

PHOTOMETRIC RESULTS FOR TWENTY MINOR PLANETS

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Photometric measurements were made for 20 main-belt asteroids, based on CCD observations made from 2023 October through 2023 December. Phased lightcurves were created for all twenty asteroids, and an orbital period was computed for one binary asteroid. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 20 main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe, AZ and NAC Observatory (MPC U98) in Benson, AZ.

Images were taken at V02 using a 0.32-m f/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a ‘clear’ glass filter. Exposure time for the images was either 2 minutes or 1 minute. The image scale after 2×2 binning was 1.76 arcsec/pixel.

Images from U98 were taken through a clear filter using a 0.35-m Corrected Dall-Kirkham telescope operating at f/4.7 and an SBIG CCD47-10 CCD camera, whose image scale with 1×1 binning is 1.60 arcsec/pixel. Exposure times are 1 minute for brighter objects, 2 minutes for all others.

Table I shows the observing circumstances and results. All of the images for these asteroids were obtained between 2023 October and 2023 December.

Images taken at V02 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.

Images taken at U98 were calibrated using bias, dark and flat frames. Flat-field images were made using an electroluminescent panel.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2023). 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.

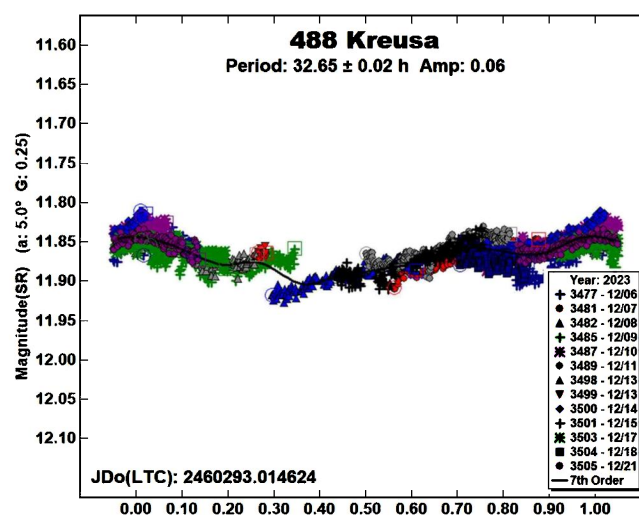
The clear-filtered images were reduced to Sloan r' to minimize error with respect to a color term. Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *MPO Canopus*. The ATLAS catalog derives Sloan $griz$ magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required or shifts of only a few hundredths of a magnitude in a series.

Data reduction for V02 images used a 9-pixel (16 arcsec) diameter measuring aperture for asteroids and comp stars. A 12-pixel (19 arcsec) diameter aperture was used for U98 images. It was typically necessary to employ star subtraction to remove contamination by field stars.

For the asteroids described here, the 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 (Harris et al., 1989). Phased lightcurves show the maximum at phase zero. Magnitudes in these plots are apparent and scaled by *MPO Canopus* to the first night.

Asteroids were selected from the CALL website (Warner, 2011), either for having uncertain periods or for needing more lightcurves for shape modeling. In this set of observations, eight of the 10 asteroids had $U = 2$, two were rated as $U = 1$, and four had no published periods. 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.

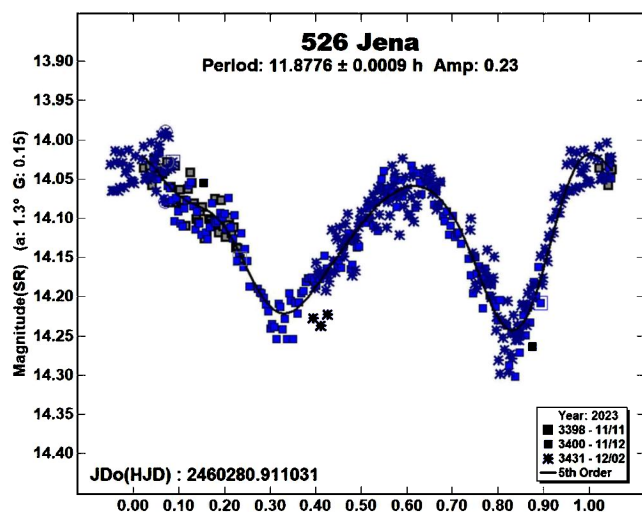
488 *Kreusa* was discovered by Max Wolf and Luigi Carnera at Heidelberg in 1902. Stephens (2014) and Pilcher (2019) published similar rotation periods of 32.666 ± 0.003 h and 32.645 ± 0.001 h, while Colazo et al. (2022) obtained 639 ± 5 h. During this apparition, obtaining a clean lightcurve for this asteroid proved to be difficult, possibly due to a pole-on orientation or tumbling. A period similar to that of Stephens and Pilcher does appear in the period spectrum. Observing on 12 nights, 2091 data points were used to determine a period of 32.65 ± 0.02 h, with an amplitude of only 0.06 ± 0.012 mag.



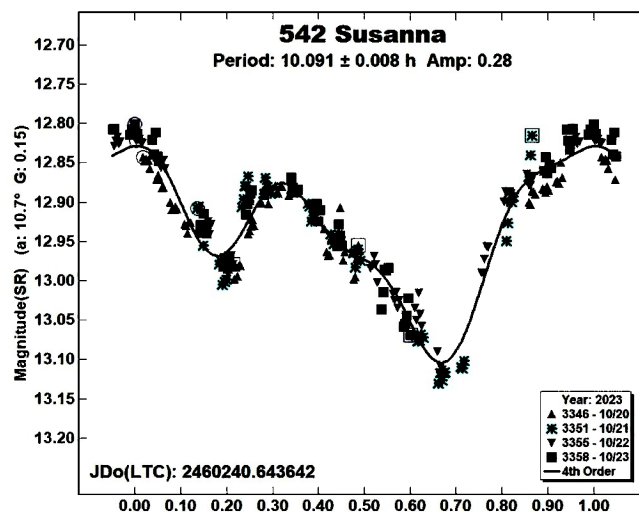
Number	Name	yy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
488	Kreusa	23/12/06-12/21	*4.9, 1.1	86	1	32.65	0.020	0.06	0.01	MB-O
526	Jena	23/11/11-12/02	1.3, 7.3	50	-3	11.8776	0.0009	0.23	0.02	THM
542	Susanna	23/10/20-10/23	10.6, 11.8	6	-10	10.091	0.008	0.28	0.02	MB-O
674	Rachele	23/11/07-11/10	7.6, 8.6	30	-7	30.82	0.07	0.14	0.01	MB-O
717	Wisibada	23/10/05-10/25	*7.5, 2.8	26	1	480.8	2.2	0.19	0.02	MB-O
1033	Simona	23/10/10-10/20	3.8, 8.1	8	0	136.7	0.9	0.20	0.03	EOS
1048	Feodosia	23/11/02-11/04	3.6, 2.9	49	-2	10.426	0.007	0.27	0.02	MB-O
1112	Polonia	23/10/05-10/07	5.1, 5.0	14	11	18.50	0.08	0.11	0.01	EOS
1332	Marconia	23/10/21-10/24	1.1, 2.4	25	1	31.34	0.12	0.22	0.02	MARC
1372	Haremari	23/12/03-12/05	10.9, 10.7	75	21	--	--	--	--	WAT
1429	Pemba	23/11/02-12/11	*5.2, 16.5	48	1	836.6	0.7	0.76	0.06	MB-I
1631	Kopff	23/11/05-11/06	4.9, 4.5	47	5	6.880	0.005	0.28	0.02	MB-I
1887	Virton	23/10/05-10/20	*4.2, 4.7	18	6	69.64	0.08	0.31	0.02	EOS
2165	Young	23/10/18-10/20	6.2, 7.1	11	0	6.388	0.003	0.67	0.02	THM
2203	van Rhijn	23/11/02-11/05	2.1, 0.7	44	0	30.72	0.08	0.42	0.03	THM
2244	Tesla	23/12/03-12/07	3.4, 4.0	70	-6	--	--	--	--	MB-O
2967	Vladisvyat	23/11/05-11/06	3.5, 3.3	48	6	8.378	0.006	0.57	0.03	URS
3115	Baily	23/11/05-11/06	5.7, 6.0	38	9	16.172	0.027	0.34	0.02	MB-I
3921	Klement'ev	23/10/18-10/19	11.6, 12.1	13	-12	6.740	0.019	0.17	0.04	MB-M
14835	Holdridge	23/10/21-10/29	12.9, 10.5	33	14	112.2	0.3	0.56	0.03	PHO

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an 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).

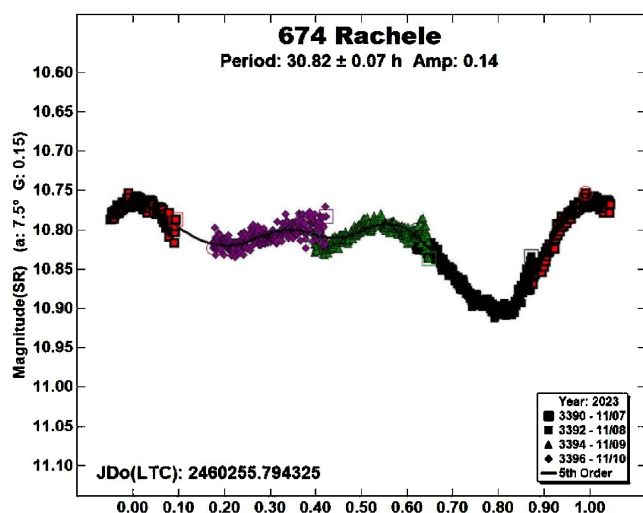
526 Jena. This Themis-family asteroid was discovered in 1904 by Max Wolf at Heidelberg. Hanus et al. (2016) found a rotation period of 9.51664 ± 0.00005 h, but Erasmus et al. (2020) shows 11.877 ± 0.009 h, and Martikainen (2021) computed a similar period of 11.876510 ± 0.0000601 h. A total of 396 images were taken over the course of three nights, with a three-week wait for the third night to account for its commensurate period with half of an earth rotation. The result is a period of 11.8776 ± 0.0009 h, in agreement with Erasmus and Martikainen. The lightcurve has an amplitude of 0.23 mag, and an RMS error on the fit of 0.023 mag.



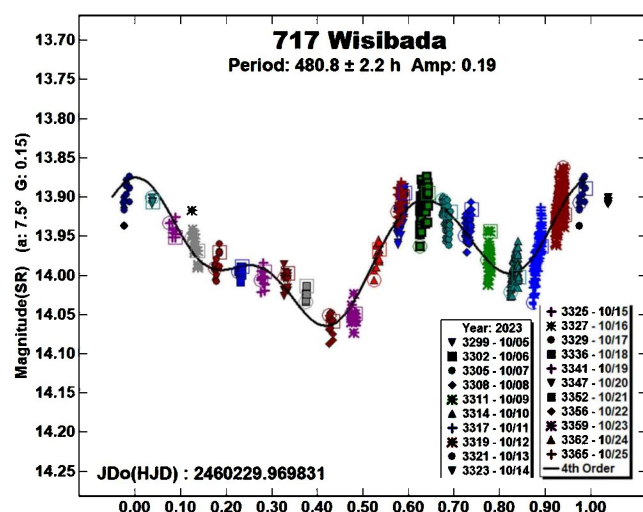
542 Susanna was discovered at Heidelberg in 1904 by Paul Götz and August Kopff. Its rotation period is well known, most recently computed by Pilcher (2022), who obtained 10.089 ± 0.001 h. During four nights, 250 images were used to compute a synodic period of 10.091 ± 0.008 h, in agreement with previous results. The amplitude is 0.28 mag, with an RMS error of 0.021 mag.



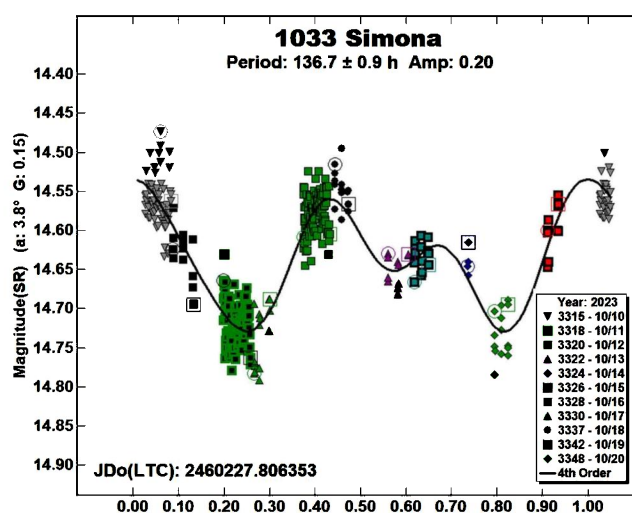
674 Rachele. Hendrik Lorenz discovered this minor planet at Heidelberg in 1904. Again, the period is established, with the most recent value of 30.957 ± 0.005 h coming from Pál et al. (2020). A total of 966 images were gathered in four nights. This analysis produced a period of 30.82 ± 0.07 h, with an amplitude of 0.14 ± 0.008 mag, agreeing with previous values.



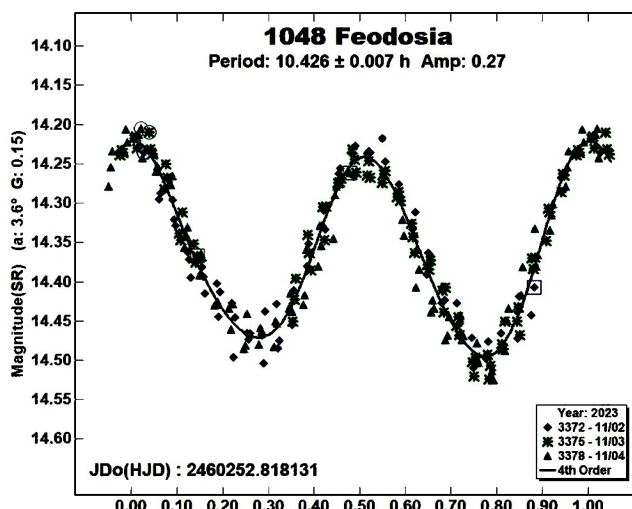
717 Wisibada, an outer main-belt asteroid, was discovered in 1911 at Heidelberg by Frederik Kaiser. No period solutions appear in the LCDB. During 21 consecutive October nights, 813 images were gathered, resulting in a period of 480.8 ± 2.2 h. The amplitude of the lightcurve is 0.19 ± 0.018 h.



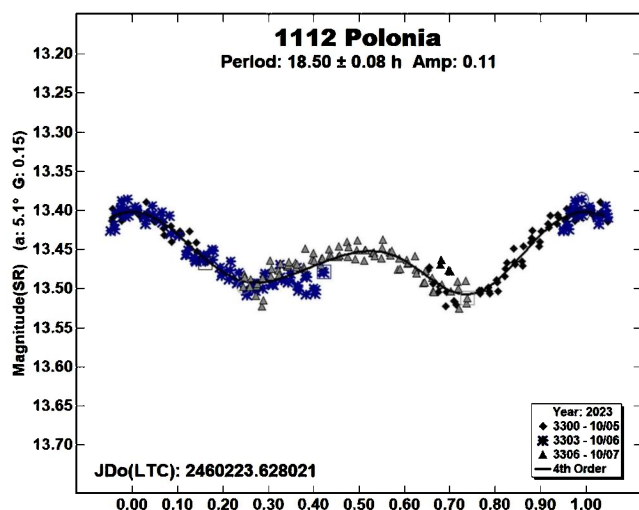
1033 Simona. George Van Biesbroeck discovered this Eos-family asteroid at Williams Bay in 1924. The only period solution in the LCDB belongs to Shipley et al. (2008), 10.07 ± 0.06 h. An 11-night run during which 380 images were taken was used to arrive at a rotation period of 136.7 ± 0.9 h, disagreeing with Shipley's result. The lightcurve has an amplitude of 0.20 mag, with an RMS error of 0.028 mag.



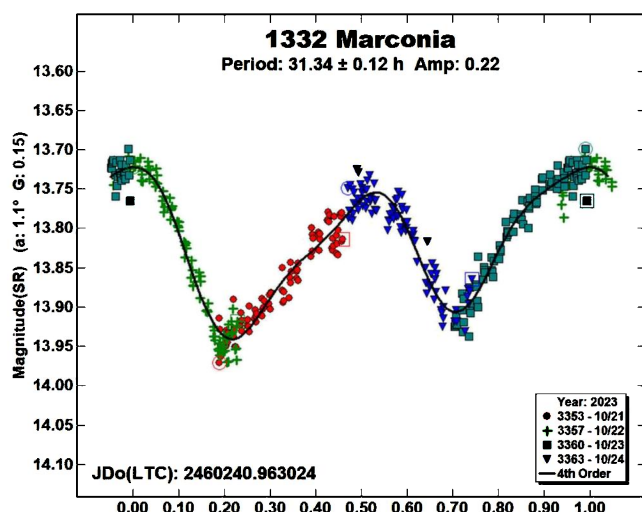
1048 Feodosia is an outer main-belt asteroid, which Karl Reinmuth discovered at Heidelberg in 1924. Polakis (2020) found a period of 10.42 ± 0.02 h, while Franco et al. (2021) computed 10.417 ± 0.001 h. Colazo et al. (2023) found a different period of 15.635 ± 0.006 h. Three nights and 235 images were sufficient to calculate a synodic period of 10.426 ± 0.007 h, in agreement with Polakis and Franco. The amplitude is 0.27 ± 0.019 mag.



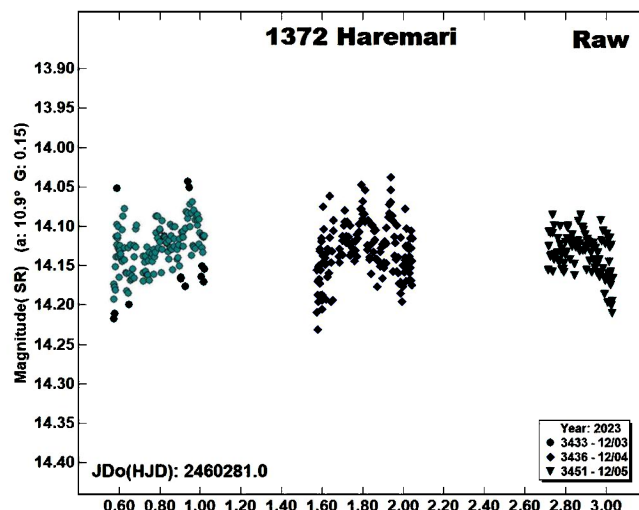
1112 Polonia. Pelageya Shajn discovered this asteroid in 1928 at Simeis. The period computed by Behrend (2018web) is 18.605 ± 0.002 h, while Polakis (2020) shows 18.71 ± 0.04 h. A total of 236 data points were acquired on three nights, resulting in a rotation period of 18.50 ± 0.08 h, agreeing with Behrend and Polakis. The amplitude of the lightcurve is 0.11 mag, with an RMS error of 0.011 mag.



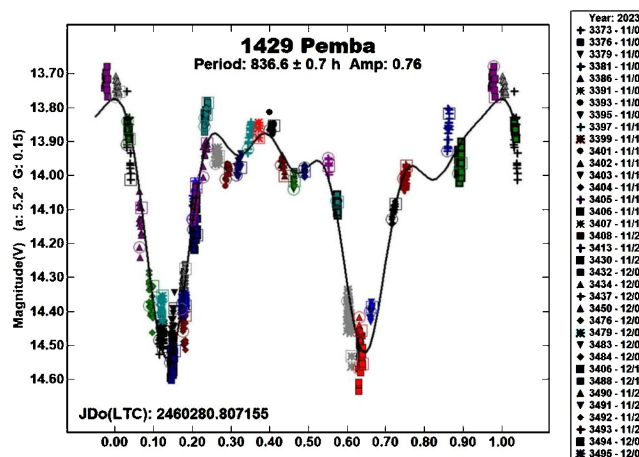
1332 Marconia was discovered in 1934 at Pino Torinese by Allesandro Volta. Durech et al. (2016) published a period solution of 19.2264 ± 0.0001 h, and Devoegele et al. (2017) calculated 32.1201 ± 0.0005 h. During four nights, 376 images were gathered, resulting in a period of 31.34 ± 0.12 h, in agreement with Devoegele. The amplitude is 0.22 mag., and the RMS error is 0.016 mag.



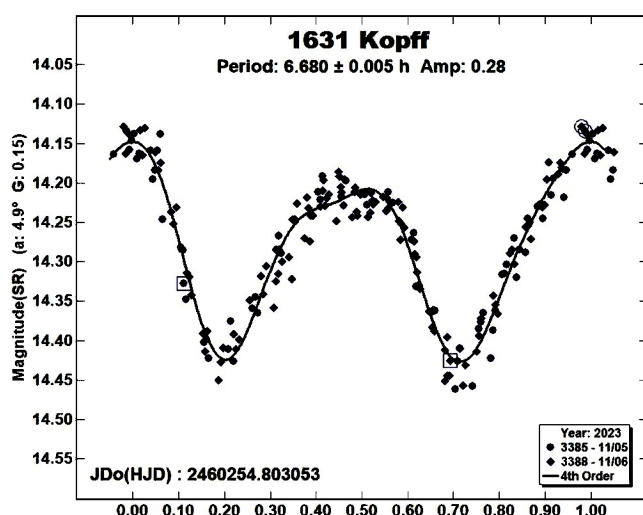
1372 Haremar is a member of the Watsonia asteroid family. Its discovery was made by Karl Reinmuth in 1935, at Heidelberg. Two similar periods appear in the LCDB; Durkee (2010), 15.25 ± 0.03 h, and Devoegele et al. (2017), 1524 ± 0.03 h. It was apparent after three nights and 401 images that the amplitude would be too small for a period solution to be obtained. The raw lightcurve is provided.



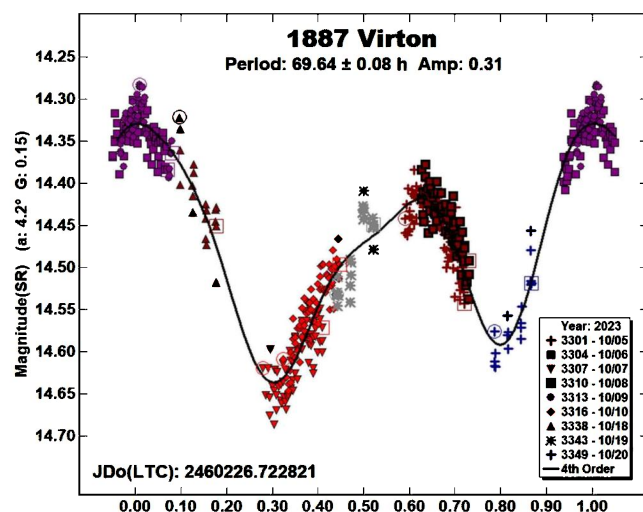
1429 Pemba is an inner main-belt minor planet in a highly eccentric orbit. Cyril Jackson discovered it at Johannesburg in 1937. The only period in the LCDB is Harris et al. (1999), >20 h. The asteroid showed only small changes in brightness, and only after several weeks did a period solution begin to emerge. After completing 38 nights of observing with only one lost to clouds, the period was determined as 836.6 ± 0.7 h, with an amplitude of 0.76 ± 0.056 mag.



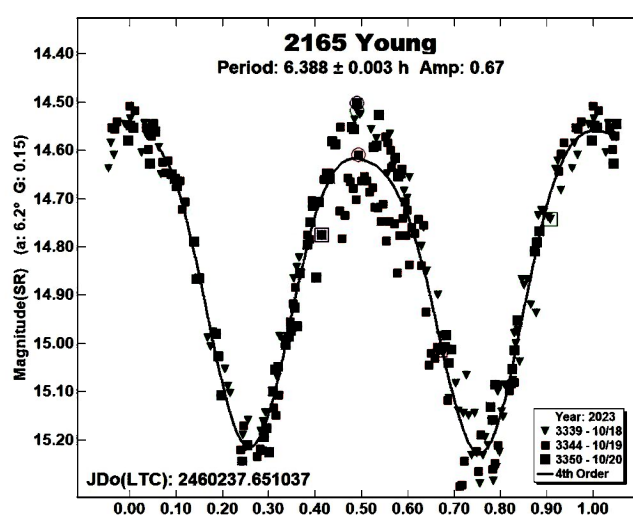
1631 Kopff, Yrjö Väisälä discovered this asteroid in 1936 at Turku, and named it after August Kopff, himself a discoverer of 68 minor planets. Sada et al. (2004) published a period of 6.683 ± 0.001 h, and Durech et al. (2020) calculated 6.68106 ± 0.00005 h. After acquiring 192 images in two nights, a synodic period of 6.680 ± 0.005 h was computed. The amplitude of the lightcurve is 0.28 ± 0.021 mag.



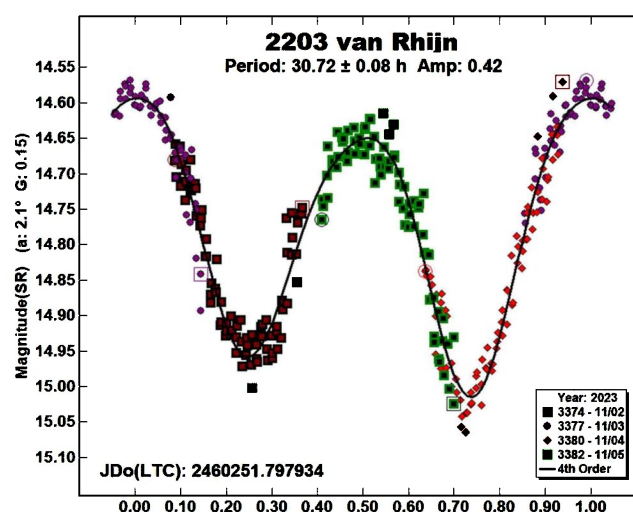
1887 Virton. This Eos-family minor planet was discovered at Uccle by Sylvain Arend in 1950. No period solutions appear in the LCDB. Over the course of nine nights, 455 images were taken. The synodic period is 69.64 ± 0.08 h, with an amplitude of 0.31 ± 0.023 mag.



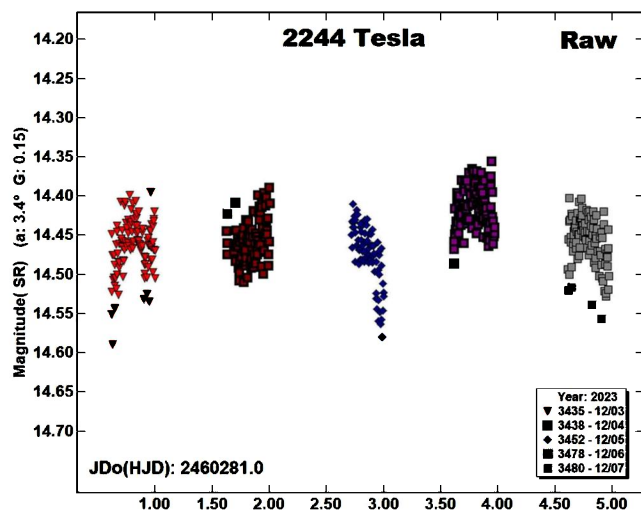
2165 Young was discovered in 1956 at Goethe Link Observatory, near Brooklyn, Indiana USA. Durech et al. (2020) shows a period of 6.39014 ± 0.00002 h, and Erasmus et al. (2020) published a value of 6.389 ± 0.003 h. A total of 247 data points acquired during three nights were used to compute a synodic period of 6.388 ± 0.003 h, in agreement with published values. The amplitude is 0.67 ± 0.055 mag.



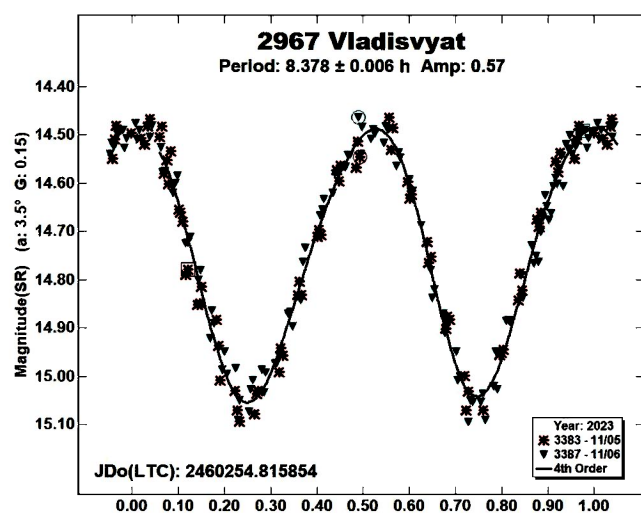
2203 van Rhijn. This member of the Themis family was discovered by Hendrik van Gent at Johannesburg in 1935. The two most recent periods in the LCDB are Durech et al. (2020), 30.6088 ± 0.0008 h, and Erasmus et al. (2020), 30.590 ± 0.067 h. In four nights, 315 data points were gathered, resulting in a period of 30.72 ± 0.08 h, and an amplitude of 0.42 ± 0.030 mag.



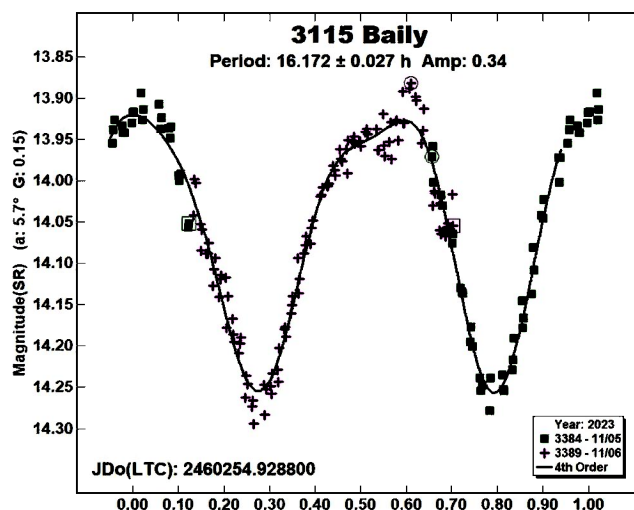
2244 Tesla was discovered at Belgrade in 1952 by Milorad Protitch. No periods appear in the LCDB. After five nights, 486 images were taken, but the amplitude is too small to discern a rotation period. The raw lightcurve is given.



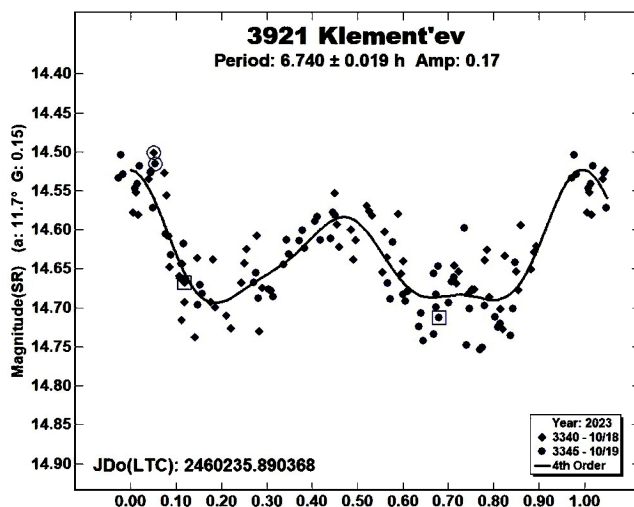
2967 Vladisvyat is a member of the Ursula family. Nikolai Chernykh discovered this minor planet at Nauchnyj in 1977. The LCDB contains no period solutions for it. Two nights and 192 images were sufficient to create a phased lightcurve, which shows a period of 8.378 ± 0.006 h, and an amplitude of 0.57 ± 0.029 mag.



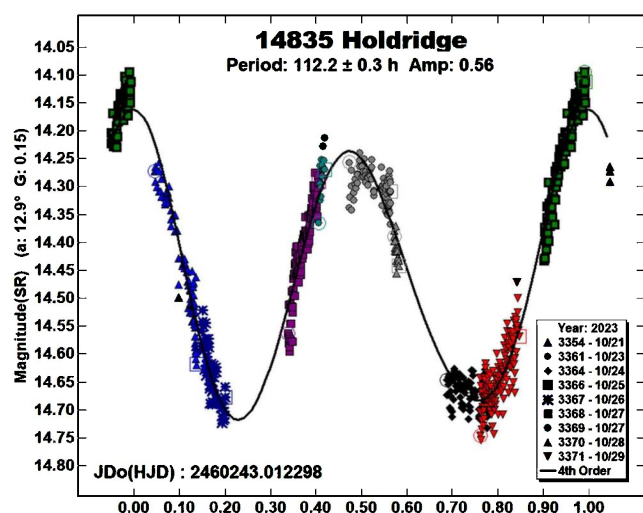
3115 Baily. Ted Bowell discovered this inner main-belt asteroid at Flagstaff in 1981. The two most recent, agreeing periods belong to Aznar et al. (2016), 16.012 ± 0.001 h, and Durech et al. (2020), 16.2414 ± 0.0005 h. During two nights, 172 images were taken, which produced a rotation period of 16.172 ± 0.027 h, and an amplitude of 0.34 ± 0.021 mag.



3921 Klement'ev is a member of the inner main-belt, discovered in 1971 by Bella Burnasheva at Nauchnyj. One rotation period appears in the LCDB, belonging to Behrend (2019web), who lists it as 6.754 ± 0.005 h. Two nights and 128 images were enough to determine a period of 6.740 ± 0.019 h, agreeing with Behrend's result. The amplitude is 0.17 mag, with an RMS error on the fit of 0.035 mag.



14835 Holdridge lies in a highly eccentric orbit, which brought it to a favorable opposition in 2023. It was discovered by Eugene and Carolyn Shoemaker in 1987. Pravec (2005web) gives a rotation period of >10 h. Eight nights of observing and 709 images produced a period of 112.2 ± 0.3 h, with an amplitude of 0.56 ± 0.033 mag. Some of the fit error could be accounted for by tumbling.



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