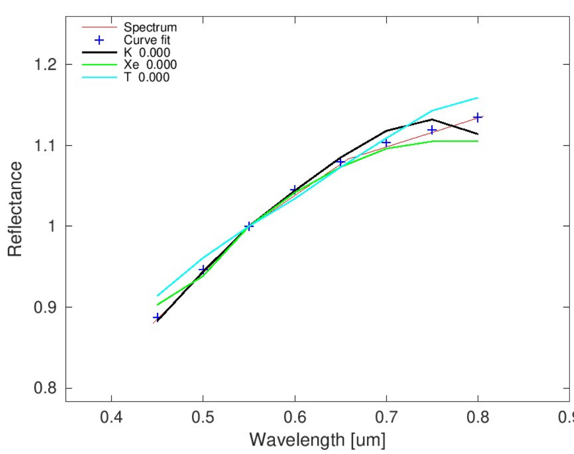

Fig. 2. Relative reflectance of 2020 BV14 compared with observed asteroid spectra using the chi-squared method (Bus and Binzel, 2002a, 2002b).

The color indices are consistent with the X-complex type, which was confirmed by comparing its relative reflectance with the observed asteroid spectra using M4AST (Modeling for Asteroids) engine (*https://spectre.imcce.fr/m4ast/index.php/index/home*) (Fig. 2). The comparison with meteorite spectra from RELAB showed a match with several laboratory meteorite spectra (Fig. 3). Each laboratory spectrum is identified by file_id, sample_id, sample name, General type, type, and subtype. For instance, the second match is a laboratory meteorite with MGP116 as file identity, Warrenton as sample name, Rock as general type, Carbonaceous chondrite as type, and CO3 as subtype.

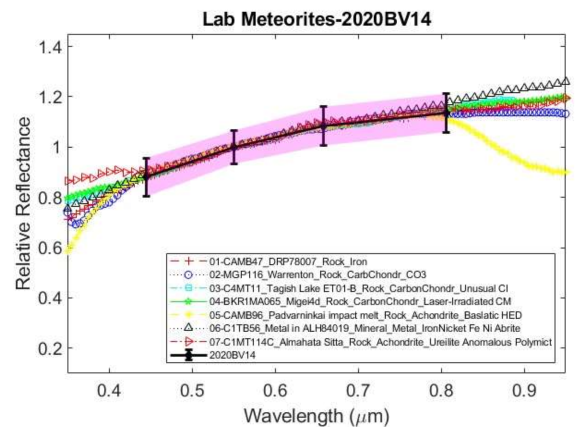

Fig. 3. Relative reflectance of 2020 BV14 compared with the laboratory meteorite spectra using the chi-squared method.

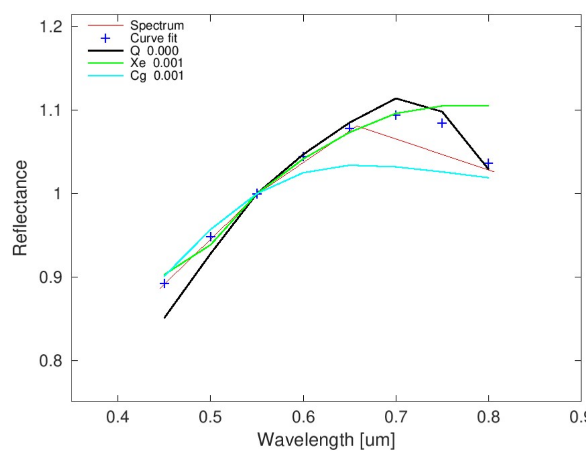

Fig. 4. Relative reflectance of 2023 HH3 compared with observed asteroid spectra using the chi-squared method.

2023 HH3. This H = 27.1 Apollo asteroid was discovered by the Mount Lemmon Survey on 2023 April 21 UT and observed with VATT on April 24 UT, one day before passing 0.0027 au from Earth. We took 38 V images at the beginning of the sequence and 30 V images at the end. Its lightcurve and rotation period was indeterminate. Derived colors of B-V = 0.773 ± 0.083, V-R = 0.439 ± 0.039, and V-I = 0.716 ± 0.021 yield a C taxonomy class from the two-axes plots, and the chi-squared comparison with observed spectra (Fig. 4). We found four matches with the laboratory meteorite spectra. One of them is a carbonaceous chondrite (Fig. 5) with file identity being CIMB64, sample name Murchison heated at 500 C, general type being Rock, with the type being Carbonaceous chondrite and sous-type CM2.

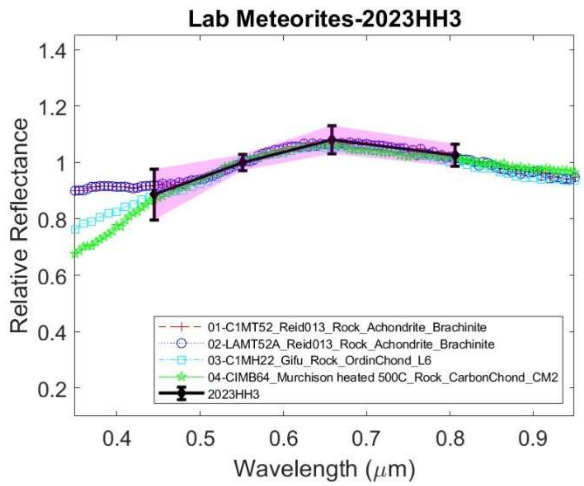

Fig. 5. Relative reflectance of 2023 HH3 and meteorite spectra.

2023 HT3. This H = 24.1 Aten asteroid was discovered by the Zwicky Transient Facility on 2023 April 22 UT, while passing 0.046 au from Earth. Ninety-three images were obtained in V on April 24 UT finding a rotation period of 0.08167 ± 0.00001 h and amplitude of 0.25 ± 0.05 mag, confirming that it is a fast rotator (Fig. 6). Several images were also obtained in B, R, and I for computing the color indices: B-V = 0.716 ± 0.048; V-R = 0.395 ± 0.059; and V-I = 0.809 ± 0.095. 2023 HT3 turned out to be an X type from both the two-axes color plots, and the chi-squared comparison with the observed asteroid spectra showed a chi-squared value of less than 0.0001 (Fig. 7).

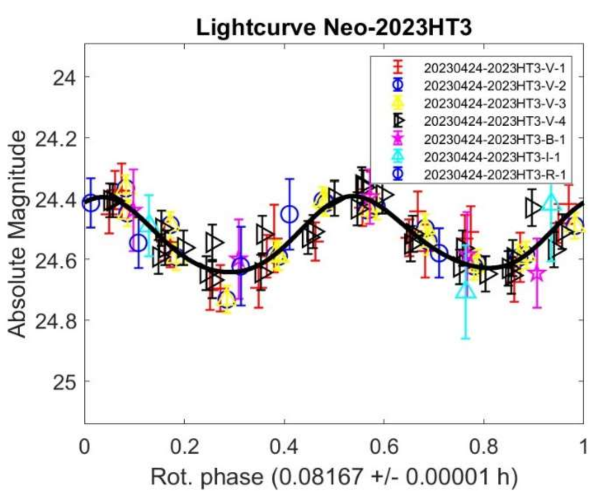

Fig. 6. Lightcurve of 2023 HT3 phased to a period of 0.08167 ± 0.00001 h.

When compared with the laboratory meteorite spectra, the relative reflectance of 2023 HT3 matches four of them, particularly a stony iron pallasite (meteorite spectrum with a file identity R4MB39, name Y-8451, general type being rock, type being stony iron and subtype being Pallasite) (Fig. 8).

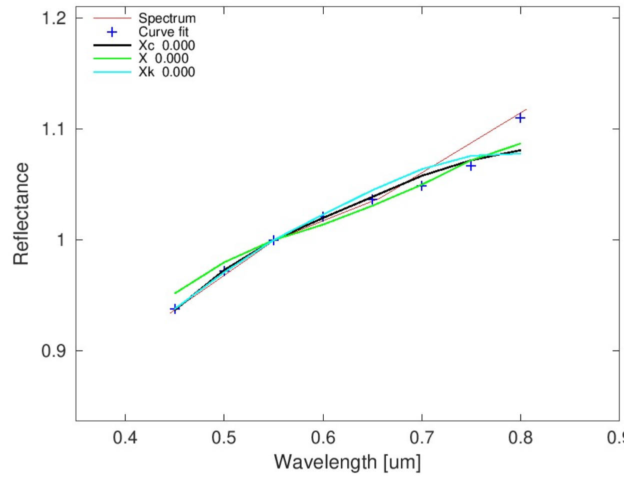

Fig. 7. Relative reflectance of 2023 HT3 compared with observed asteroid spectra using the chi-squared method.

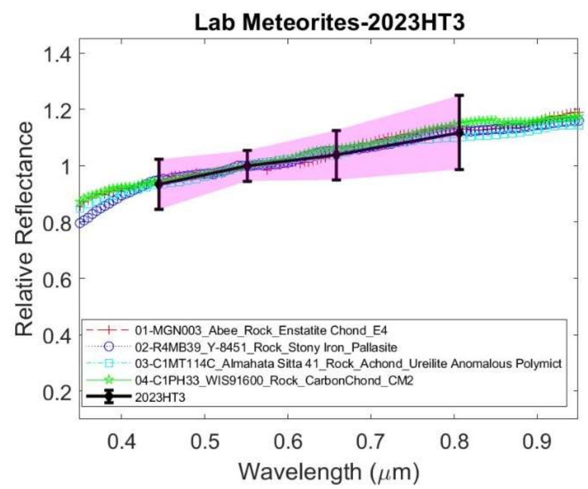

Fig. 8. The relative reflectance of 2023 HT3 matches four laboratory meteorite spectra with a chi-squared value of less than 0.00001.

2023 KQ. The South African station of the ATLAS survey discovered this H = 24.9 Aten on 2023 May 19. V images were obtained on May 22 UT near the time of closest approach to Earth (0.035 au) to construct a lightcurve yielding a rotation period of 0.70 ± 0.01 h with an amplitude of 0.20 ± 0.04 mag (Fig. 9). Several images were obtained in three other filters (B, R, and I) for computing the color indexes. We found B-V = 0.859 ± 0.039, V-R = 0.450 ± 0.043, and V-I = 0.808 ± 0.044, suggesting that 2023 KQ belongs to the S-type taxonomy class. The comparison with the observed asteroid spectra using the chi-squared method showed a match between the relative reflectance of 2023 KQ with three asteroid spectra with a chi-squared value of less than 0.001. Among the three solutions, there are two (Sq and Sr) from the S-complex taxonomy (Fig. 10).

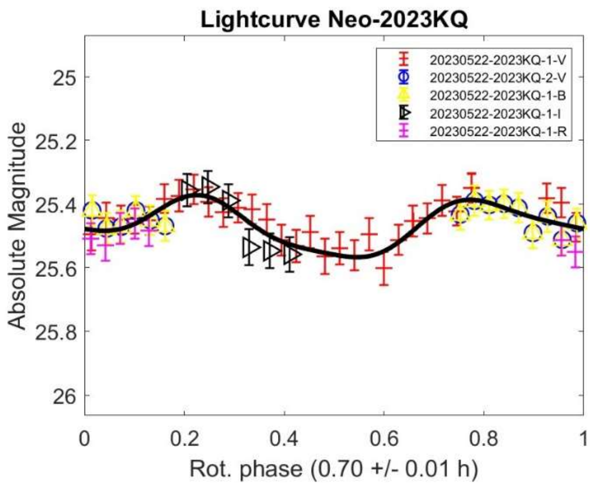

Fig. 9. Lightcurve of 2023 KQ phased to a period of 0.70 ± 0.01 h.

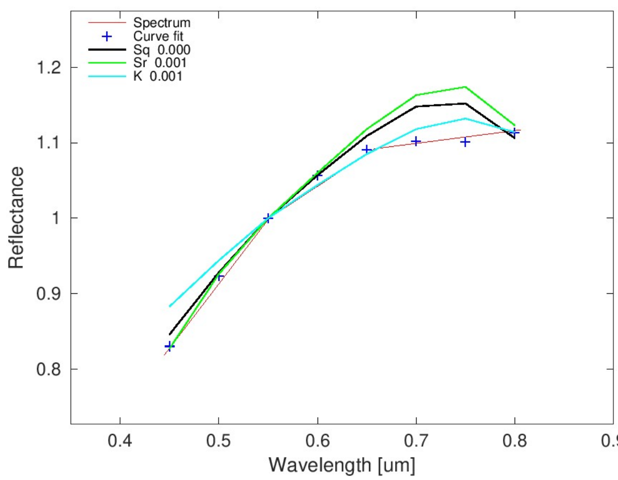

Fig. 10. Among the observed spectra matching 2023 HH3 with a chi-squared value less than 0.001 are the Sq-, Sr-, and K-types (Bus and Binzel, 2002 a, 2002b).

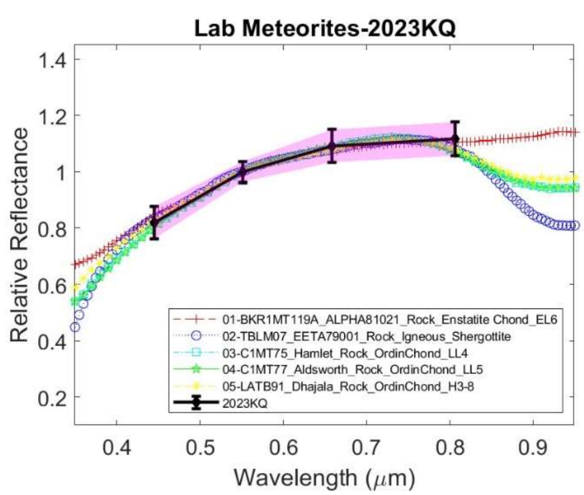

Fig. 11. Relative reflectance of 2023 KQ matches 5 meteorite spectra, among which are three ordinary chondrite meteorites.

The comparison with the laboratory meteorite spectra showed that the relative reflectance of 2023 KQ matches 5 meteorite spectra, among which three (Hamlet, Aldsworth, and Dhajala) are ordinary chondrite meteorites (Fig. 11).

Acknowledgments

We want to thank the Vatican Observatory for allowing us to use VATT. We would also like to express our gratitude to Petr Pravec for letting us use ALC software for the lightcurve solution and also for the determination of the color indexes of our objects.

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ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES PALMER DIVIDE STATION: 2023 MAY-JULY

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CCD photometric observations of twenty asteroids were made at the Center for Solar System Studies Palmer Divide Station during 2023 May and July. Data analysis found two likely binary asteroids: 2449 Kenos and (236716) 2007 FV42. Hungaria asteroids 3225 Hoag and 4232 Aparicio have unexplained secondary periods, and the near-Earth asteroid (467336) 2002 LT38 is very likely to be in non-principal axis rotation, i.e., it is a tumbler.

CCD photometric observations of twenty asteroids were carried out at the Center for Solar System Studies Palmer Divide Station (CS3-PDS) during 2023 May to July as part of an ongoing general study of asteroid rotation periods with a concentration on near-Earth, Hungaria, and Hilda group/family asteroids.

Telescope	Camera
0.30-m *f*/6.3 SCT	SBIG STL-1001E
0.35-m *f*/9.1 SCT (x3)	FLI Microline 1001E
0.50-m *f*/8.1 Ritchey-Chrétien	FLI Proline 1001E

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

Table I lists the five telescope/CCD cameras pairs used at CS3-PDS. All the cameras use CCD chips from the KAF 1001 blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel. All lightcurve observations were made with no or a clear filter. The exposures varied depending on the asteroid's brightness.

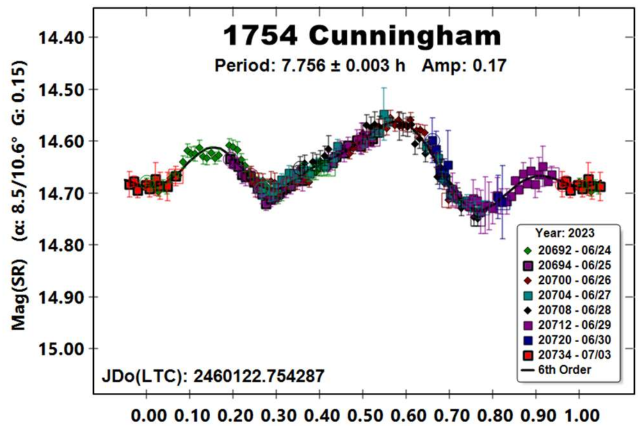
To reduce the number of times and amounts of adjusting nightly zero-points, the ATLAS catalog r´ (SR) magnitudes (Tonry et al., 2018) are used. Those adjustments are usually ≤ ±0.03 mag. The rare larger corrections may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction. Another cause may be selecting what appears to be a single star but is actually an unresolved pair.

The Y-axis values are ATLAS SR "sky" (catalog) magnitudes. The values in the parentheses give the phase angle(s), *a*, along with the value of *G* used to normalize the data to the comparison stars and asteroid phase angle used in the earliest session. This, in effect, adjusts all the observations so that they seem to have been made at a single fixed date/time and phase angle. Presumably, any remaining variations are due only to the asteroid's rotation and/or albedo changes.

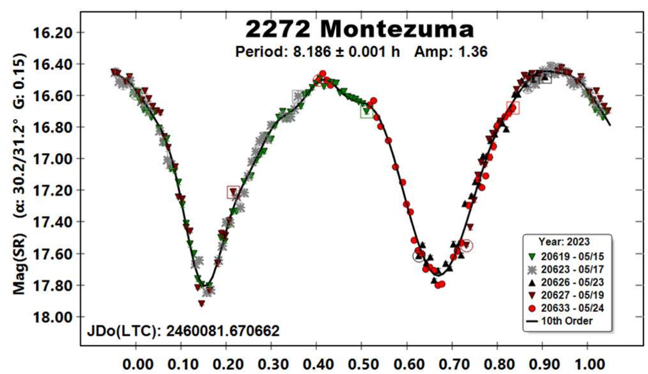
There can be up to three phase angles If two, the values are for the first and last night of observations. If three, the middle value is the extrema (maximum or minimum) reached between the first and last observing runs. The X-axis shows rotational phase from -0.05 to 1.05. If the plot includes the amplitude, e.g., "Amp: 0.65," this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

For brevity, only some of the previous results are referenced. A more complete listing is in the asteroid lightcurve database (Warner et al, 2009; "LCDB" from here on).

1754 Cunningham. This member of the Hilda orbital group has been studied many times, e.g., Stephens (2015; 7.7416 h), and twice later at CS3: Warner and Stephens (2018, 7.709; 2021, 7.737 h). The data from 2023 June led to P = 7.756 ± 0.003 h, A = 0.17 ± 0.01 mag.



2272 Montezuma is a Hungaria orbital group member, i.e., not part of the collisional group named after 434 Hungaria (Nesvorny, 2015; Nesvorny et al., 2015). The asteroid had been previously observed four times at CS3 with the derived periods all close to 8.18 h. The 8.186 h period from the 2023 observations is in good agreement.

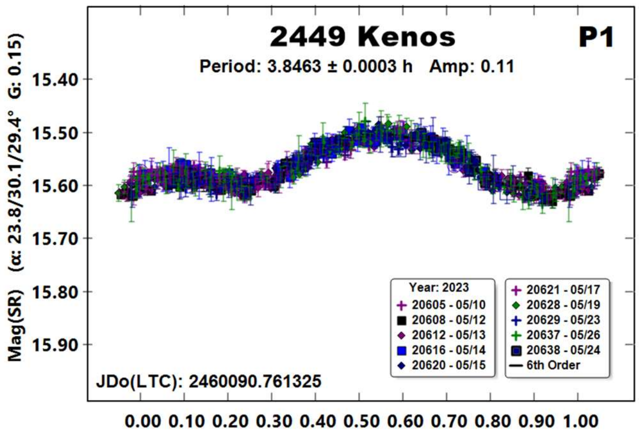


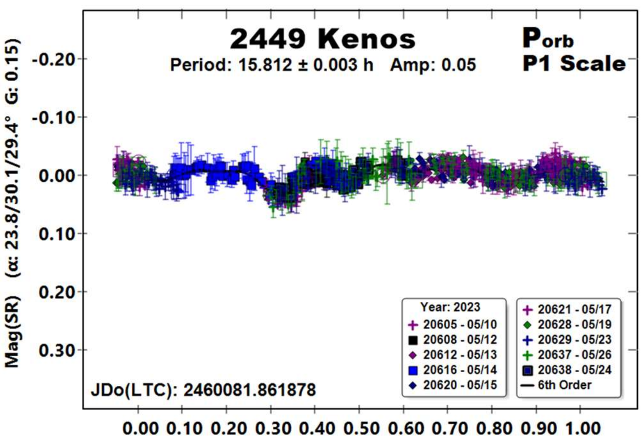
2449 Kenos. Observations of this Hungaria (group) in 2015 (Warner, 2015b) led to speculation that the asteroid might be binary with an orbital period for the satellite of 15.85 h. The 2023 observations further supported the supposition.

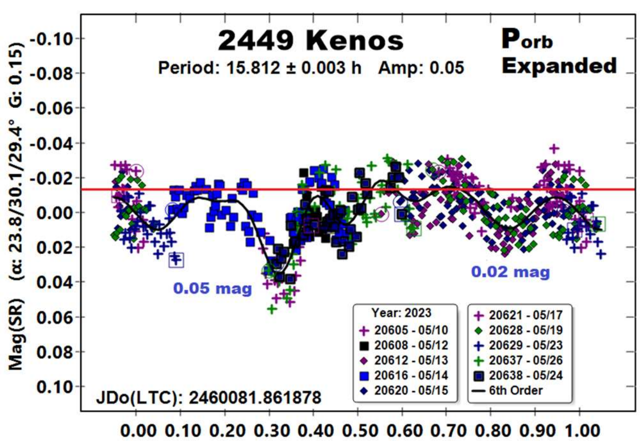
The adopted period for the primary, P_1 = 3.8463 ± 0.0003 h, is consistent with previous results, e.g., Warner (2007a, 3.846 h; 2018, 3.8387 h). The proposed orbital period (P_{ORB} = 15.812 ± 0.003 h) is also consistent when the effect of the very low amplitudes of the events is taken into account. In 2023, those events were 0.02-0.05 mag in depth. This is at the very edge of the limit for discovering a satellite using ground-based photometry alone (Pravec et al., 2006).

There are two plots for the satellite's lightcurve. "P1 Scale" uses the same Y-axis scaling as that used for the primary's lightcurve. The "Expanded" plot significantly expands the Y-axis scale to help show the events. In addition, the error bars were hidden since they made seeing the events difficult, especially the shallower one. It is that event (0.02 mag) that was used to compute the effective secondary-to-primary diameter ratio of Ds/Dp ≥ 0.16 ± 0.04.

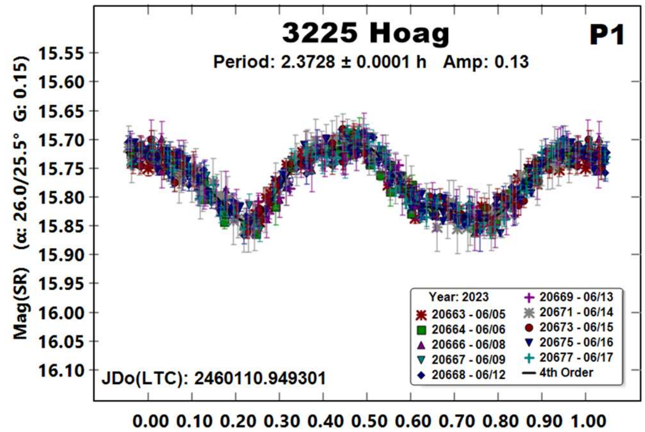
Given the two sets of results from observations at similar phase angle bisector longitudes (2015: 190°; 2023: 210°), the case for the asteroid being a binary is stronger but with the shallow events (so far), strict confirmation from ground-based photometry may not be possible.

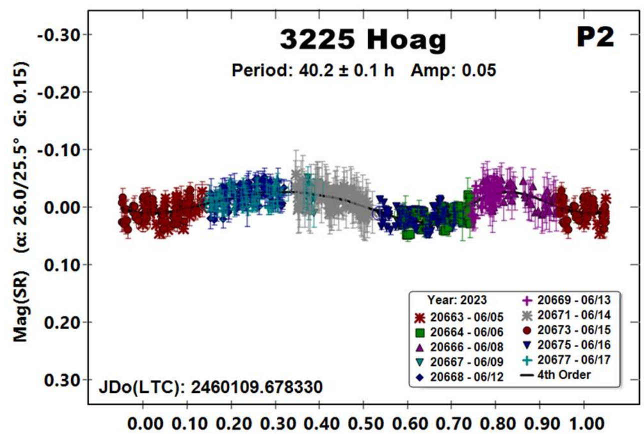




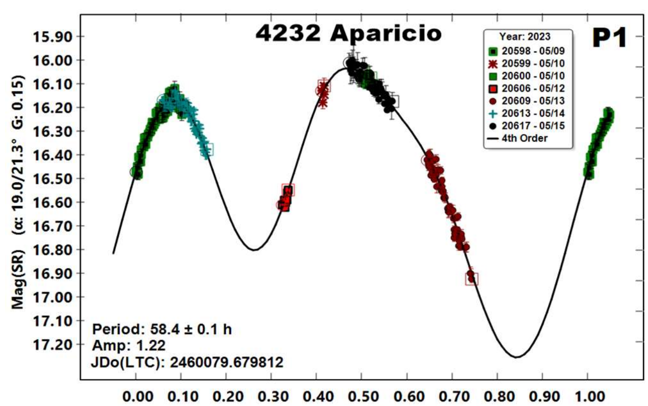


3225 Hoag. Another Hungaria group member, Hoag has been observed by the author at eight different apparitions since 2007, and yet there may still be some doubt about its true nature. The results from the seven previous apparitions have been close to 2.372 h and did not include suspicions of the asteroid being binary. However, the 2023 observations seem to show a previously unreported secondary period of 40.2 ± 0.1 h with a bimodal lightcurve amplitude of 0.05 mag. Assuming the secondary period is valid, one explanation might be a slightly elongated satellite tidally locked to its orbital period. Observations at future apparitions may verify, or refute, this concept.

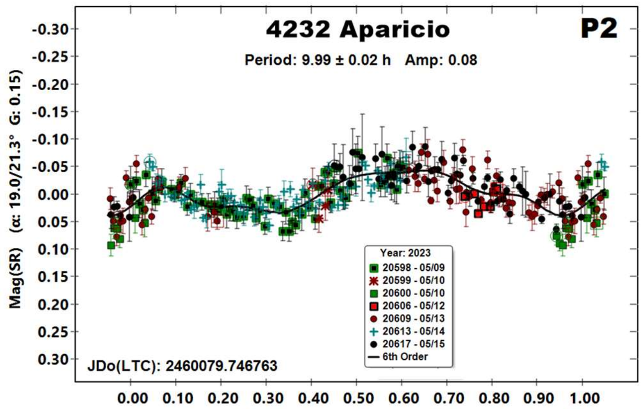




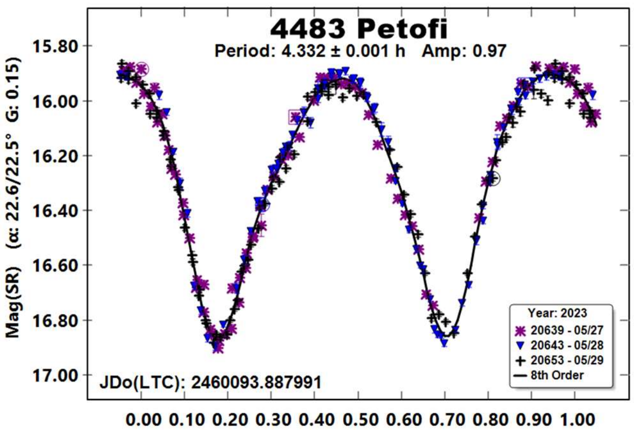
4232 Aparicio. Previous results for this member of the Hungaria collisional family (Nesvorny, 2015; Nesvorny et al., 2015) average 54.2 ± 0.2 h, e.g., Warner (2015c). The data from 2023 were too sparse to duplicate that result exactly buy they did lead to a plausible solution of 58.4 h. The stated amplitude in the plot is likely overstated.



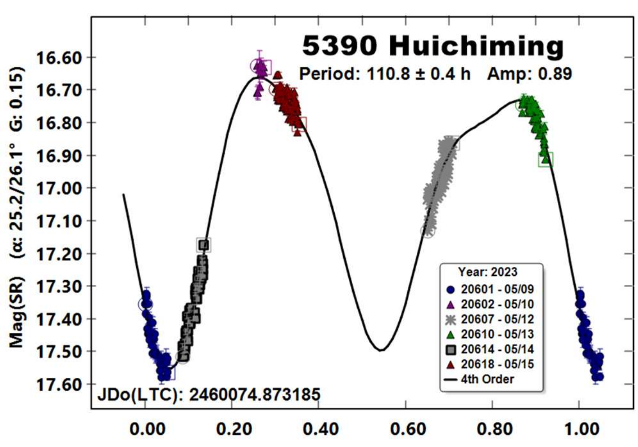
A secondary period affected the quality of the fit for those parts of the lightcurve with overlapping data from different sessions. A dual-period search using *MPO Canopus* extracted a weak solution of $P_2 = 9.99 \pm 0.02$ h, $A_2 = 0.08 \pm 0.01$ mag. If due to a physical cause, the asteroid might be a *very wide binary*. (Warner, 2016).



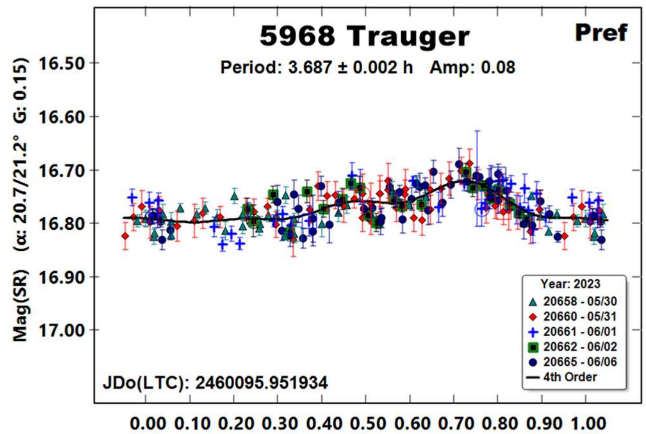
4483 Petofi. Six previous results from the author, e.g., Warner (2012b), have a rotation period very close to 4.33 h. The 2023 results are consistent. The amplitude is about the average of the range reported in the LCDB.

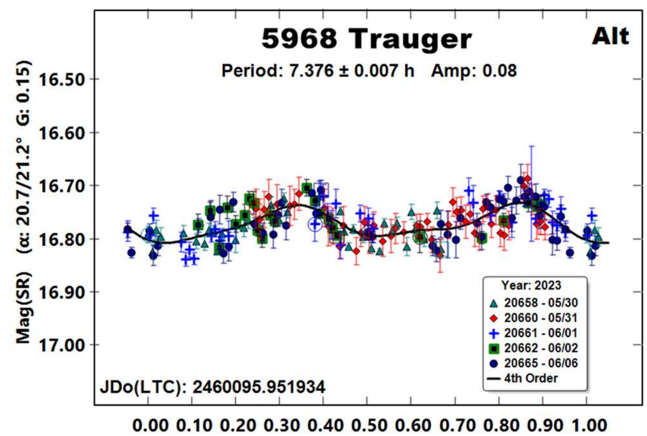


5390 Huichiming. The first time the author observed this Hungaria family member (Warner, 2007b), a period of 33.6 h was reported. This turned out to be "curving a fit," i.e., forcing the data to fit an assumed, incorrect, period. Later observations (Warner, 2009) led to P = 111 h. The 2007 data were revisited (Warner, 2011) and a new value, P = 110 h, was found. Despite the lack of lightcurve coverage, the comparison star magnitudes from the highly-reliable ATLAS rf2 catalog (Tonry et al., 2018) allowed a reasonable fit to a consistent solution of P = 110.8 h.

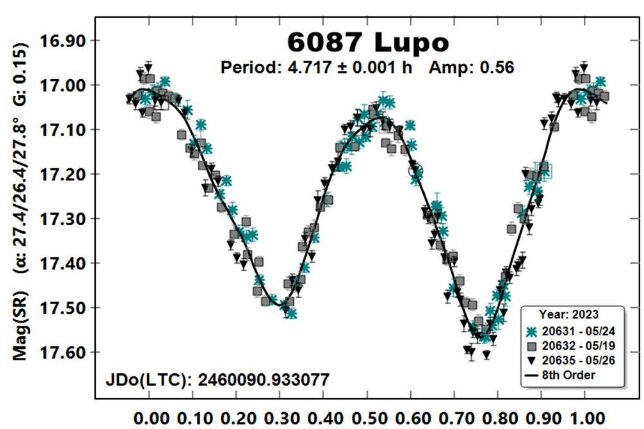


5968 Trauger. A period close to 3.786 h for this Hungaria seems to be the consensus among the LCDB results. The possibility that the asteroid was binary was made by Warner (2014a). No signs of such were seen in the 2023 data. Unfortunately, they led to an ambiguous solution, with one being 3.687 h and the other nearly the double-period. A split-halves plot for the longer period shows that the lightcurve is very symmetrical about the two halves, which favors, but does not assure, that the shorter period is correct.



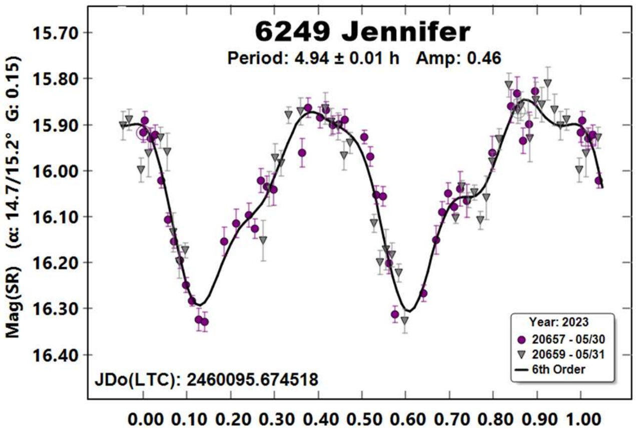


6087 Lupo. Observations by the author at three previous apparitions led to a highly consistent period of 4.71 h, e.g., Warner (2015a; 4.717 h). When modeling the asteroid, Hanuš et al. (2016) found a sideral period in keeping with the synodic periods found before.

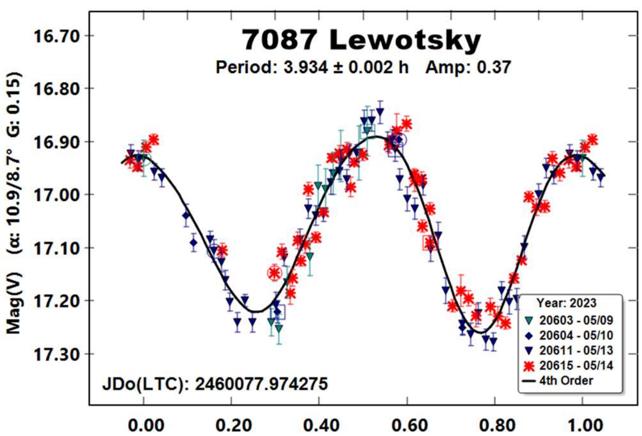


6249 Jennifer. Only a sparse dataset could be managed for the 2023 apparition. However, the resulting period of 4.94 h was consistent with previous results such as Stephens and Warner (2022;

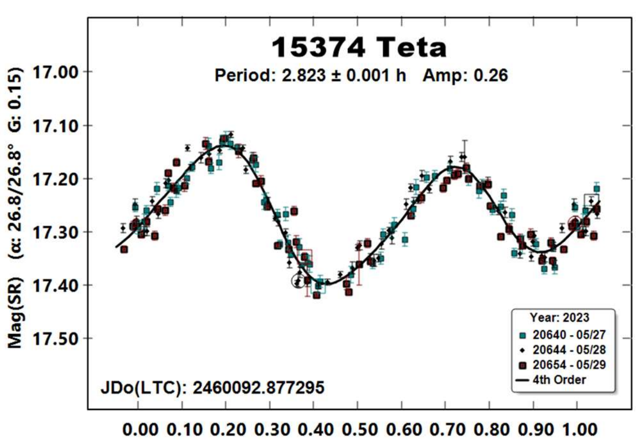
4.958 h). The LCDB reported amplitude range is 0.06-0.55 mag. The large amplitude in 2023 helped overcome the sparse dataset.



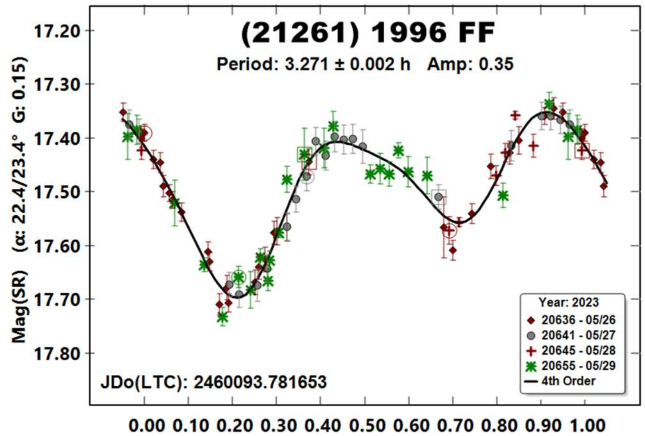
7087 Lewotsky. The primary period for this suspected binary asteroid has been reported many times to be close to 3.942 h. Warner and Stephens (2022) found a weak indication of a satellite with an orbital period of 17.11 h. The dataset was too sparse to support that result. No evidence of a satellite was seen in the 2023 data. Observations at phase angle bisector longitudes near 10° (the value in 2021 September), or 190° are encouraged for future observations.



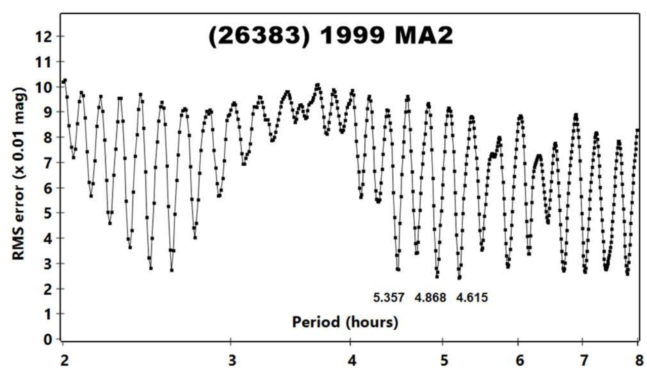
15374 Teta. Observations in 2023 led to a period of 2.823 h, which is consistent with reports from two previous apparitions (Warner, 2010, 2.8204 h; 2014b, 2.820 h). This is the smallest amplitude to-date in the LCDB, the previous range being 0.30-0.39 mag.

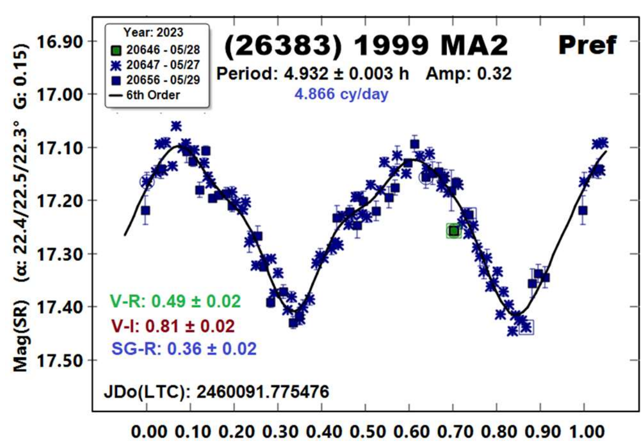


(21261) 1996 FF is a "chip off the block," meaning it is a piece of the parent body of the Hungaria asteroid family. The only previous period in the LCDB was 3.260 h (Warner, 2015c).



(26383) 1999 MA2. This Hungaria family member served double-duty. The first was a demonstration of "fit by exclusion," which is where the wrong solution can be found, no matter how "good" it looks. The period spectrum shows a number of nearly identical solutions with a group at 2-3 hours and another in the 4.5-5.9 h range. The numbers below the three minima are the cycles/day at the minimum period. When a number of similar solutions differ by about 0.5 rotation per day and the lightcurve is fairly symmetrical, it's easy to fall into the trap of accepting the period with the lowest RMS fit to the Fourier curve as being the correct one.

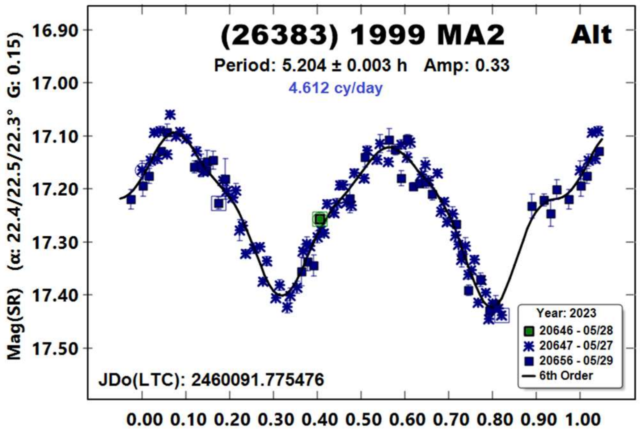




Previous results, e.g., Warner (2012a) are near 4.92 h. This was not the period found in the initial search, but was the alternate period below of 5.204 h.

Keep in mind that the Fourier algorithm finds the lowest possible RMS fit, many times by reducing the number of overlapping data points for a given period, thus the gap in coverage at the far right of both plots. This is a “fit by exclusion,” meaning reducing the number of overlapping data points.

An indication of the longer period being incorrect is the way that the Fourier curve has to bend to try to fit the data at large rotation phases. It has lost the symmetry seen in the 4.9 h solution.

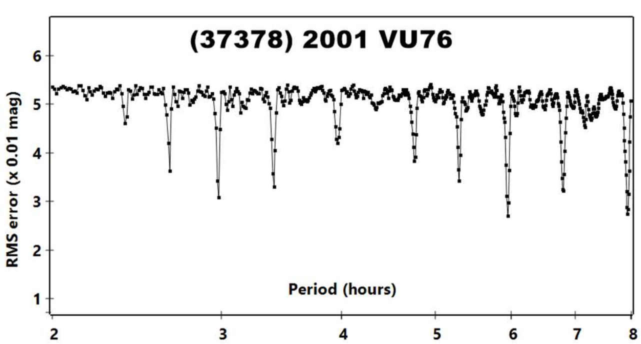


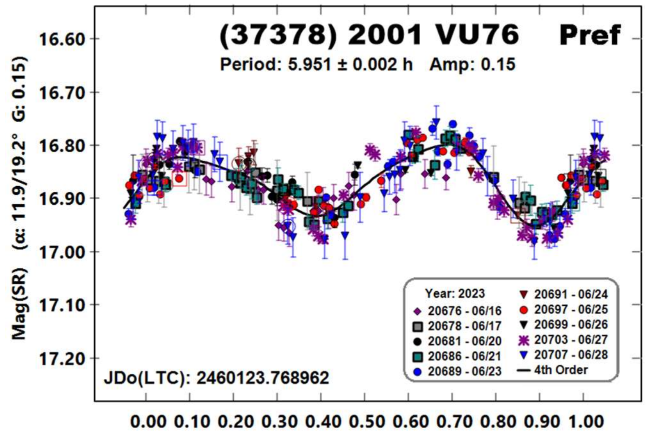
The second duty served was by a serendipitous accident. When editing the script used to image the asteroids on the second night, it was overlooked that the script would take filtered images in Clear/V/R/SG order throughout the night instead of using only a clear filter. The unintended data were used to find three color indexes. The same data could also be used to find the second-order extinction terms for V-R and SG-R. That was left for another time.

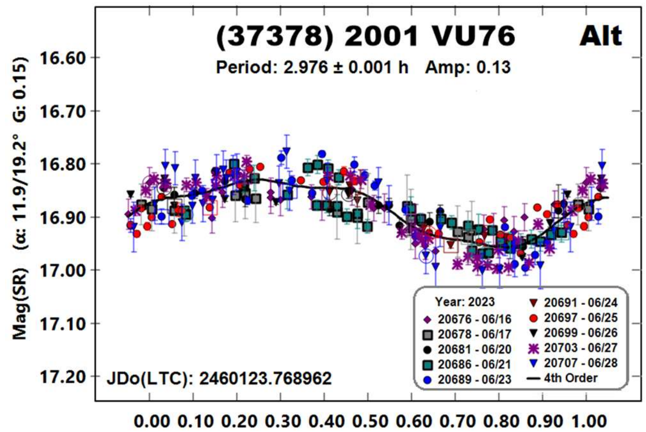
(37378) 2001 VU76. Two datasets from 2018, one obtained in late June and the other in early August, both led to a period of about 1.785 h (Warner, 2019). Despite being so fast, no other “more common” (longer) periods could be found. Both results are now considered entirely wrong.

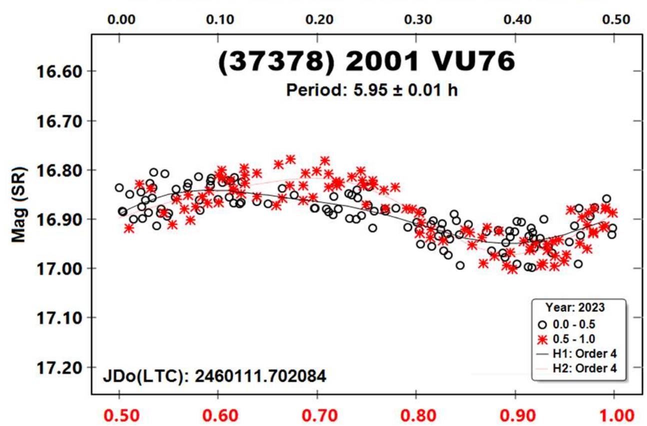
The period spectrum using data from the 2023 observations shows several possible solutions, about 3 h and 6 h in particular. Lightcurves at 2.976 h and 5.951 h are monomodal and bimodal, respectively. Neither one is necessarily correct since at low amplitudes, multimodal lightcurves are possible (Harris et al., 2014).

The split-halves plot led to adopting the 5.951 h period because of the asymmetry of the two halves. Had they been the same, then the shorter period might have been just as valid of a solution.





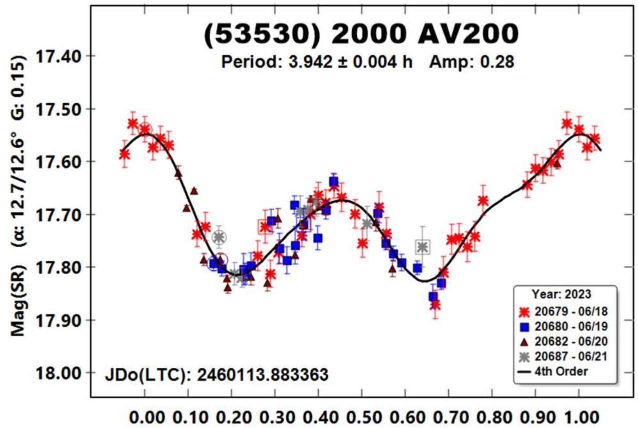


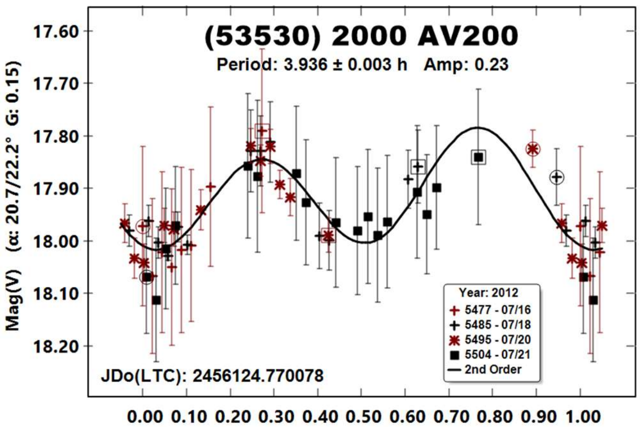


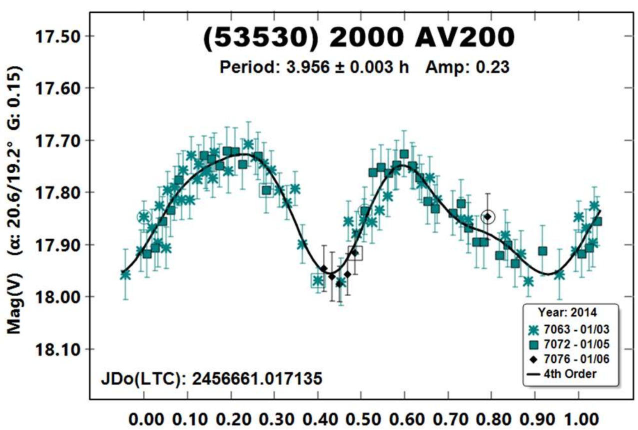
(53530) 2000 AV200. Previous work on this Hungaria collisional member found different periods. Using data from 2012, Warner (2013) found 3.628 h while 2014 data led to a period of 4.310 h (Warner, 2014b). These two periods differ by almost exactly one rotation over 24 hours.

Analysis of the 2023 dataset found a period of 3.942 h. This happens to be about one-half rotation different over a day from either of the other two periods. The earlier datasets were reviewed with the period forced to be near the 2023 solution.

The 2012 dataset was noisy and sparse, so it was easy to see how a false solution might have been found. The forced fit produces an acceptable bimodal lightcurve. The 2014 dataset was better, both in noise and number of data points. It, too, could be fit to a period near 3.94 h. On the other hand, forcing the 2023 data to one of the earlier periods produced “almost good, but not good enough” fits to a bimodal lightcurve.



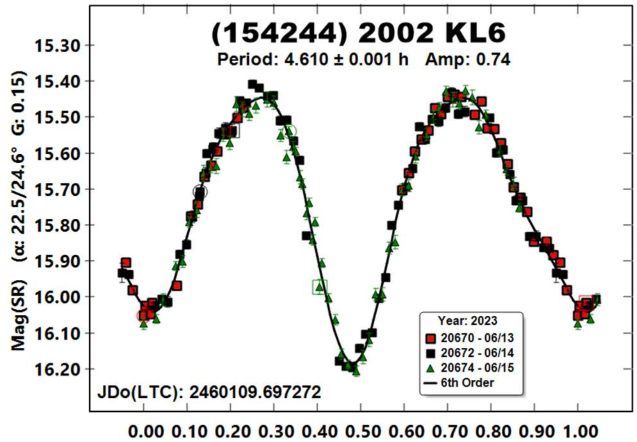




(154244) 2002 KL6. Galad et al. (2010) have the earliest reported results in the LCDB: P = 4.6063 h, A = 1.00 mag. There are more than a dozen other period analysis results in the LCDB, all of them with a period close to 4.60 h. The analysis of the 2023 data gives P = 4.610 h, making it consistent with earlier results.

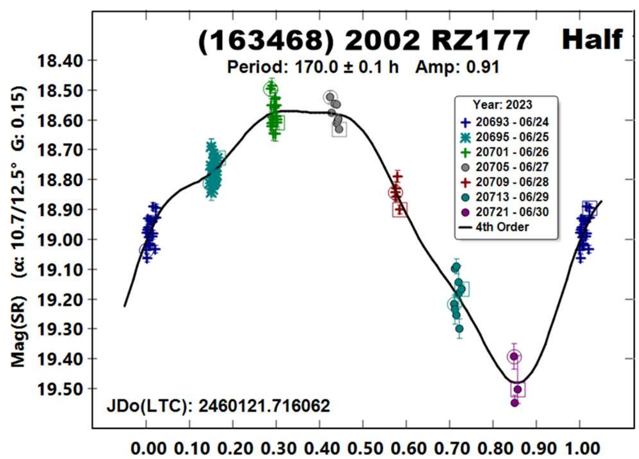
Warner et al. (2016) reported that the asteroid might be binary based on data obtained in 2016 June. A bimodal secondary period of 24.05 h and lightcurve amplitude of 0.08 mag were found but no mutual events were seen then or in the 2023 data.

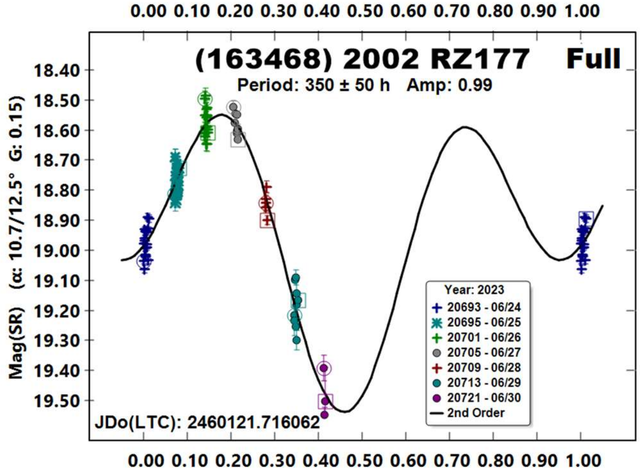
The phase angle bisector longitude (L_{PAB}) in 2016 was about 260°. The closest duplicate (or diametric opposite 80°) observations are from Aznar et al. (2018; 263°). They did not report signs of a satellite. As always with unexplained and/or unconfirmed results, additional observations are encouraged. The asteroid won't be V < 19 mag until 2030 August: V ~ 14.1, Dec +49°.



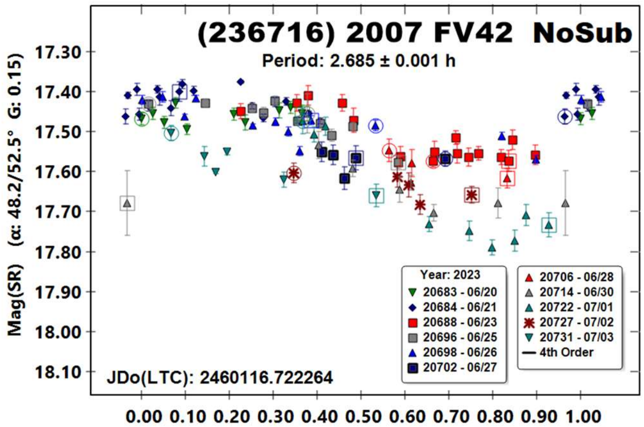
(163468) 2002 RZ177. There were no previously reported periods in the LCDB for this outer main-belt asteroid that kept pace in the field of another target, 1754 Cunningham. Circumstances did not allow long nightly runs nor a long campaign since the field was west of the meridian at the end of twilight.

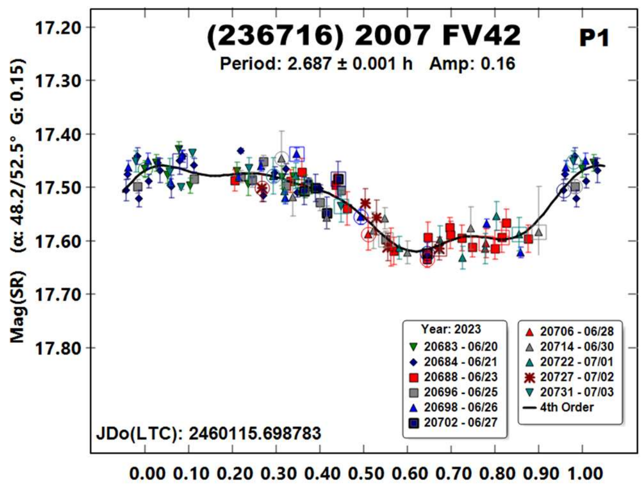
With a large amplitude and relatively low phase angle, the longer, bimodal lightcurve is far more likely correct given the dataset (Harris et al., 2014). The lack of coverage of the full lightcurve makes the solution a "good guess" for the time being. The brightest it will manage in the coming years will be V ~ 18.6 in 2034 May.

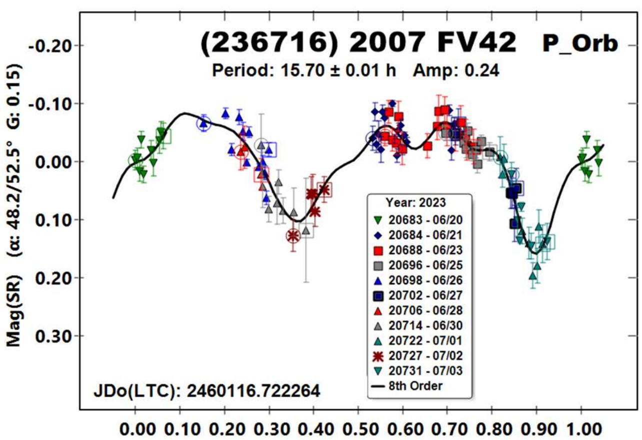




(236716) 2007 FV42. The only previous entry in the LCDB for this NEA is from Binzel et al. (2019), who determined its taxonomic type as S,Sr. The 2023 dataset is somewhat sparse, but it does provide enough information to say it's very possible that this NEA is a binary asteroid. Both periods and the effective diameter ratio, *Ds/Dp* ≥ 0.54 ± 0.03, are consistent with other binary asteroids (Pravec et al., 2018).



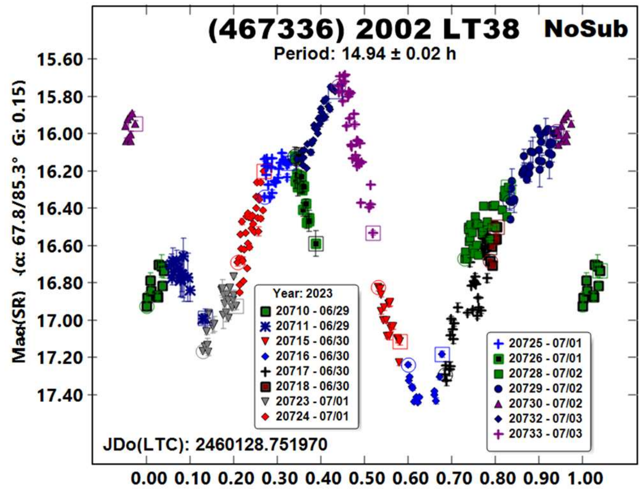


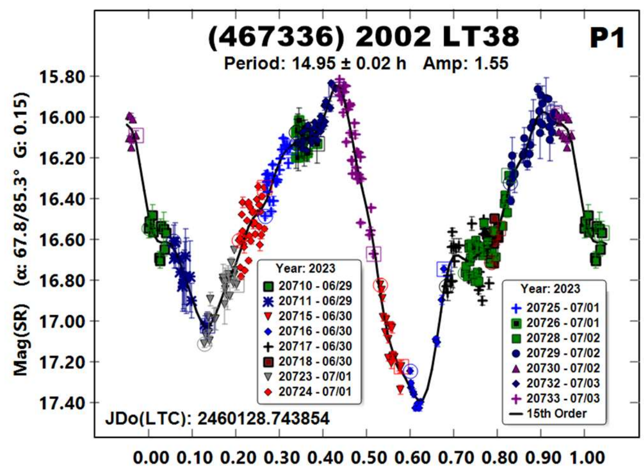


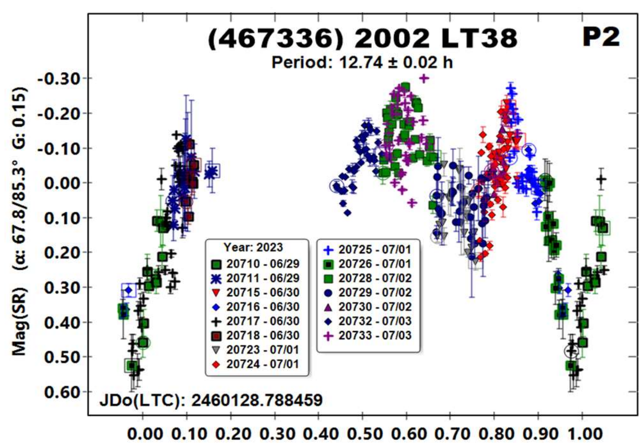
(467336) 2002 LT38. Warner (2017) reported this NEA as a possible tumbler with a dominant period of P = 21.80 h, A = 1.16 mag. A secondary period could not be determined, so the only evidence of tumbling was the shape of the single period lightcurve. The 2023 dataset was more supportive of tumbling (see Pravec et al., 2005; 2014).

The "NoSub" plot shows that a single period could not fit the data and that any secondary period would not be additive, e.g., due to a satellite. The dominant period was found to be 14.94 h. *MPO Canopus* does not handle non-additive periods correctly. Even so, it was used to extract a second period that would at least make for a reasonable dominant period lightcurve. The resulting secondary period of 12.74 h produces a poor lightcurve (at best) but does reach the goal for the dominant period lightcurve. *Neither* period should be considered the true periods of rotation and precession. They are constructs used to establish the strong possibly that the asteroid is tumbling.

The next good chance for observations is 2030 June when the asteroid will be V ~ 15.4 and Dec +21°.







Number	Name	2023/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp Ds/Dp
1754	Cunningham	06/24-07/03	8.6,10.7	252	14	7.756	0.003	0.17	0.02	H
2272	Montezuma	05/15-05/24	30.2,31.3	252	14	8.186	0.001	1.36	0.03	H
2449	Kenos	05/10-05/24	23.9,29.5	210	26	[B]3.8463	0.0003	0.11	0.01	H
						15.812	0.003	0.05	0.01	0.13
3225	Hoag	06/05-06/16	26.0,25.5	271	37	2.3728	0.0001	0.13	0.01	H
						40.2	0.1	0.05	0.01	H
4232	Aparicio	05/12-05/15	20.3,21.4	202	15	[B]58.4	0.1	1.1	0.2	H
						9.99	0.02	0.08	0.01	
4483	Petofi	05/27-05/29	22.6,22.5	257	36	4.332	0.001	0.97	0.03	H
5390	Huichiming	05/09-05/15	25.2,26.2	188	28	110.8	0.4	0.89	0.05	H
5968	Trauger	05/30-06/02	20.8,20.9	250	31	[A]3.687	0.002	0.08	0.02	H
						7.376	0.007	0.08	0.02	
						7.376	0.007	0.08	0.01	
6087	Lupo	05/19-05/24	26.4,27.4	216	32	4.717	0.001	0.56	0.03	H
6249	Jennifer	05/30-05/31	14.8,15.3	225	8	4.94	0.01	0.46	0.03	H
7087	Lewotsky	05/09-05/14	10.9,8.7	243	8	3.934	0.002	0.37	0.03	H
15374	Teta	05/27-05/29	26.8,26.8	252	43	2.823	0.001	0.26	0.03	H
21261	1996 FF	05/27-05/29	22.8,23.5	209	9	3.271	0.002	0.35	0.03	H
26383	1999 MA2	05/27-05/29	22.5,22.3	249	32	[A]4.932	0.003	0.32	0.02	H
						5.204	0.003	0.33	0.03	
37378	2001 VU76	06/23-06/28	16.2,19.3	257	15	[A]5.951	0.002	0.15	0.02	H
						2.976	0.001	0.13	0.02	
53530	2000 AV200	06/18-06/23	12.7,12.6	266	20	3.942	0.003	0.28	0.03	H
		[2012]07/16-07/21	20.6,22.2	262	17	[C]3.936	0.003	0.23	0.04	
		[2014]01/03-01/06	20.8,19.4	136	4	[C]3.956	0.003	0.23	0.02	H
154244	2002 KL6	06/13-06/15	22.6,24.7	248	8	4.61	0.001	0.74	0.02	NEA
163468	2002 RZ177	06/24-06/30	10.7,12.5	254	14	350	50	0.95	0.05	MB-O
						[HP]170.0	0.1	0.91	0.05	
236716	2007 FV42	06/20-07/03	48.2,52.5	238	9	2.687	0.001	0.16	0.01	NEA
						15.70	0.01	0.24	0.02	0.54
467336	2002 LT38	06/29-07/03	68.1,85.5	245	25	[D]14.95 T	0.01	1.6	0.1	NEA
						12.74	0.02	0.70	0.06	

Table II. Observing circumstances and results. [A]Preferred period of an ambiguous solution. [B]Period of primary with one or more confirmed or suspected satellites. [D]Dominant period of an apparent tumbler. [HF]Half-period used to estimate actual period. If a suspected binary with mutual events, the second line gives the effective diameter ratio (*Ds/Dp*). 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).

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LIGHTCURVES AND ROTATION PERIODS OF 102 MIRIAM, 126 VELLEDA, 294 FELICIA, 547 PRAXEDIS, 716 BERKELEY, 1166 SAKUNTALA, AND 2535 HAMEENLINNA

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Synodic rotation periods and lightcurve amplitudes at their year 2023 oppositions are found for 102 Miriam 23.618 ± 0.002 hours, 0.11 ± 0.01 magnitudes; 126 Velleda 5.3674 ± 0.0001 hours, 0.20 ± 0.01 magnitudes; 294 Felicia 10.426 ± 0.001 hours, 0.15 ± 0.01 magnitudes; 547 Praxedis 9.104 ± 0.002 hours, 0.06 ± 0.02 magnitudes; 716 Berkeley 15.580 ± 0.001 hours, 0.16 ± 0.02 magnitudes; 1166 Sakuntala 6.2912 ± 0.0002 hours, 0.21 ± 0.01 magnitudes; 2535 Hameenlinna 3.2312 ± 0.0002 hours, 0.10 ± 0.02 magnitudes. For 102 Miriam, V-R = 0.36, H = 9.32, G = 0.21. For 126 Velleda, V-R = 0.49, H = 9.40, G = 0.21.

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 to 120 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.

102 Miriam. All early observations were made at oppositions near perihelion at longitude 358° and assumed the usual two maxima and minima per rotational cycle. These include Shevchenko et al. (1997), 15.789h; Riccioli et al. (2001), 15.853h; Johnson et al. (2008), 15.789 h; and a recent result by Behrend (2020web), 15.79h. This author (Pilcher, 2008), with observations extending for a much longer interval of two months near celestial longitude 21°, found a period of 23.613h with three unequal maxima and minima per rotational cycle that ruled out all periods near 15.8h. At a different celestial longitude of 117°, this author (Pilcher, 2013), again based on two months of observations, found a good fit to a period of 23.625h with a lightcurve including two unevenly spaced maxima and minima and smaller scale irregularities, again definitively ruling out a period approximately 2/3 as great. Franco et al. (2021) near celestial longitude 24° published a period of 23.63 hours. New observations on seven nights 2023 Mar. 27 - May 23 near celestial longitude 202° also provide a good fit to a lightcurve (Figure 1) with two asymmetric maxima, additional irregularities, a period of 23.618 ± 0.002 hours, and amplitude 0.11 ± 0.01 magnitudes. This period is compatible with the dense lightcurves of Pilcher (2008), Pilcher (2013), and Franco et al. (2021).

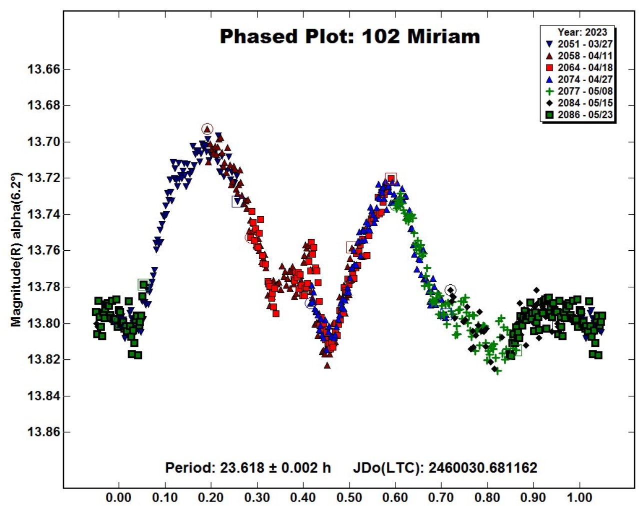

Figure 1. Phased lightcurve of 102 Miriam.

On 2023 Apr. 18, twenty images were obtained alternately with the R and V filters. Both image sets were measured with the same calibration stars. The method of extracting their R and V colors is explained by this author in Pilcher et al. (2016). The composite lightcurve (Figure 2) shows that V-R = 0.36. The calibrated R magnitudes found for each session were converted to V magnitudes by adding 0.36. An H-G plot in the V band (Figure 3) shows that at mid-light H = 9.323 ± 0.026, G = 0.212 ± 0.042.

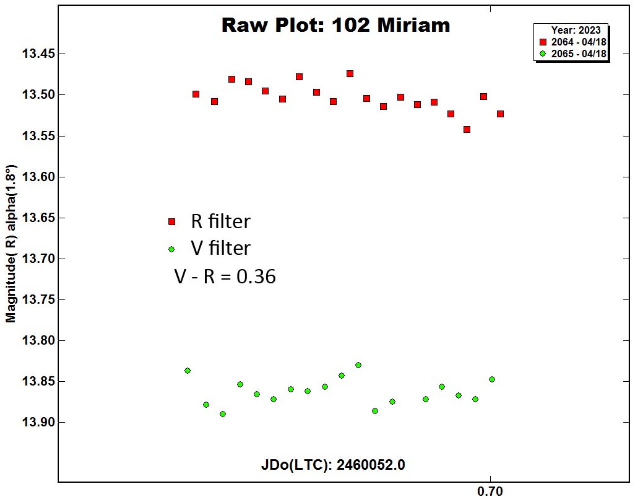

Figure 2. Raw lightcurve of 102 Miriam with V and R filters.

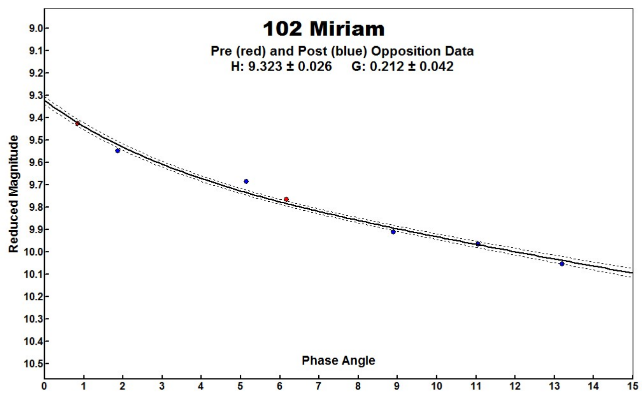

Figure 3. H-G plot for 102 Miriam.

126 Velleda. The Lightcurve Database (Warner et al., 2009) lists seven previously published rotation periods of 126 Velleda, all of them close to the adopted value of 5.3672 hours. New observations were made on eight nights 2023 Mar. 28 at phase angle -6.0° to Apr. 10 at phase angle 0.2° to May 13 at phase angle 13.8°. They provide an excellent fit to an irregular lightcurve (Figure 4) with period 5.3674 ± 0.0001 hours, amplitude 0.20 ± 0.01 magnitudes. This value is in very close agreement with previously published values. On 2023 Apr. 22 twenty images were taken alternately with R and V filters. Using the same method described in Pilcher (2016) as for 102 Miriam, the composite lightcurve with both filters shows V-R = 0.49 (Figure 5). An H-G plot in the V band (Figure 6) shows that at mid-light H = 9.399 ± 0.041, G = 0.208 ± 0.071.

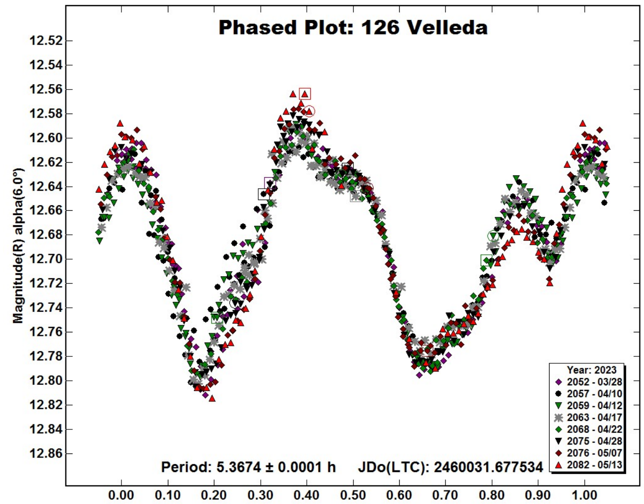

Figure 4. Phased lightcurve of 126 Velleda.

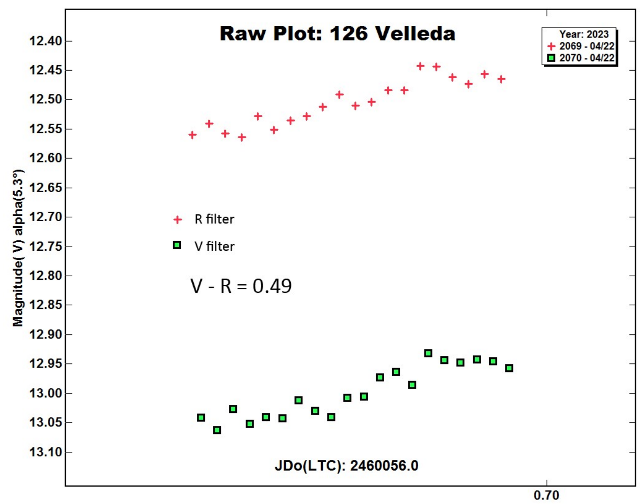

Figure 5. Raw lightcurve of 126 Velleda with V and R filters.

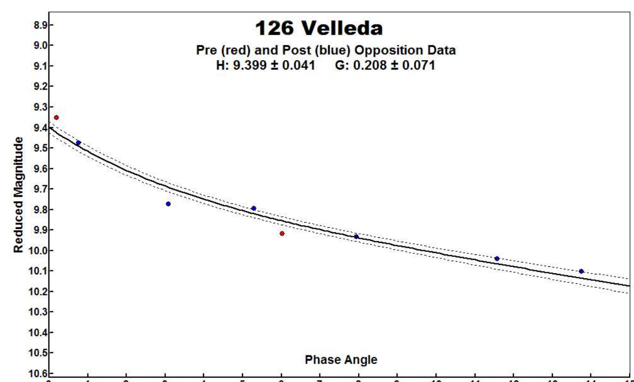

Figure 6. H-G plot for 126 Velleda.

294 Felicia. The Lightcurve Database (Warner et al., 2009) lists three previously published rotation periods of 294 Felicia, all of them near longitude 315° at the opposition of 2007 August and very close to the adopted value of 10.4227 hours. New observations on five nights 2023 Apr. 20 - May 10 near longitude 223° provide a good fit to a somewhat asymmetric bimodal lightcurve (Figure 7) with period 10.426 ± 0.002 hours, and amplitude 0.15 ± 0.01 magnitudes. This period is in excellent agreement with the rotation periods found in the year 2007.

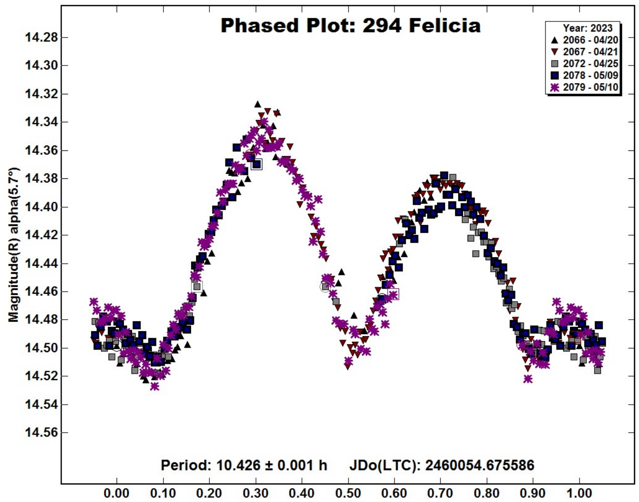

Figure 7. Phased lightcurve of 294 Felicia.

547 Praxedis. Previously published rotation periods are by Cooney and Robinson (2002), 9.105 h; Higgins et al. (2008), 9.106 h; and Behrend, (2019web), 9.1035 h., all with amplitudes between 0.04 and 0.12 magnitudes and irregular lightcurves. New observations on six nights 2023 June 11 - July 7 fit a lightcurve with period 9.104 ± 0.002 hours (Figure 8). The lightcurve has a single maximum and minimum, as often occurs when an asteroid is observed at an aspect not far from the rotational pole. The amplitude increased from 0.04 magnitudes in early June at phase angle near 8° to 0.08 magnitudes July 7 at phase angle 12.6°. The rotation period found in this investigation is in very close agreement with all other published rotation periods.

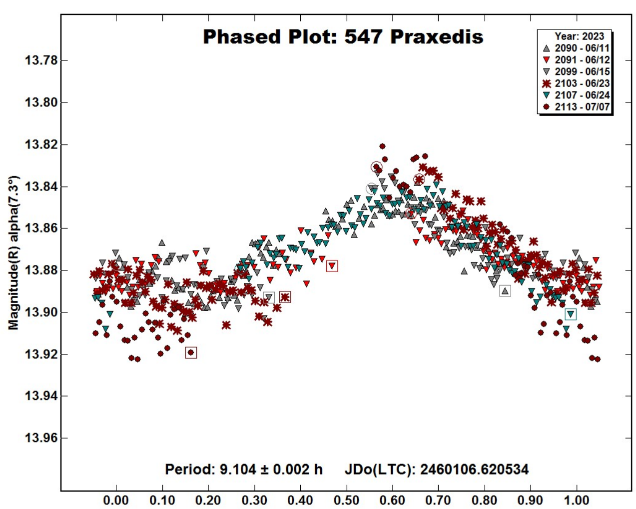

Figure 8. Phased lightcurve of 547 Praxedis.

716 Berkeley. Previously published rotation periods are by Lagerkvist (1978), >17h; Garlitz (2011), 15.55h; Behrend (2018web), 34.3h; and Polakis (2021), 15.46h. New sessions on seven nights 2023 Mar. 24 - Apr. 26 provide a good fit to a period 15.580 ± 0.001 hours, amplitude 0.16 ± 0.02 magnitudes, with an unsymmetrical bimodal lightcurve (Figure 9). This value is consistent with Garlitz (2011) and Polakis (2021), and rules out the results by Lagerkvist (1978) and Behrend (2018web).

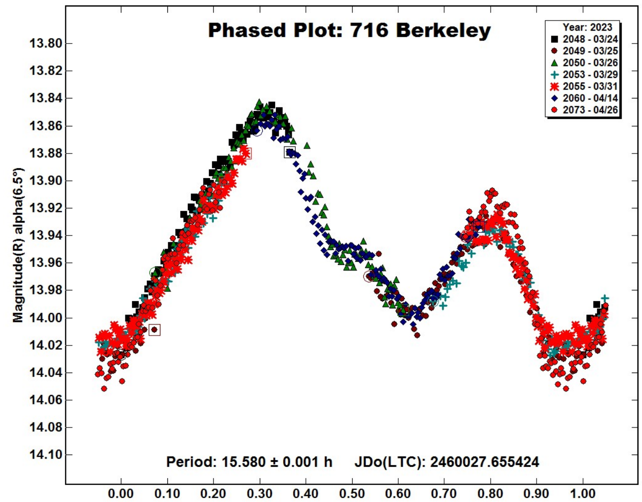

Figure 9. Phased lightcurve of 716 Berkeley.

1166 Sakuntala. Previously published periods are by Malcolm (2001), 6.3 h; Behrend (2002web), >20 h; Behrend (2003web), >20h; Behrend (2005web), >20h; Brincat, (2016), 6.2915 h; Garcerán et al. (2016), 6.29h; Franco et al. (2019), 6.2918 h; Franco et al. (2022), 6.291h. New observations on four nights 2023 June 13 - 25 provide a good fit to a lightcurve (Figure 10) with period 6.2912 ± 0.0002 hours, amplitude 0.21 ± 0.01 magnitudes. This value is in excellent agreement with Malcolm (2001), Brincat (2016), Garcerán et al. (2016), Franco et al. (2019) and Franco et al. (2022), and rules out all three values published by Behrend.

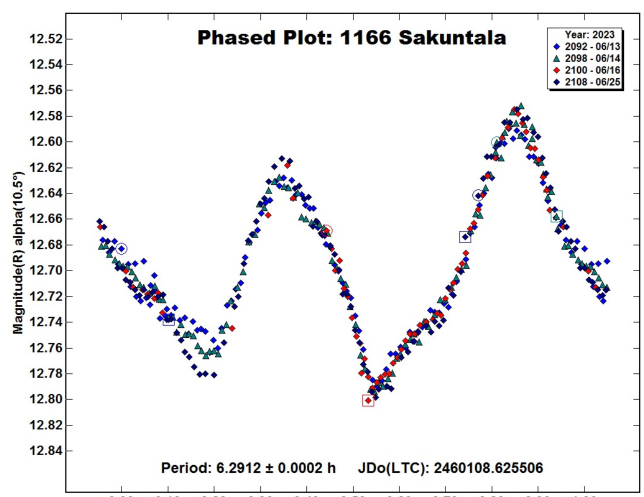

Figure 10. Phased lightcurve of 1166 Sakuntala.

Number	Name	yyyy/mm/dd	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
102	Miriam	2023/03/27-2023/05/23	* 6.2 - 13.2	202	-1	23.618	0.002	0.11	0.01
126	Velleda	2023/03/28-2023/05/13	* 6.0 - 13.8	200	0	5.3674	0.0001	0.20	0.01
294	Felicia	2023/04/20-2023/05/10	* 5.7 - 3.9	223	8	10.426	0.001	0.15	0.01
547	Praxedis	2023/06/11-2023/07/07	7.3 - 12.6	255	19	9.104	0.002	0.06	0.02
716	Berkeley	2023/03/24-2023/04/26	* 6.5 - 10.4	194	8	15.580	0.001	0.16	0.02
1166	Sakuntala	2023/06/13-2023/06/25	10.5 - 14.1	235	13	6.2912	0.0002	0.21	0.01
2535	Hameenlinna	2023/03/30-2023/04/19	3.7 - 7.8	195	2	3.2312	0.0002	0.10	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. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

2535 Hameenlinna. Previously published rotation periods are by Benishek et al. (2016), 3.23106 h; Sada et al. (2017), 3.2311 h; Behrend (2018web), 3.2288 h; Pravec et al. (2018web), 3.2312 h; and Pál et al. (2020), 3.2305 h. New sessions on four nights 2023 Mar. 30 - Apr. 19 provide a good fit to a lightcurve (Figure 11) with period 3.2312 ± 0.0002 hours, amplitude 0.10 ± 0.02 magnitudes, and a slightly asymmetric bimodal lightcurve. The period spectrum (Figure 12) is symmetric about the deepest minimum at 3.23 hours and rules out all alias periods except possibly a double period with 4 maxima and minima per rotational cycle. This paper, Benishek et al. (2016), Sada et al. (2017), and Pravec et al. (2018) all find rotation periods agreeing within 0.0002 hours. We may be confident that a rotation period both accurate and reliable has been found for 2535 Hameenlinna.

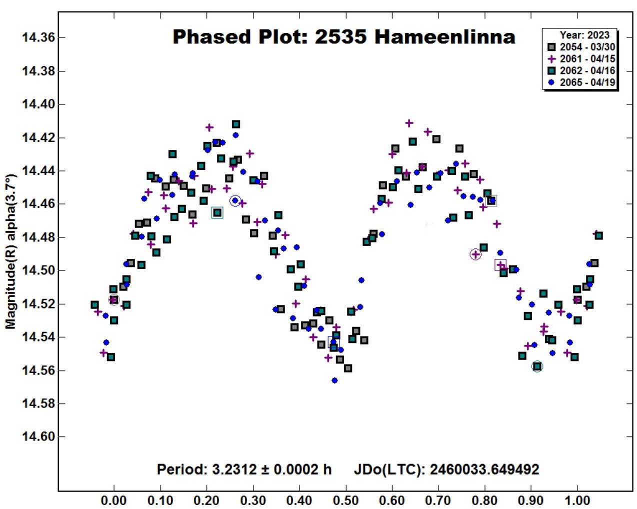

Figure 11. Phased lightcurve of 2535 Hameenlinna.

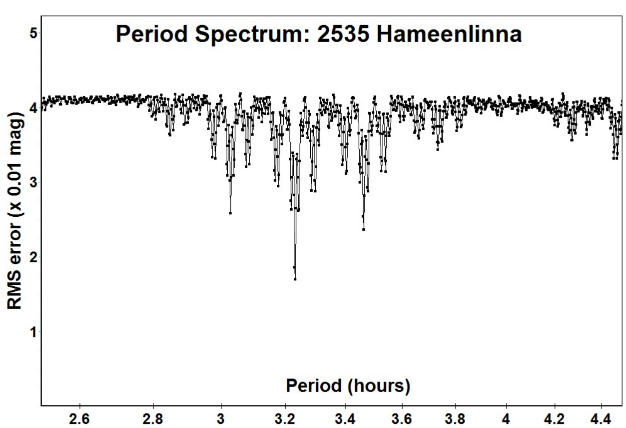

Figure 12. Period spectrum of 2535 Hameenlinna.

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2023 OCTOBER-DECEMBER

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We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling using lightcurve inversion. The “Radar-Optical Opportunities” section includes a list of potential radar targets as well as some that might be in critical need of astrometric data.

We present several lists of asteroids that are prime targets for photometry and/or astrometry during the period 2023 October through December. The “Radar-Optical Opportunities” section provides an expanded list of potential NEA targets, many of which are planned or good candidates for radar observations.

In the first three sets of tables, “Dec” is the declination and “U” is the quality code of the lightcurve. See the latest asteroid lightcurve data base (LCDB from here on; Warner et al., 2009) documentation for an explanation of the U code:

http://www.minorplanet.info/lightcurvedatabase.html

The ephemeris generator on the MinorPlanet.info web site allows creating custom lists for objects reaching V ≤ 18.0 during any month in the current year and up to five years in the future, e.g., limiting the results by magnitude and declination, family, and more.

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

We refer you to past articles, e.g., Warner et al. (2021a; 2021b) for more detailed discussions about the individual lists and points of advice regarding observations for objects in each list.

Once you’ve obtained and analyzed your data, it’s important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It’s also important to make the data available at least on a personal website or upon request. We urge you to consider submitting your raw data to the ALCDEF database. This can be accessed for uploading and downloading data at

http://www.alcdef.org

The database contains more than 10.4 million observations for 24,202 objects (as of 2023 April 6), making it one of the more useful sources for raw data of *dense* time-series asteroid photometry.

Lightcurve/Photometry Opportunities

Objects with U = 3– or 3 are excluded from this list since they will likely appear in the list for shape and spin axis modeling. Those asteroids rated U = 1 or have only a lower limit on the period, should be given higher priority over those rated U = 2 or 2+. On the other hand, do not overlook asteroids with U = 2/2+ on the assumption that the period is sufficiently established. Regardless, do not let the existing period influence your analysis since even highly-rated result have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

All objects are reaching one of their five brightest apparitions from 1995-2050. Bold text indicates a near-Earth asteroid (NEA).

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
1033	Simona	10 01.7	14.6	+3	10.07	0.04	1+
34155	2000 QJ22	10 02.2	15.4	-12	3.008	0.10	2+
9333	Hiraimasa	10 03.3	15.5	-10	6.911	0.37	2+
2165	Young	10 04.3	14.7	+4	6.389		2
7355	Bottke	10 06.1	15.1	-6	2.636	0.21	2
1112	Polonia	10 08.1	13.8	+18	18.71	0.12-0.26	2
5417	Solovaya	10 08.6	15.4	+8	3.833	0.09	2+
35360	1997 TY11	10 08.8	15.5	+1	2.896	0.11	2
2437	Amnestia	10 13.9	14.4	+10	85	0.45-0.51	2
1332	Marconia	10 18.9	14.0	+10	19.16	0.30-0.4	2
12332	1992 UJ6	10 22.8	15.5	+10	43	0.62	2
9262	Bordovitsyna	10 23.7	15.3	+24	9	0.08	2
26853	1992 UQ2	10 28.9	14.9	+4	8.27	0.14	2+
14835	Holdridge	10 29.4	14.5	+30	>10	0.08	2-
3242	Bakhchisaraj	10 30.1	15.4	+5	15	0.07	2-
2889	Brno	11 02.2	15.2	+15	9.51	0.42-0.80	2+
3576	Galina	11 02.3	15.3	+21	3.342	0.04-0.15	2
14031	Rozyo	11 02.4	15.3	-4	S 2.901		2
3819	Robinson	11 03.3	14.9	+13	3.7	0.10-0.32	2+
8142	Zolotov	11 04.7	15.4	+15	4.323		2-
2203	van Rhijn	11 06.8	14.8	+16	30.55	0.38	2
3415	Danby	11 07.1	15.1	+17	5.675	0.09-0.35	2+
363505	2003 UC20#	11 07.5	14.3	-66	29.6	0.88	2+
1429	Pemba	11 10.1	13.8	+17	>20	0.3	1
3589	Loyola	11 13.1	15.3	+10	4.166		2
2716	Tuulikki	11 13.4	15.5	+16	50.18	0.05-0.12	2
3148	Grechko	11 15.1	15.4	+19	5.983	0.34-0.35	2
6086	Vrchlicky	11 17.1	15.0	+16	2.768	0.05	2
7201	Kuritariku	11 17.3	15.5	+21	S 48.849		2
2959	Scholl	11 17.6	15.2	+12	4.359	0.14	2+
27136	1998 XJ16	11 18.7	15.3	+6	26	0.10	2-
82256	2001 KM8	11 19.8	15.4	+13	3.036	0.34	2
4264	Karljosephine	11 19.9	14.9	+14	30.96	0.09-0.45	2
3442	Yashin	11 21.8	15.5	+7	8.552	0.50	2
4458	Oizumi	11 28.8	15.5	+17	S11.406		2
2269	Efremiana	11 30.8	15.0	+22	6.458	0.09	2
8021	Walter	12 07.2	15.4	+5	4.84	0.07	2
3629	Lebedinskij	12 08.9	15.3	+19	9.342	0.33	2+
10936	1998 FN11	12 10.9	14.8	+8	25.7	0.28-0.40	2
19370	Yukyung	12 18.7	15.0	+22	15.185	0.14-0.15	2
5765	Izett	12 22.2	14.8	+34	8.955	0.29	2+
1504	Lappeenranta	12 22.8	13.8	+22	15.19	0.09-0.29	2+
2140	Kemerovo	12 27.1	15.3	+23	9.2	0.18-0.19	2

Low Phase Angle Opportunities

The Low Phase Angle list includes asteroids that reach very low phase angles ($\alpha < 1°$). The "α" column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the "opposition effect." Use the on-line query form for the LCDB to get more details about a specific asteroid.

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

The best chance of success comes with covering at least half a cycle a night, meaning periods generally < 16 h, when working objects with low amplitude. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data must be reduced to the average magnitude of the asteroid for each night. Refer to Harris et al. (1989) for the details of the analysis procedure.

As an aside, it is arguably better for physical interpretation (e.g., *G* value versus albedo) to use the maximum light rather than mean level to find the phase slope parameter (*G*), which better models the behavior of a spherical object of the same albedo, but it can produce significantly different values for both *H* and *G* versus using average light, which is the method used for values listed by the Minor Planet Center. Using and reporting the results of both methods can provide additional insights into the physical properties of an asteroid.

The International Astronomical Union (IAU) has adopted a new system, H-G_{12}, introduced by Muinonen et al. (2010). It will be some years before H-G_{12} becomes widely used, and hopefully not until a discontinuity flaw in the G_{12} function has been fixed. This discontinuity results in false "clusters" or "holes" in the solution density and makes it impossible to draw accurate conclusions.

We strongly encourage obtaining data as close to 0° as possible, then every 1-2° out to 7°, below which the curve tends to be non-linear due to the opposition effect. From 7° out to about 30°, observations at 3-6° intervals should be sufficient. Coverage beyond 50° or so is not generally helpful since the H-G system is best defined with data from 0-30°.

It's important to emphasize that all observations should (must) be made using high-quality catalogs to set the comparison star magnitudes. These include ATLAS, Pan-STARRS, SkyMapper, and Gaia2/3. Catalogs such as CMC-15, APASS, or the MPOSC from *MPO Canopus* have too high systematic errors.

Also important is that that there are sufficient data from each observing run such that their location can be found on a combined, phased lightcurve derived from two or more nights obtained *near the same phase angle.* If necessary, the magnitudes for a given run should be adjusted so that they correspond to mid-light of the combined lightcurve. This goes back to the H-G system being based on average, not maximum or minimum light.

The asteroid magnitudes are brighter than in others lists because higher precision is required and the asteroid may be a full magnitude or fainter when it reaches phase angles out to 20-30°. Even so, starting now, the list will include objects that reach $V \leq 15.0$ at opposition. The list of objects using the previous limit of $V \leq 14.0$ was becoming very short.

Num	Name	Date	α	V	Dec	Period	Amp	U
492	Gismonda	10 01.8	0.63	13.3	+2	6.488	0.10 0.14	3
29	Amphitrite	10 02.2	0.90	8.8	+5	5.392	0.04 0.15	3
428	Monachia	10 04.1	0.86	13.4	+3	3.634	0.16 0.37	3
204	Kallisto	10 17.9	0.12	12.7	+9	19.489	0.09 0.26	3
1332	Marconia	10 18.9	0.29	14.0	+10	19.16	0.30 0.4	2
717	Wisibada	10 20.1	0.83	13.6	+12			
1204	Renzia	10 21.0	0.74	13.1	+12	7.885	0.42 0.49	3
122	Gerda	10 23.7	0.38	12.2	+10	10.685	0.10 0.26	3
1675	Simonida	10 24.9	0.13	13.7	+12	5.289	0.16 0.65	3
184	Dejopeja	10 28.6	0.43	13.1	+14	6.44	0.22 0.3	3
509	Iolanda	10 29.9	0.27	12.1	+14	12.306	0.20 0.45	3
127	Johanna	10 30.7	0.46	12.1	+15	12.799	0.18 0.21	3
343	Ostara	10 30.7	0.23	12.9	+13	109.87	0.52	3-
641	Agnes	11 03.9	0.12	13.9	+15	178.0	0.55	3
299	Thora	11 06.1	0.39	13.9	+17	272.9	0.37 0.50	3-
743	Eugenisis	11 06.9	0.27	13.6	+17	10.23	0.10-0.20	3
1429	Pemba	11 10.3	0.19	13.9	+17	>20.	0.3	1
90	Antiope	11 15.8	0.30	12.7	+18	16.509	0.05-0.88	3

Num	Name	Date	α	V	Dec	Period	Amp	U
363	Padua	11 21.6	0.39	12.4	+19	8.401	0.08-0.3	3
425	Cornelia	11 21.8	0.12	13.8	+20	17.505	0.19-0.21	3
24	Themis	11 23.1	0.15	11.4	+21	8.374	0.09-0.14	3
503	Evelyn	11 24.5	0.47	12.1	+19	38.871	0.30-0.5	3
1133	Lugduna	11 24.5	0.41	13.6	+21	5.477	0.33-0.49	3
300	Geraldina	11 29.2	0.17	14.0	+22	6.842	0.04-0.32	3
95	Arethusa	11 30.4	0.65	11.4	+20	8.705	0.24-0.35	3
149	Medusa	12 14.8	0.84	12.5	+21	26.023	0.47-0.56	3
488	Kreusa	12 18.7	0.34	11.8	+24	32.645	0.08-0.20	3
1504	Lappeenranta	12 22.7	0.75	13.9	+22	15.190	0.09-0.29	2+
1176	Lucidor	12 27.0	0.21	14.0	+23	4.079	0.05-0.06	3

Shape/Spin Modeling Opportunities

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

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

Additional lightcurves could lead to the asteroid being added to or improving one in DAMIT, thus increasing the total number of asteroids with spin axis and shape models.

Included in the list below are objects that:

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

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

With the wide use of sparse data from the surveys for modeling that produces hundreds of statistically valid poles and shapes, the need for data for main-belt objects is not what it used to be. The best use of observing time might be to concentrate on near-Earth asteroids, or on asteroids where the only period was derived from sparse data, which can help eliminate alias periods.

The latter targets are usually flagged with an 'S' on the LCDB summary line. Regardless, it's a good idea to visit the DAMIT site and see what it has, if anything, on the target(s) you've picked for observations.

All objects are at a favorable apparition. Those in italic text are near-Earth objects.

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
4254	Kamel	10 09.0	14.8	+8	2.739	0.17-0.19	3
7778	Markrobinson	10 15.9	14.9	+24	7.23	0.64-0.84	3
24643	MacCready	10 21.8	15.4	+21	2.829	0.11-0.20	3
7350	1993 VA#	10 23.9	15.4	-47	3.583	0.15-0.38	3
164121	2003 YT1#	11 02.6	12.2	-20	2.343	0.16-0.27	3
1362	Griqua	11 03.3	14.2	-25	6.907	0.23-0.25	3
3567	Alvema	11 04.8	14.9	+25	8.17	0.17-0.45	3-
3838	Epona#	11 18.1	15.4	+17	2.381	0.05-0.38	3
363	Padua	11 21.6	12.4	+19	8.401	0.08-0.3	3
481	Emita	11 21.6	11.4	+17	14.412	0.13-0.30	3
895	Helio	11 24.5	12.4	+37	9.347	0.09-0.23	3
346	Hermentaria	11 27.0	10.7	+14	28.523	0.07-0.20	3
4700	Carusi	11 30.3	14.8	+20	11.671	0.11-0.53	3-
1316	Kasan	12 01.7	14.6	+9	5.843	0.19-0.26	3
5536	Honeycutt	12 02.9	14.9	+22	3.583	0.08-0.09	3
815	Coppelia	12 09.0	14.1	+31	4.421	0.13-0.24	3
6170	Levasseur	12 13.6	15.4	+69	2.653	0.09-0.14	3
1011	Laodamia	12 16.1	13.6	+13	5.172	0.41-0.45	3

Radar-Optical Opportunities

Table I below gives a list of near-Earth asteroids reaching maximum brightness for the current quarter-year based on calculations by Warner. We switched to this presentation in lieu of ephemerides for reasons outlined in the 2021 October-December opportunities paper (Warner et al., 2021b), which centered on the potential problems with ephemerides generated several months before publication.

The initial list of targets started using the planning tool at

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

where the search was limited to near-Earth asteroids only that were V ≤ 18 for at least part of the quarter.

The list was then filtered to include objects that might be targets for the Goldstone radar facility or, if it were still operational, the Arecibo radar. This was based on the calculated radar SNR using

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

and assuming a rotation period of 4 hours (2 hours if $D \leq 200$ m) if a period was not given in the asteroid lightcurve database (LCDB; Warner et al., 2009). The SNR values are estimates only and assume that the radar is fully functional.

If an asteroid was on the list but failed the SNR test, we checked if it might be a suitable target for radar and/or photometry sometime through 2050. If so, it was kept on the list to encourage physical and astrometric observations during the current apparition. In most of those cases, the SNR values in the "A" and "G" columns are not for the current quarter but the year given in the Notes column. If a better apparition is forthcoming through 2050, the Notes column in Table I contains SNR values for that time.

The final step was to cross-reference our list with that found on the Goldstone planned targets schedule at

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

In Table I, objects in bold text are on the Goldstone proposed observing list as of 2023 July.

It's important to note that the final list in Table I is based on *known* targets and orbital elements when it was prepared. It is common for newly discovered objects to move in or out of the list. We recommend that you keep up with the latest discoveries by using the Minor Planet Center observing tools.

In particular, monitor NEAs and be flexible with your observing program. In some cases, you may have only 1-3 days when the asteroid is within reach of your equipment. Be sure to keep in touch with the radar team (through Benner's email or their Facebook or Twitter accounts) if you get data. The team may not always be observing the target but your initial results may change their plans. In all cases, your efforts are greatly appreciated.

For observation planning, use these two sites

MPC: *http://www.minorplanetcenter.net/iau/MPEph/MPEph.html*
JPL: *http://ssd.jpl.nasa.gov/?horizons*

Cross-check the ephemerides from the two sites just in case there is discrepancy that might have you imaging an empty sky.

About YORP Acceleration

Near-Earth asteroids are particularly sensitive to YORP acceleration. YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack; Rubincam, 2000) is the asymmetric thermal re-radiation of sunlight that can cause an asteroid's rotation period to increase or decrease. High precision lightcurves at multiple apparitions can be used to model the asteroid's *sidereal* rotation period and see if it's changing.

It usually takes four apparitions to have sufficient data to determine if the asteroid rotation rate is changing under the influence of YORP. This is why observing an asteroid that already has a well-known period remains a valuable use of telescope time. It is even more so when considering the BYORP (binary-YORP) effect among binary asteroids that has stabilized the spin so that acceleration of the primary body is not the same as if it would be if there were no satellite.

The Quarterly Target List Table

The Table I columns are

Num	Asteroid number, if any.
Name	Name assigned by the MPC.
H	Absolute magnitude from MPCOrb.
Dkm	Diameter (km) assuming $p_V = 0.2$.
Date	Date (mm dd.d) of brightest magnitude.
V	Approximate V magnitude at brightest.
Dec	Approximate declination at brightest.
Period	Synodic rotation period from summary line in the LCDB summary table.
Amp	Amplitude range (or single value) of reported lightcurves.
U	LCDB U (solution quality) from 1 (probably wrong) to 3 (secure).
A	Approximate SNR for Arecibo (if operational and at full power).
G	Approximate SNR for Goldstone radar at full power.
Notes	Comments about the object.

"PHA" is a potentially hazardous asteroid. NHATS is for "Near-Earth Object Human Space Flight Accessible Targets Study." Presume that that astrometry and photometry have been requested to support Goldstone observations. The sources for the rotation period are given in the Notes column. If none are qualified with a specific period, then the periods from multiple sources were in general agreement. Higher priority should be given to those where the current apparition is the last one V ≤ 18 through 2050 or several years to come.

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Num	Name	H	Diam	BDate	BMag	BDec	Period	AMn	AMx	U	A	G	Notes
349507	2008 QY	18.54	0.582	10 06.7	14.8	23					910	260	
518635	2008 HO3	18.2	0.681	10 11.5	15.5	17	13.413		0.88		25		Warner/Stephens (2019)
	2011 GA	20.8	0.193	10 16.9	15.0	-5							PHA.
	1998 HH49	21.3	0.161	10 17.9	13.1	-2							PHA.
7350	1993 VA	17.28	1.04	10 23.9	15.4	-47	3.58264	0.15	0.38	3	25	-	
	2019 HH4	19.9	0.307	10 27.2	17.0	-35							PHA.
302169	2001 TD45	19.89	0.313	10 28.3	15.1	79					750	215	PHA.
525229	2004 UU1	21.25	0.167	10 31.5	14.2	10					625	180	PHA.
31669	1999 JT6	16.15	1.75	11 01.9	17.0	12	5.807	0.07	0.27	3	-	-	Galad et al. (2005)
164121	2003 YT1	16.33	1.61	11 02.6	12.2	-20	2.343	0.16	0.27	3	970	280	PHA. Binary. Nolan et al. (2004); Pravec et al. (2006)
363505	2003 UC20	18.5	0.593	11 07.5	14.3	-66	29.6		0.88	2+	6010	1725	PHA. NHATS. Pravec et al. (2019web)
25330	1999 KV4	16.79	1.3	11 14.2	14.8	19	4.919	0.14	0.15	3	-	-	Pravec et al. (2002web)
3838	Epona	15.71	2.14	11 18.1	15.4	17	2.3812	0.05	0.38	3	-	-	Pravec et al. (1999web)
1943	Anteros	15.89	1.97	11 19.2	16.7	23	2.86923	0.07	0.14	3	-	-	Binary. Warner et al. (2017)
219071	1997 US9	17.18	1.09	11 24.4	16.8	-20	3.319	0.14	0.20	3-	-	-	Skiff et al. (2019)
	1998 WB2	21.8	0.113	12 01.3	16.2	43	0.313		0.6	3	115	35	PHA. Pravec et al. (2000)
13962	2001 QQ142	18.5	0.593	12 10.4	14.2	-6					4850	1390	NHATS.
326683	2002 WP	18.54	0.582	12 11.0	16.2	36	6.262	1.13	1.65	3	-	-	Behrend (2016web)
137671	1999 XP35	18.7	0.541	12 12.8	17.0	34					-	-	
341843	2008 EV5	20.07	0.288	12 24.9	15.9	-2	3.725	0.03	0.15	3	350	100	NHATS. Galad et al. (2009)
	2018 YJ2	21.8	0.129	12 26.2	18.1	78					-	-	PHA.
168318	1989 DA	18.98	0.475	12 28.4	16.7	71	3.925		0.12	3	10	-	Wisniewski et al. (1997)

Table I. A list of near-Earth asteroids reaching brightest in 2023 January-March. PHA: potentially hazardous asteroid. NHATS: Near-Earth Object Human Space Flight Accessible Targets Study. Diameters are based on p_V = 0.20. The Date, V, and Dec columns are the mm/dd.d, approximate magnitude, and declination when at brightest. Amp is the single or range of amplitudes. The A and G columns are the approximate SNRs for an assumed full-power Arecibo (not operational) and Goldstone radars. The references in the Notes column are those for the adopted period.

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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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