

**PHOTOMETRY OF 24 ASTEROIDS FROM SOPOT
ASTRONOMICAL OBSERVATORY:
2024 MARCH - OCTOBER**

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Lightcurves and synodic rotation periods for 24 asteroids are derived from photometric data obtained at Sopot Astronomical Observatory during 2024 March - October.

Photometric observations of 24 asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2024 March through October 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 ($0.5 \leq B-V \leq 0.9$) 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, 2024) 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 rotation period by minimizing the *residual standard error* of the lightcurve Fourier fit.

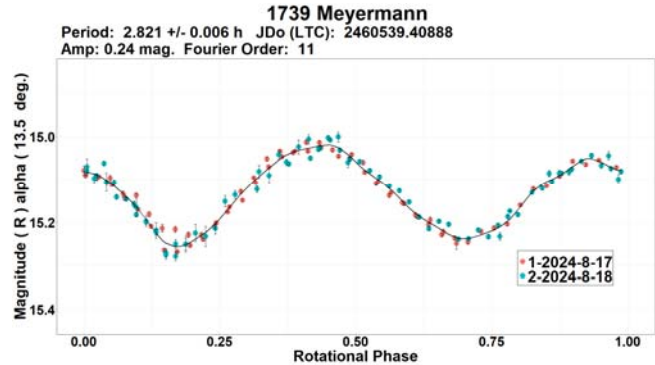
The lightcurve plots presented in this paper show so-called 2% error for rotation periods, i.e. an error that would cause the last data point in a combined data set by date order to be shifted by 2% (Warner, 2012) and represented by the following formula:

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

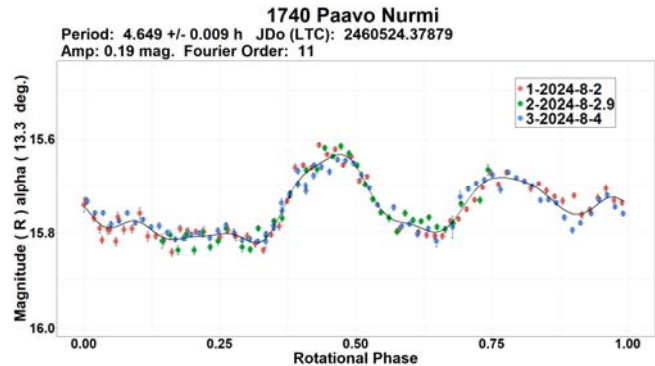
where *P* and *T* are the rotation period and the total time span of observations, respectively. Both of these quantities must be expressed in the same units. Table I gives the observing circumstances and results.

Observations and results

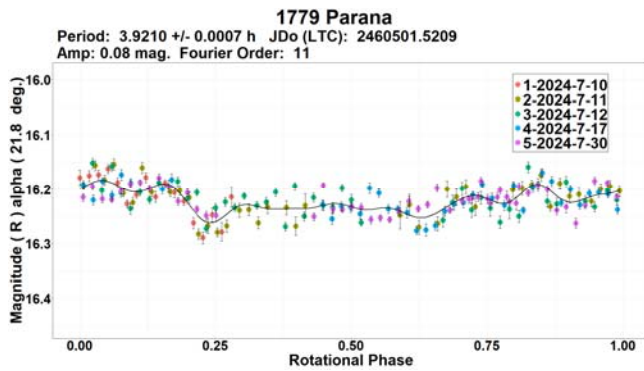
1739 Meyermann. A bimodal solution for a rotational period of $P = 2.821 \pm 0.006$ h, obtained from observations performed on two consecutive nights in 2024 August, statistically matches virtually all previously found period results present in the Asteroid Lightcurve Database (LCDB; Warner et al., 2009). Some of those previous period results are as follows: 2.8219 h (Pravec, 2007web), 2.82146 h (Behrend, 2020web), 2.821 h (Pravec, 2021web).



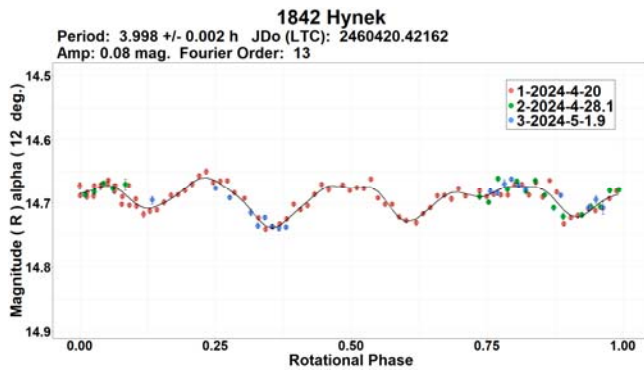
1740 Paavo Nurmi. According to the LCDB records, there were no rotation period determinations for this asteroid previously. Photometric observations carried out over three consecutive nights in early 2024 August show a period of $P = 4.649 \pm 0.009$ h.



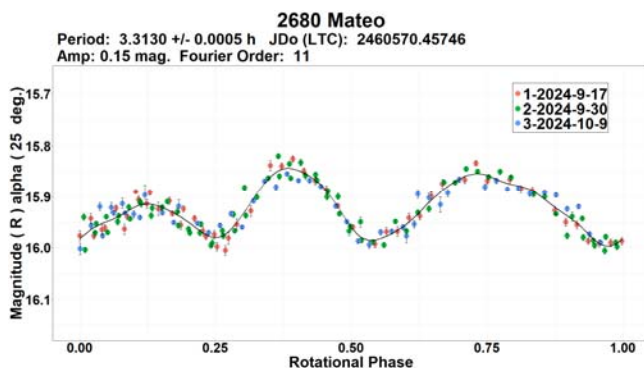
1779 Parana. No records on previous rotation period results for this asteroid were found. A period of $P = 3.9210 \pm 0.0007$ h associated with a low-amplitude lightcurve ($A = 0.08$ mag.) and obtained from the five-night 2024 July dataset, emerges as a statistically most favorable solution in the period analysis. More thorough observations of this asteroid in future apparitions would be expressly desired for the sake of verification of this currently only rotation period result.



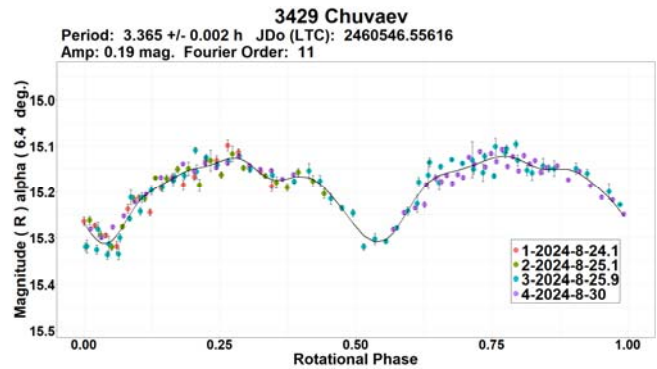
1842 Hynek. Period of $P = 3.998 \pm 0.002$ h obtained from the SAO observations conducted over three nights in 2024 April-May, although sufficiently close to the most of the previous results in the LCDB ranged between 3.94 h and 3.943 h still shows some deviation from them, which is most likely a consequence of the shortness of two of the three individual datasets, as well as partially fragmentary data and the lack of repeated data coverage of the entire rotational cycle due to bad weather conditions and the inability to focus exclusively on this target.



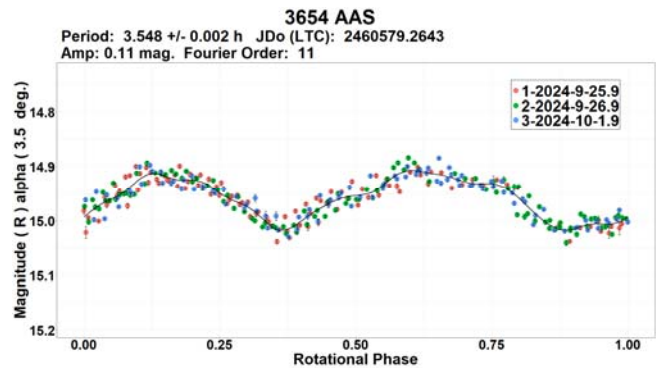
2680 Mateo. Another asteroid with no known rotation period. Period analysis of dense photometric data obtained on three nights in 2024 September-October strongly suggests as the most likely solution a trimodal lightcurve with a period of $P = 3.3130 \pm 0.0005$ h.



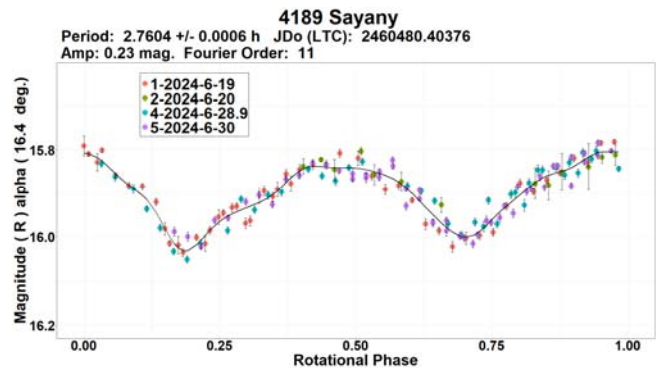
3429 Chuvaev. A bimodal solution for a period of $P = 3.365 \pm 0.002$ h matches exactly the only previously found period result of 3.365 h by Waszczak et al. (2015).



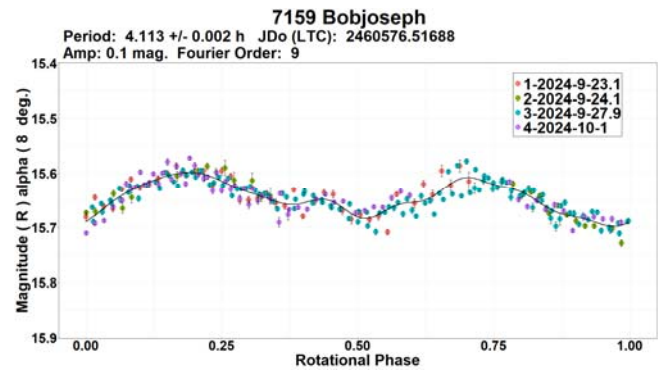
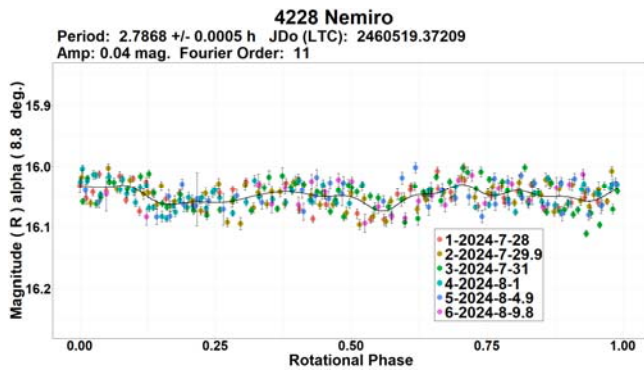
3654 AAS. According to the LCDB records this is the first rotation period determination for this asteroid. Period analysis conducted upon the data acquired on three nights in 2024 September-October yielded a bimodal period solution of $P = 3.548 \pm 0.002$ h.



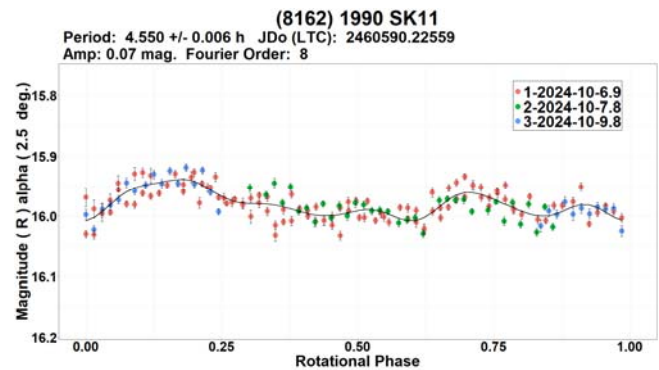
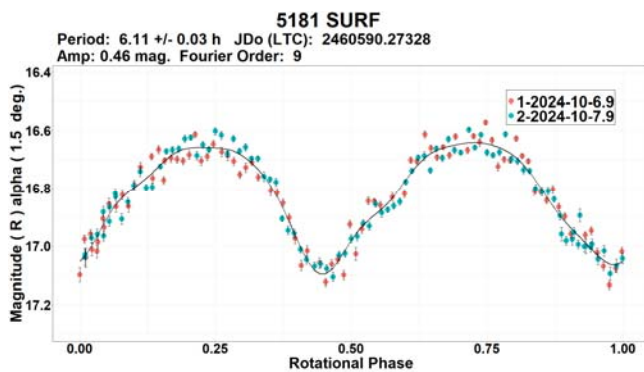
4189 Sayany. Pal et al. (2020) found the only previous rotation period result of 2.76132 h, which matches the value of $P = 2.7604 \pm 0.0006$ found from the 2024 June data.



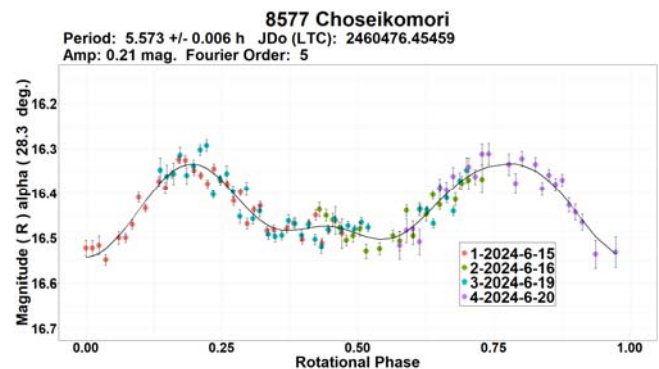
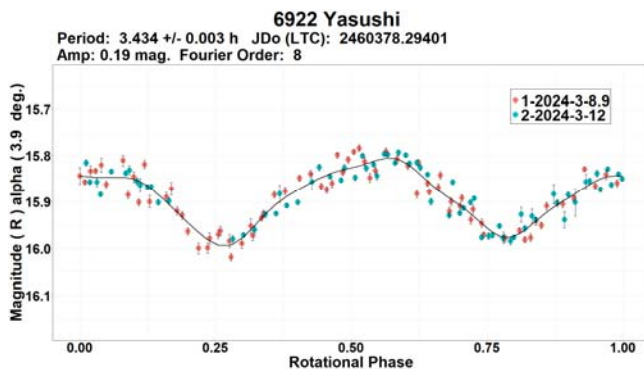
4228 Nemiro. Data obtained over six nights in 2024 July-August revealed a very low amplitude lightcurve ($A = 0.04$ mag.) and a period of $P = 2.7868 \pm 0.0005$ h. The result found is largely consistent with the only previous period result of 2.772 ± 0.003 h by Pravec (2007web).



5181 SURF. Observations from two consecutive nights in early 2024 October show a bimodal solution and a period of $P = 6.11 \pm 0.03$ h, which is highly consistent with two previously found rotation periods of 6.111 h (Hayes-Gehrke et al., 2015) and 6.1097 h (Pravec, 2015web).

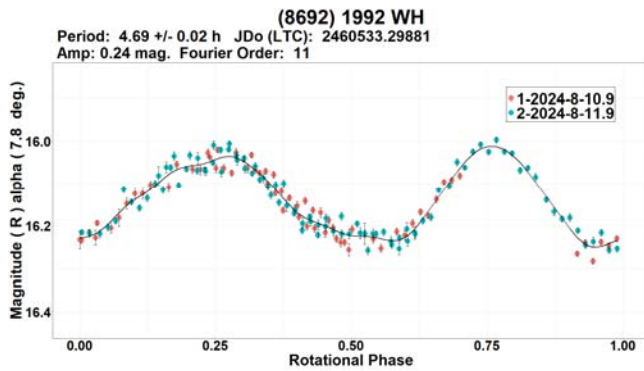


6922 Yasushi. Erasmus et al. (2020) found a rotation period of 3.434 h, identical to that derived from the SAO observations from two nights in the first half of 2024 March: $P = 3.434 \pm 0.003$ h.

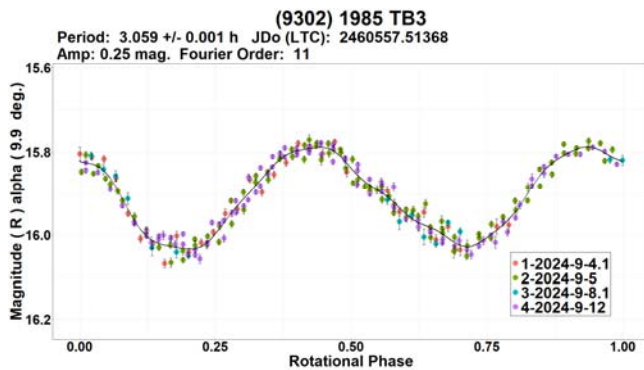


7159 Bobjoseph. Prior to this rotation period determination, there were no period results reported. Dense photometric data acquired in 2024 September-October indicate a bimodal period solution of $P = 4.113 \pm 0.002$ h.

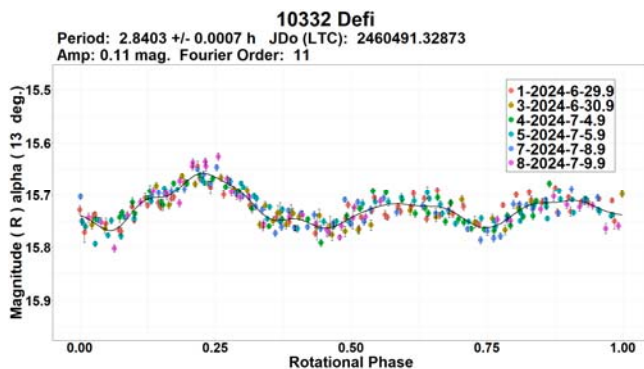
(8692) 1992 WH. A bimodal period value ($P = 4.69 \pm 0.02$ h) found using the 2024 August SAO data collected on two consecutive nights is in good agreement with two previous results by Waszczak et al. (2015, 4.698 h) and by Pal et al. (2020, 4.68562 h).



(9302) 1985 TB3. A bimodal rotation period of $P = 3.059 \pm 0.001$ h derived from a dense photometric dataset taken in 2024 September is identical to the only previously reported result by Waszczak et al. (2015, 3.059 h).

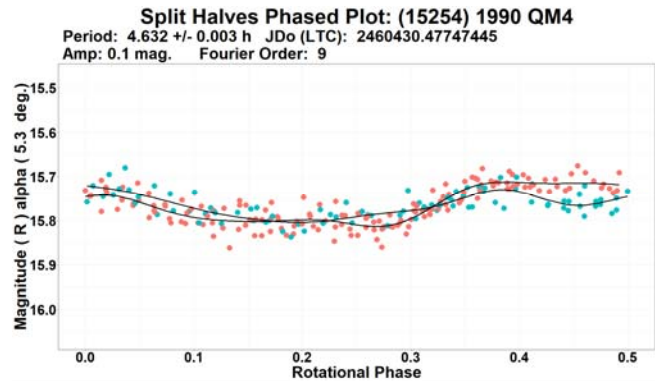
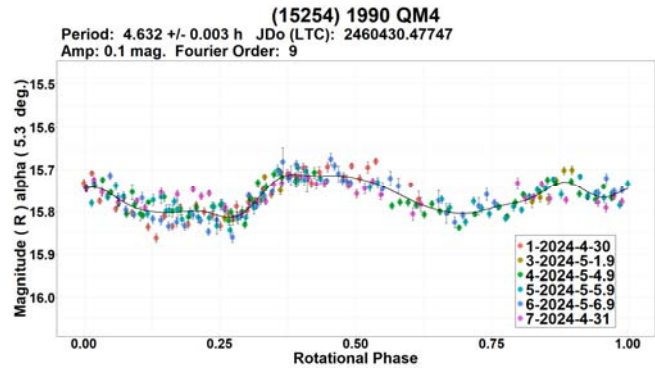


10332 Defi. Dense photometry performed over six nights in 2024 late June - early July unambiguously indicates a period of $P = 2.8403 \pm 0.0007$ h as the most favorable solution. The only previously reported solution derived from sparse photometry by Pal et al. (2020, 20.5142 h) shows a significant discrepancy with the newly established value.

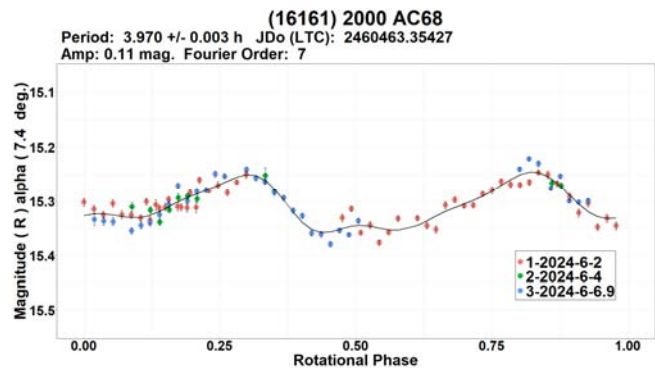


(15254) 1990 QM4. Waszczak et al. (2015) found a period of 2.318 h. A bimodal period of $P = 4.632 \pm 0.003$ h was derived as a solution from the SAO observations in 2024 April-May, which is exactly twice the value found by Waszczak et al. The lightcurve corresponding to a longer period is characterized by two distinctive maxima, different in shape and intensity, and the splitting of the lightcurve into two equal halves indicates their apparent mismatch.

The maximum difference in the intensity of the two halves of the lightcurve reaches ~ 0.05 mag., which is not negligible and cannot be the result of noise, which is certainly well below this level. These facts are in favor of a longer period of 4.632 h over the previously derived half-shorter period of 2.318 h. Certainly, it would be very desirable to continue observing this asteroid in the future apparitions in order to definitively resolve period ambiguity.



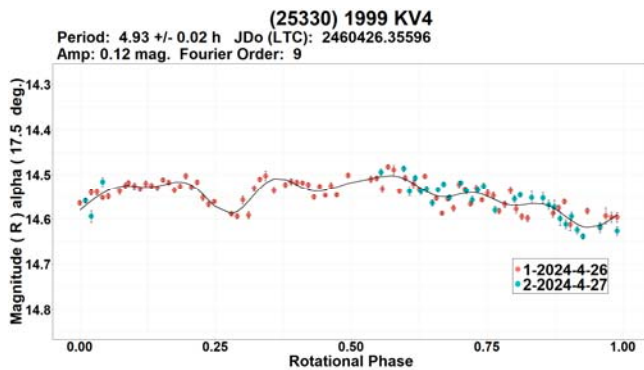
(16161) 2000 AC68. No previous rotation period determinations were found in the LCDB. Photometric data from 2024 June show a bimodal period solution of $P = 3.970 \pm 0.003$ h.



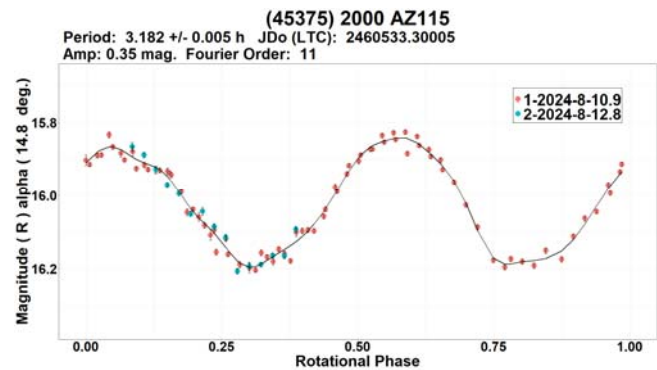
(25330) 1999 KV4. Although the 2024 April 2024 SAO data obtained over two consecutive nights did not cover a large portion of the rotation cycle twice, the result for the period ($P = 4.93 \pm 0.02$ h) derived from such a combined dataset shows very good agreement with the only previously found rotation period by Pravec (2002web, 4.919 h).

Number	Name	20yy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1739	Meyermann	24/08/16–24/08/18	13.5, 12.9	346	3	2.821	0.006	0.24	0.03	MB-I
1740	Paavo Nurmi	24/08/01–24/08/04	13.3, 12.3	332	1	4.649	0.009	0.19	0.02	MB-I
1779	Parana	24/07/10–24/07/30	21.8, 11.6	322	1	3.9210	0.0007	0.08	0.03	MB-I
1842	Hynek	24/04/19–24/05/01	12.0, 6.7	227	8	3.998	0.002	0.08	0.01	MB-I
2680	Mateo	24/09/16–24/10/09	25.0, 16.2	41	2	3.3130	0.0005	0.15	0.02	HER
3429	Chuvaev	24/08/24–24/08/30	6.4, 2.7	340	1	3.365	0.002	0.19	0.03	MB-I
3654	AAS	24/09/25–24/10/02	*3.5, 1.0	8	1	3.548	0.002	0.11	0.02	MB-I
4189	Sayany	24/06/18–24/06/30	16.4, 11.4	294	8	2.7604	0.0006	0.23	0.03	V
4228	Nemiro	24/07/27–24/08/09	*8.8, 5.4	316	8	2.7868	0.0005	0.04	0.03	MB-I
5181	SURF	24/10/06–24/10/08	1.5, 1.7	13	–3	6.11	0.03	0.46	0.03	HER
6922	Yasushi	24/03/08–24/03/12	3.9, 2.9	173	4	3.434	0.003	0.19	0.03	FLOR
7159	Bobjoseph	24/09/23–24/10/01	8, 3.2	11	3	4.113	0.002	0.10	0.02	MB-I
8162	1990 SK11	24/10/06–24/10/09	2.5, 3.6	12	4	4.550	0.006	0.07	0.02	MB-I
8577	Choseikomori	24/06/14–24/06/20	28.3, 27.2	312	9	5.573	0.006	0.21	0.04	MB-I
8692	1992 WH	24/08/10–24/08/12	7.8, 7.2	328	8	4.69	0.02	0.24	0.03	V
9302	1985 TB3	24/09/04–24/09/12	9.9, 4.9	356	0	3.059	0.001	0.25	0.02	MB-I
10332	Defi	24/06/09–24/07/10	*13.0, 12.4	285	21	2.8403	0.0007	0.11	0.02	MB-I
15254	1990 QM4	24/04/29–24/05/07	*5.3, 5.9	222	8	4.632	0.003	0.10	0.03	MB-I
16161	2000 AC68	24/06/01–24/06/06	*7.4, 7.6	252	11	3.970	0.003	0.11	0.02	MB-I
25330	1999 KV4	24/04/25–24/04/27	17.5, 16.6	213	12	4.93	0.02	0.12	0.03	NEA
45375	2000 AZ115	24/08/10–24/08/12	14.8, 14.3	330	15	3.182	0.005	0.35	0.03	MB-I
66251	1999 GJ2	24/08/20–24/08/24	34.3, 32.7	343	22	2.461	0.002	0.11	0.02	NEA
67976	2000 XA7	24/07/26–24/08/07	11.9, 8.7	319	12	6.306	0.003	0.18	0.03	MB-I
70410	1999 SE3	24/06/28–24/07/16	28.9, 26.3	317	30	2.5890	0.0004	0.14	0.03	PHO

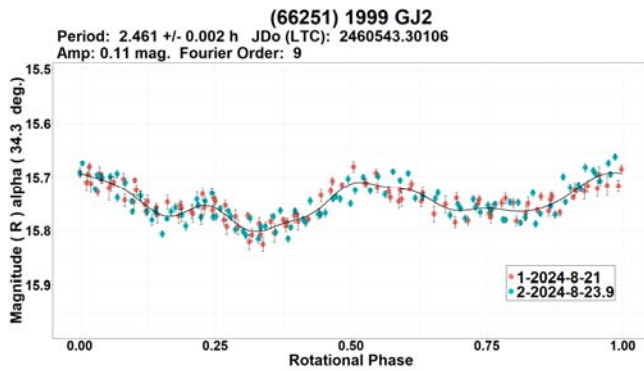
Table I. Observing circumstances and results. Phase is the solar phase angle given at the start and end of the date range. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude at the mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009): MB-I = main-belt inner, NEA = near-Earth asteroid, V = Vestoid, PHO = Phocaea, HER = Hertha, FLOR = Flora.



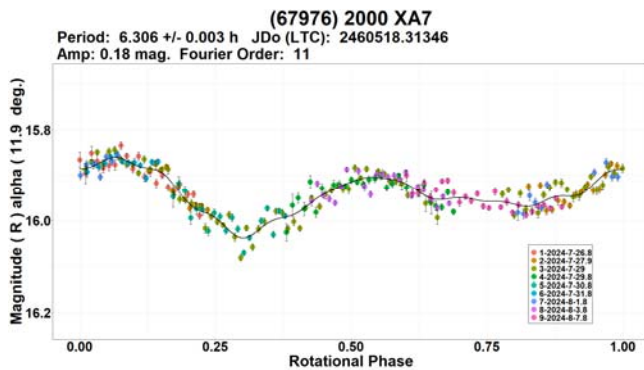
(45375) 2000 AZ115. Another main-belt asteroid with no previously known rotation period. Dense photometry from two nights in 2024 August points to a bimodal period solution of $P = 3.182 \pm 0.005$ h and a fairly large lightcurve amplitude of 0.35 mag., at a relatively low solar phase angles. Nevertheless, despite the dense photometric data, it should be noted that a large part of the rotation cycle for the obtained period is covered by observations only once, so this period result should be treated with a certain degree of caution. Refinement of the period result obtained in the 2024 apparition would be highly desirable in the future.



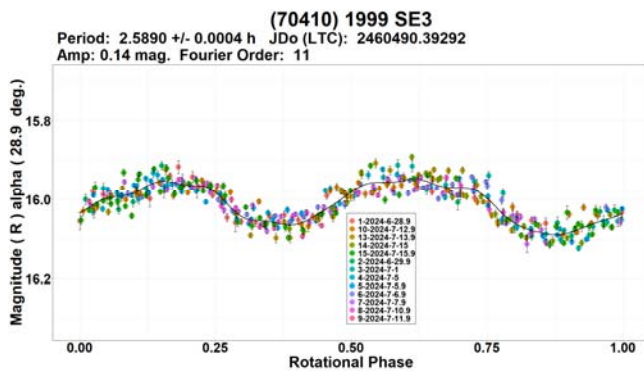
(66251) 1999 GJ2. Previously established rotation period results by Pravec (2005web, 2.4621 h; 2022web, 2.4614 h and 2.4629 h) for this near-Earth asteroid are in good agreement with the period value ($P = 2.461 \pm 0.002$ h) found from dense photometric data collected at SAO during two nights in late 2024 August. The 2024 result is somewhat different from the value found by Warner and Stephens (2022, 2.573 h) from the observations done in 2022 June.



(67976) 2000 XA7. The only previous rotation period is from Pal et al. (2020, 26.4765 h), derived from sparse photometric data. Dense photometric observations at SAO in 2024 July - August indicate the complete incorrectness of the previous result, yielding an unequivocal bimodal period solution of $P = 6.306 \pm 0.003$ h.



(70410) 1999 SE3. The newly established value for the rotation period ($P = 2.5890 \pm 0.0004$ h) from dense photometric data accumulated over as many as 15 nights in 2024 June-July confirms the earlier results by Stephens (2014, 2.5895 h) and by Waszczak et al. (2015, 2.590 h).



Acknowledgements

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