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PHOTOMETRIC OBSERVATIONS AND ROTATION PERIOD DETERMINATION FOR 14 MINOR PLANETS

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

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/4.7 Corrected Dall-Kirkham telescope. Images were captured using an 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 1.60 arc seconds per pixel. Table I shows observing circumstances and results. All images for these observations were obtained between 2023 September and 2023 November.

Data reduction and period analysis were done using *Tycho* (Parrott, 2023). The CCD camera provides a 27'×27' field of view. The asteroid and five or more comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B - V < 0.95$ to correspond with color ranges of asteroids.

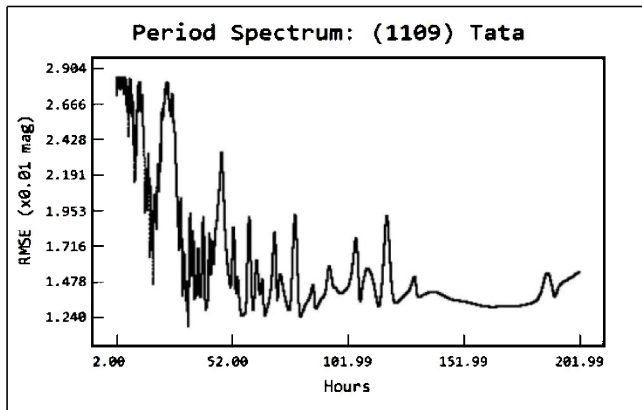
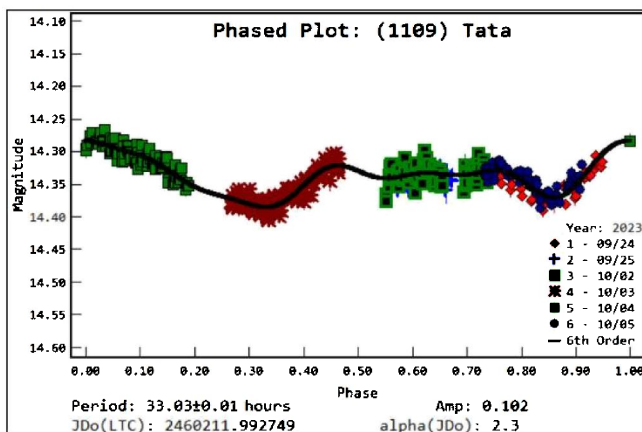
Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *Tycho*. The ATLAS catalog derives Sloan *griz* magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color indices allowed the separate nightly runs to be linked often with no zero-point offset required. The measuring aperture diameter for asteroids and comp stars was set to a value equal to the average FWHM of the session data set multiplied by four. Interference from field stars necessitated the exclusion of affected observations. Period determination was done using *Tycho*.

Asteroids were selected from the CALL website (Warner, 2011), either for having uncertain periods ($U \leq 2$) or no reported period at all. In this set of observations, six 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.

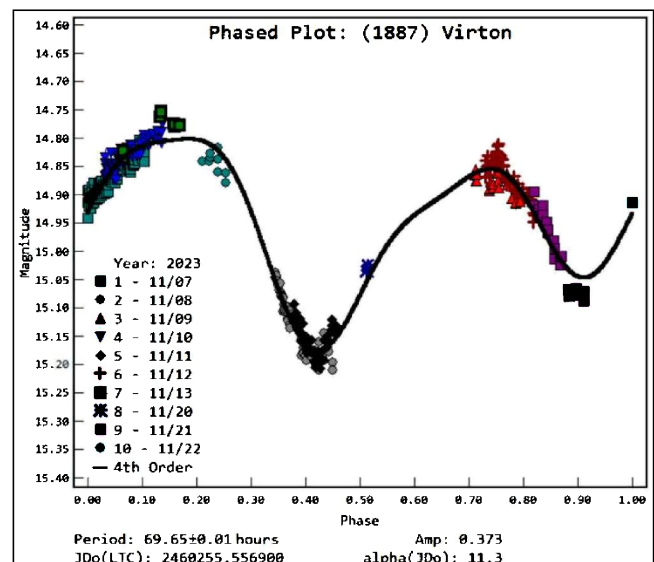
1109 Tata is a Hygiea family asteroid with two reported periods in the LCDB. Behrend (2005web) reported a period of 8.277 ± 0.002 h and Polakis (2020) reported a differing period of 55.50 ± 0.12 h. During this apparition 402 observations were made over six nights in 2023 September. The best period fit 33.03 ± 0.01 h with an amplitude of 0.102 ± 0.011 mag. This result disagrees with those of both Behrend and Polakis.

Number	Name	yy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1109	Tata	23/09/24-10/05	2.3, 5.5	357	+5.0	33.03	0.01	0.102	0.011	Hygie
1887	Virton	23/11/07-11/22	11.3, 15.9	19	7.3	69.65	0.01	0.373	0.018	Eos
2122	Pyatiletka	23/11/07-11/13	11.3, 8.8	66	-7.3	8.898	0.001	0.233	0.015	MB-I
2360	Volgo-Don	23/10/03-10/11	6.3, 2.1	20	-1.7	3.125	0.001	0.080	0.018	MB-M
2521	Heidi	23/09/15-10/05	*4.9, 5.8	0	+9.4	41.70	0.01	0.172	0.024	MB-I
2886	Tinkaping	23/11/02-11/12	6.0, 1.1	49	-1.7	108.0	0.1	0.919	0.018	MB-I
3476	Dongguan	23/11/12-10/31	8.7, 1.6	37	-4.5	7.019	0.001	0.287	0.017	MB-O
3803	Tuchkova	23/10/12-10/24	8.3, 11.2	0	14.3	6.065	0.001	0.151	0.021	MB-O
4177	Kohman	23/10/12-10/22	11.5, 14.9	359	9.9	10.831	0.001	0.069	0.022	MB-O
5147	Maruyama	23/09/15-10/20	*6.4, 9.4	5	+3.6	286.59	0.01	0.191	0.019	MB-M
9262	Bordovitsyna	23/11/08-11/23	9.4, 15.3	32	11.5	15.59	0.01	0.141	0.018	Maria
15127	2000 EN45	23/11/01-11/06	11.4, 13.5	22	12.5	12.85	0.01	0.283	0.013	MB-O
30598	2001 QA117	23/09/15-09/25	3.2, 7.3	347	+4.9	8.922	0.001	0.143	0.033	Eunom
30980	1995 QU3	23/09/27-10/11	22.1, 21.2	22	+33	8.659	0.001	0.210	0.054	MB-O

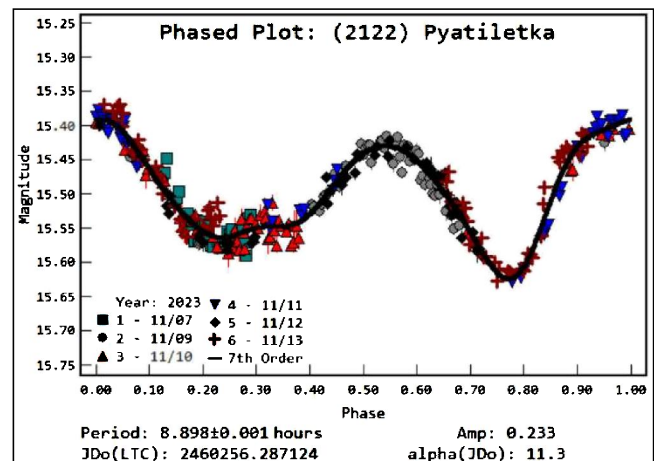
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. LPAB and BPAB are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).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



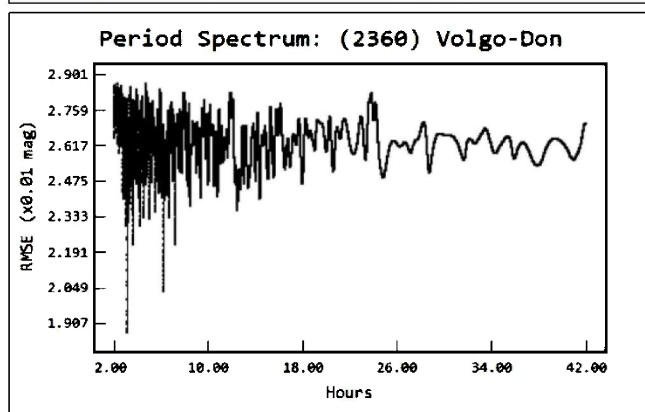
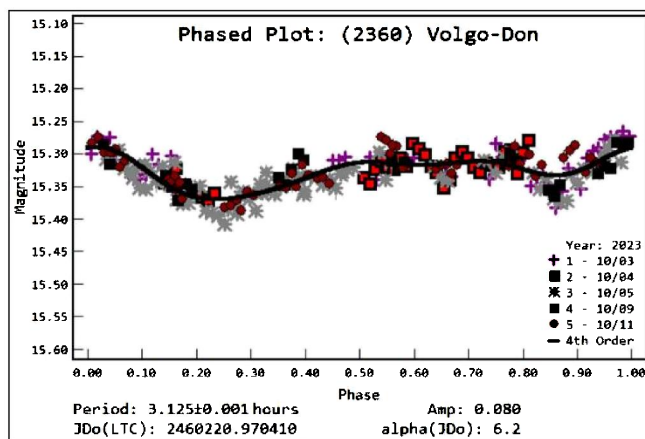
1887 *Virton* was discovered in 1950 by S. Arend at Uccles. No period solutions appear in the LCDB. A total of 464 data points obtained during ten nights were used to calculate a period solution of 69.65 ± 0.01 h. The amplitude of the lightcurve is 0.373 ± 0.018 mag.



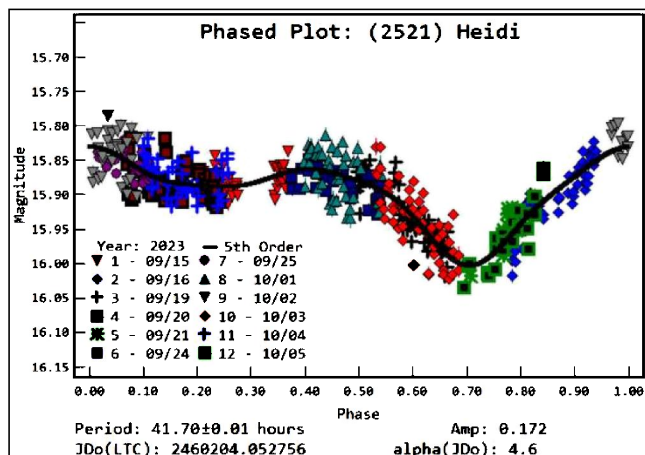
2122 *Pyatiletka* is an inner main-belt asteroid discovered at the Crimean Astrophysical Observatory in 1971 by T.M. Smirnova. Waszczak et al. (2015) reported a period of 8.899 ± 0.0053 h and Durech et al. (2020) reported a similar period of 8.90167 ± 0.00003 h. Observing over six nights during the 2023 November, 347 observations were made. A period solution of 8.898 ± 0.001 h was calculated with an amplitude of 0.233 ± 0.015 mag. This is also in close agreement with the results of Durech et al. and Waszczak et al.



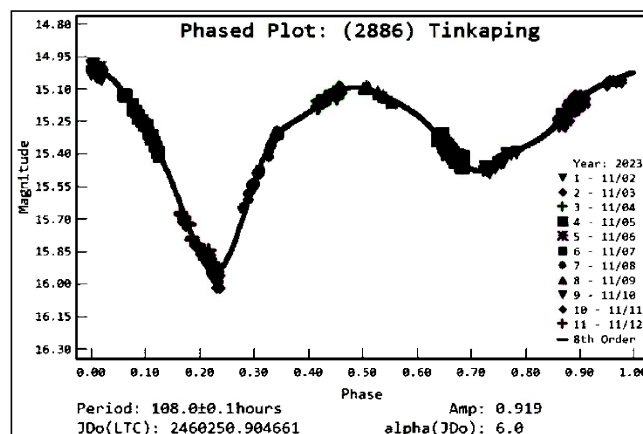
2360 Volgo-Don is a main belt asteroid discovered by T. Smirnova at Nauchnyj in 1975. No period solutions have been identified in the LCDB. Over 5 nights in 2023 October, 247 observations were obtained to calculate a rotational period of 3.125 ± 0.001 h. The amplitude of the light curve is 0.080 ± 0.018 mag.



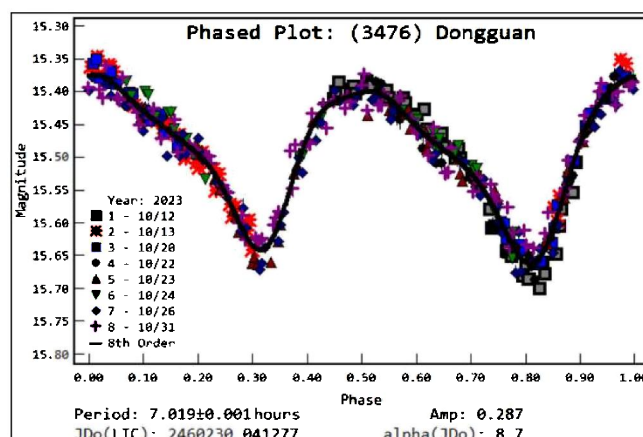
2521 Heidi was discovered in 1979 by Paul Wild at Zimmerwald. Behrend (2004web) reported a period solution of 12 hours but noted that it was a meaningless solution due to a low amplitude/uncertainty ratio. Durech et al. (2019) reported a period solution of 41.5665 ± 0.0002 h. During a 20-day period, 528 observations were made on 12 nights. A period solution of 41.70 ± 0.01 h was calculated from the observations. The amplitude of the light curve is 0.172 ± 0.024 mag.



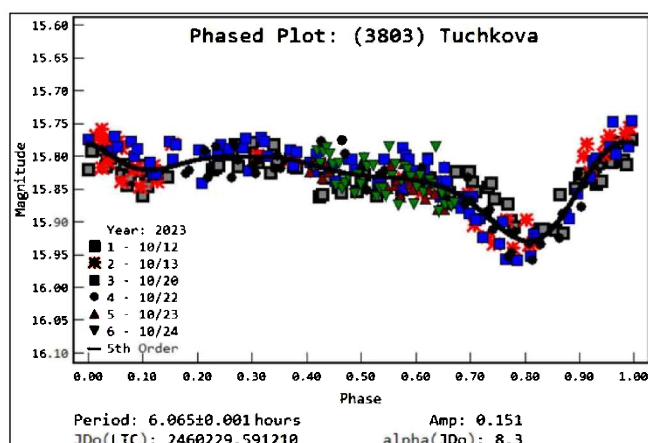
2886 Tinkaping is an inner main-belt asteroid discovered by Purple Mountain Observatory at Nanking in 1965. Wisniewski et al. (1997) published a period of 12 ± 6 h. Also found in the LCDB is a published period of 107.116 ± 0.007 h by Durech et al. (2020). Observations for the 2023 apparition were obtained on 11 consecutive nights providing 446 data points for a light curve. The period determined from those observations is 108.0 ± 0.1 h, in agreement with the period from Durech et al. The amplitude of the light curve is 0.919 ± 0.018 mag.



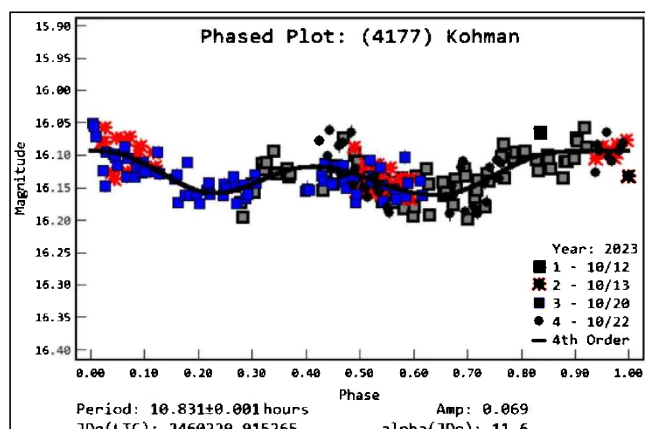
3476 Dongguan is an outer main-belt asteroid discovered in 1978 by Purple Mountain Observatory at Nanking. No periods are shown in the LCDB. During eight nights in 2023 October, 421 images were gathered, producing a period solution of 7.019 ± 0.001 h. The amplitude is 0.287 mag., and the RMS error on the fit is 0.017 mag.



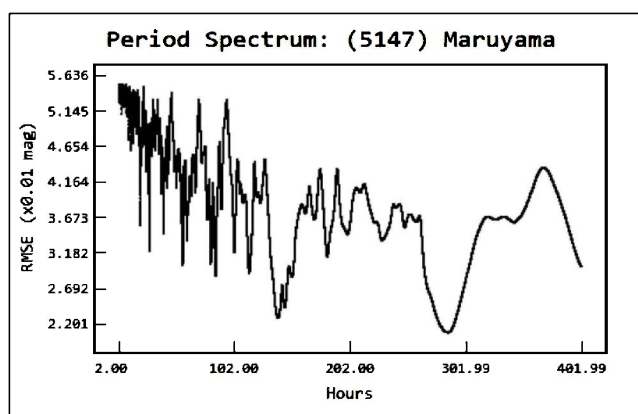
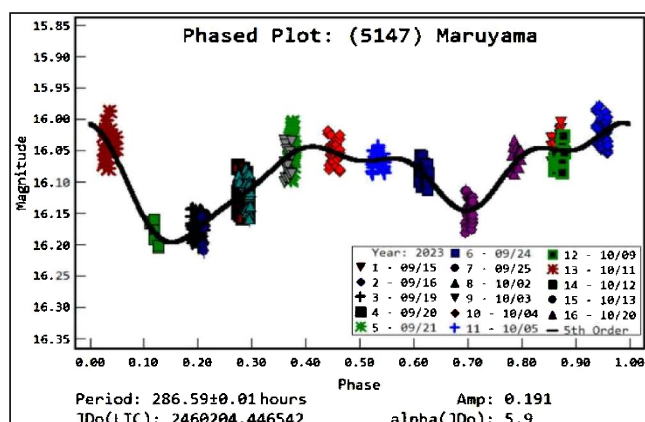
3803 Tuchkova is an outer main-belt asteroid discovered at Nauchnyj by L. Zhuravleva in 1981. Durech et al (2020) reported a period of 6.07014 ± 0.00003 h for this body. The author conducted a campaign of 320 observations in 2023 October and calculated a rotation period of 6.065 ± 0.001 h. This is in agreement with Durech et al.'s observations from 2020. The amplitude of the light curve is 0.151 mag and the RMS error on the fit is 0.021 mag.



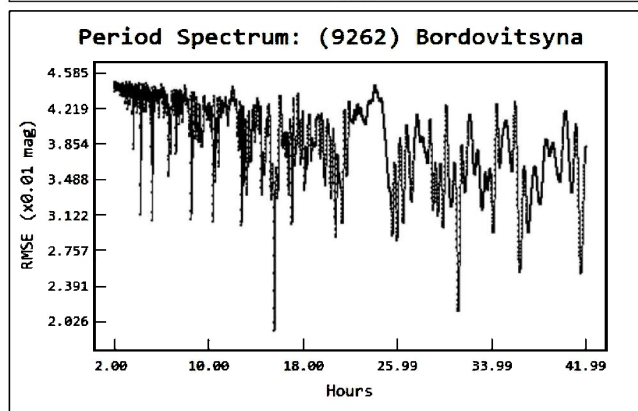
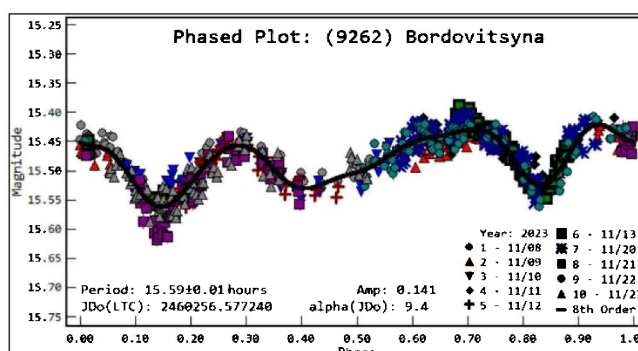
4177 *Kohman* was discovered at Lowell Observatory's Anderson Mesa Station near Flagstaff by E. Bowell in 1987. There are no reported solutions for the period in the LCDB. A total of 234 data points obtained during four nights were used to calculate a period solution of 10.831 ± 0.001 h. The amplitude of the lightcurve is 0.069 ± 0.022 mag.



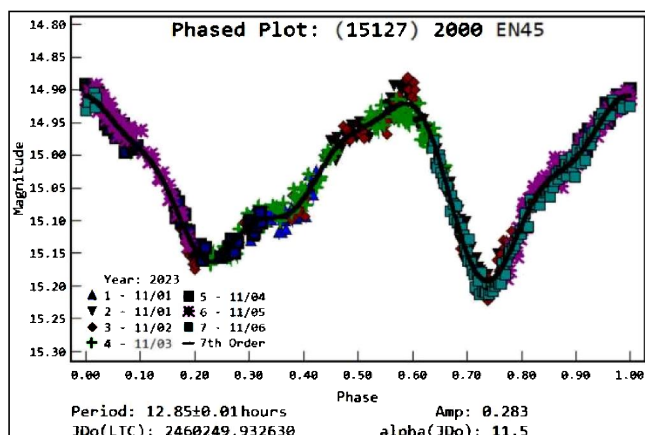
5147 *Maruyama* is a main-belt asteroid with an estimated diameter of 7.655 km. It was discovered in 1992 by S. Ueda and H. Kaneda at Kushiro. Hayes-Gehrke et al. (2023) reported a period solution of 50.9 ± 0.1 h, but noted in their observations that the period should be considered provisional and that more data was needed. This author collected 439 images observing on 16 nights of a 35-day interval during the 2023 apparition. Observations were used to calculate a rotational period of 286.59 ± 0.01 h disagreeing with the period reported by Hayes-Gehrke et al. The amplitude of the light curve is 0.191 ± 0.019 mag.



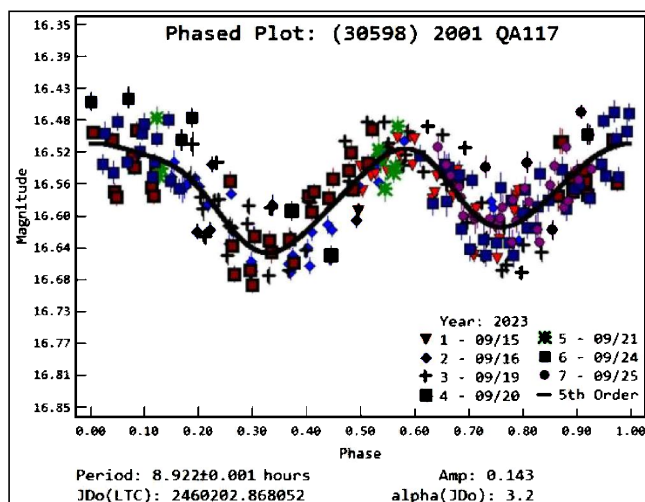
9262 *Bordovitsyna* was discovered in 1973 by T.M. Smirnova at Crimean Astrophysical Observatory. Sárneczky et al. (1999) reported an estimated period of 9 hours based on a data set consisting of less than a full period. During 2023 November the asteroid was observed on ten nights in a fifteen-night interval. A total of 669 images were taken and reduced to calculate a period solution of 15.59 ± 0.01 h with an amplitude of 0.141 ± 0.018 mag. The calculated period is in disagreement with the Sárneczky et al. period.



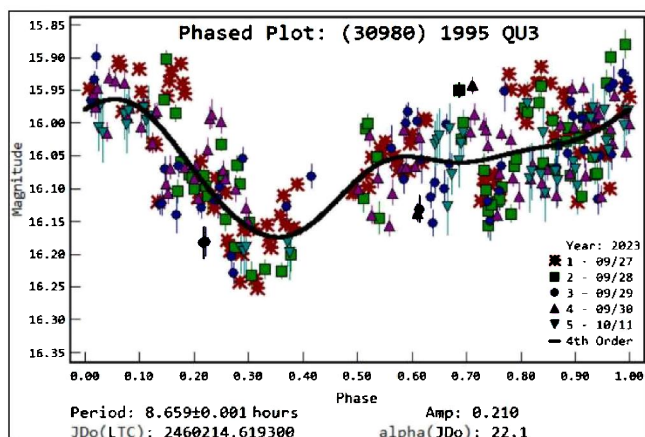
15127 2000 *EN45* was discovered in 2000 by LINEAR at Socorro. It has a 20-degree inclined orbit, and was passing through the plane of the ecliptic near its closest approach to Earth (1.2 AU) during the 2023 apparition. This presented a favorable observing opportunity compared to future upcoming apparitions. 688 images were captured on six consecutive nights to establish a rotation period, as no published periods are listed in the LCDB. Those observations produced a light curve indicating a period of 12.85 ± 0.01 h with an amplitude of 0.283 ± 0.013 mag.



30598 2001 QA117 was reported to have a period of 8.709 ± 0.0031 h by Wasczak et al. (2015). In 2023 September the author observed the asteroid on 7 nights of a 10 night period, capturing 256 images in the process. A rotational period of 8.922 ± 0.001 h with an amplitude of 0.143 ± 0.033 mag was calculated from the observations. Though the notes on the Wasczak et al. observations mentioned a low confidence in the period, the author's results are in agreement.



30980 1995 QU3 is an outer main belt asteroid with an orbit inclined 24° to the plane of the ecliptic. There are no reported periods for this asteroid in the LCDB. 324 data points were obtained during five nights to calculate a period solution of 8.659 ± 0.001 h. The fit is poor with an RMS error of 0.054 mag.



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