PHOTOMETRY OF 12 ASTEROIDS FROM SOPOT ASTRONOMICAL OBSERVATORY: 2020 OCTOBER- DECEMBER

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA
vlaben@yahoo.com

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A brief overview of the lightcurve and synodic rotation period determination for 12 asteroids from CCD photometric observations conducted at Sopot Astronomical Observatory (SAO) in the time span 2020 October - December is presented in this paper.

Photometric observations of 12 asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2020 October through 2020 December 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, 2020) 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.

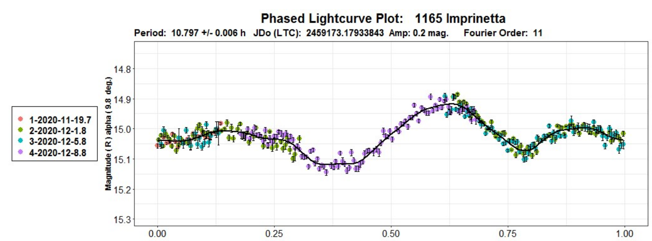
The lightcurve plots presented here show so-called 2% error for rotational periods, i.e., an error that would cause the last data point in a combined data set by date order to be shifted by 2% (Warner, 2012) and which is represented by the following formula: $\Delta P = (0.02 * P^2) / T$, where P and T are the rotational period and the total time span of observations, respectively. Both of these quantities must be expressed in the same units.

Some of the targets presented in this paper were observed within the Photometric Survey for Asynchronous Binary Asteroids (*BinAstPhot Survey*) under the leadership of Dr Petr Pravec from Ondřejov Observatory, Czech Republic.

Table I gives the observing circumstances and summarizes results.

Observations and Results

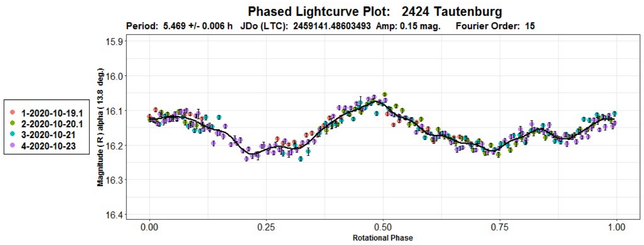
1165 Imprinetta. In reviewing previous findings, multiple rotation period determinations were reported and all yielded inconsistent results: 7.9374 h (Monson and Kipp, 2004), 8.107 h (Menke, 2005), 3.66 h (Behrend, 2018web) and a sidereal period of 10.8087 h found by Ďurech and Hanuš (2018). In an attempt to contribute to resolving this rotation period confusion, photometric observations were carried out at SAO in 2020 November-December over only 4 nights due to bad weather conditions. Nevertheless, the data collected were sufficient to unambiguously establish a value for period of P = 10.797 ± 0.006 h, which is closest to the result found by Ďurech and Hanuš.



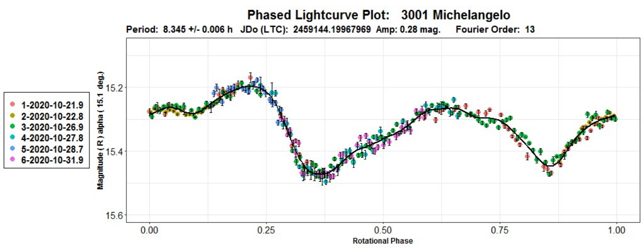
Number	Name	2020/mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1165	Imprinetta	11/19-12/08	9.8,14.7	31	-4	10.797	0.006	0.20	0.02	MB-O
2424	Tautenburg	10/18-10/23	13.8,12.0	51	3	5.469	0.006	0.15	0.02	MB-I
3001	Michelangelo	10/21-10/31	15.1,17.5	13	24	8.345	0.006	0.28	0.03	MB-I
3048	Guangzhou	10/25-10/28	13.8,12.8	58	-1	3.811	0.006	0.18	0.03	MB-I
3133	Sendai	11/30-12/02	23.2,22.8	109	8	5.75	0.03	0.75	0.02	FLOR
5111	Jacliff	11/22-12/17	*12.1,1.5	85	-2	2.8400	0.0003	0.24	0.01	V
6701	Warhol	11/25-12/10	*7.7,9.2	67	15	3.5230	0.0007	0.23	0.01	EUN
17312	7622 P-L	10/11-10/18	14.5,10.3	39	-2	2.5790	0.0009	0.11	0.03	FLOR
18418	Ujibe	10/16-10/27	12.1,4.8	40	-2	3.470	0.001	0.28	0.02	MB-I
21242	1995 WZ41	10/18-10/21	22.2,20.9	53	9	5.45	0.02	0.55	0.01	PHO
24038	1999 SL8	11/06-11/08	8.1,7.3	55	2	2.877	0.006	0.10	0.03	MB-I
137311	1999 TX9	10/27-11/09	18.4,10.2	58	1	9.926	0.007	0.17	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. Grp is the asteroid family/group (Warner *et al.*, 2009): EUN = Eunomia, FLOR = Flora, MB-I/O = main-belt inner/outer, PHO = Phocaea, V = Vestoid.

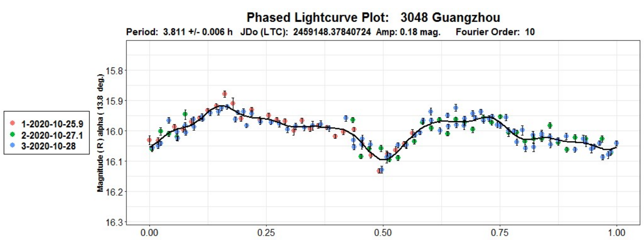
2424 Tautenburg. Interestingly, despite being a relatively low numbered asteroid its rotation period has not yet been established. The 2020 October SAO data led to an unequivocal synodic rotation period result of $P = 5.469 \pm 0.006$ h.



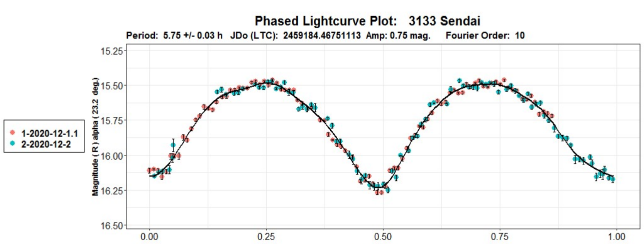
3001 Michelangelo. Previous consistent rotation period results were found by Ditteon and West (2011, 8.338 h), Waszczak et al. (2015, 8.343 h) and by Pál et al. (2020, 8.35088 h). Period analysis of the 2020 October SAO data collected over 6 nights shows a similar period result: $P = 8.345 \pm 0.006$ h.



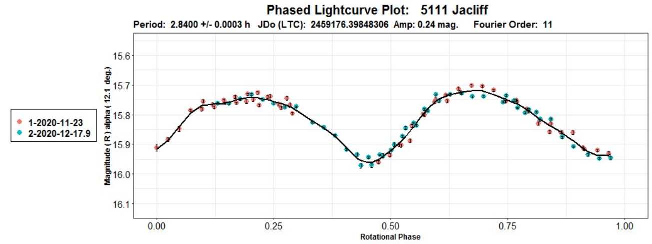
3048 Guangzhou. Previously established rotation period results by Chang et al. (2015, 3.81 h) and Waszczak et al. (2015, 3.808 h) are fully consistent with the rotation period of $P = 3.811 \pm 0.006$ h, found analyzing the 2020 October SAO data obtained over 3 nights.



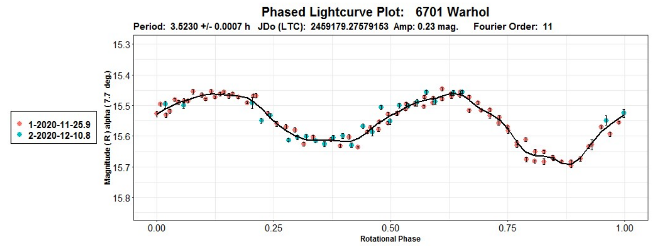
3133 Sendai. A synodic rotation period found from the SAO data obtained over only two consecutive nights in early 2020 December ($P = 5.75 \pm 0.03$ h) is in good agreement with the previously established values by Waszczak et al. (2015, 5.749 h), Erasmus et al. (2020, 5.749 h) and Pál et al. (2020, 5.75011 h).



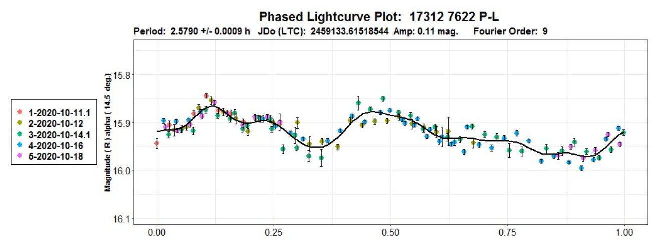
5111 Jacliff. Data taken on two nights in late 2020 November and early 2020 December led to a rotation period of $P = 2.8400 \pm 0.0003$ h, a value in very good agreement with the previous rotation period determination results by Behrend (2005web, 2.839 h), Erasmus et al. (2020, 2.840 h), and sidereal period found by Hanuš et al. (2016, 2.83990 h).



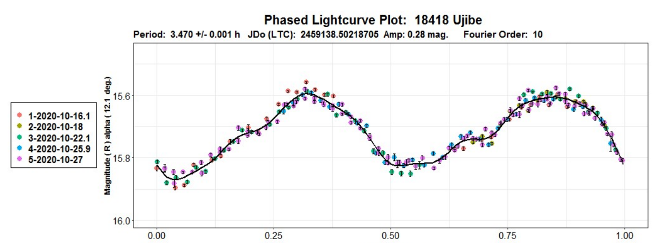
6701 Warhol. A rotation period of 3.52157 h was recently found by Pál et al. (2020) for this Eunomia family asteroid. Period analysis conducted upon the 2020 November-December SAO data obtained on two nights confirms the previously found result indicating a bimodal solution for period of $P = 3.5230 \pm 0.0007$ h as an equivocally most favorable one.



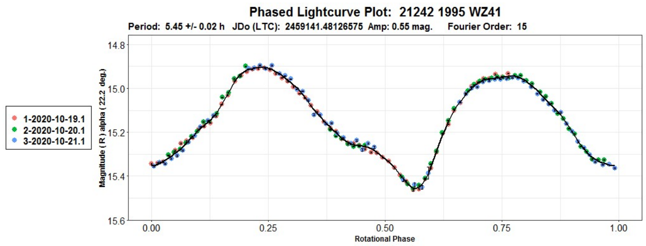
(17312) 7622 P-L. A check for previous rotation period determination reports shows no results. An analysis conducted on the 2020 October SAO data finds a rotation period of $P = 2.5790 \pm 0.0009$ h to be statistically the most plausible solution.



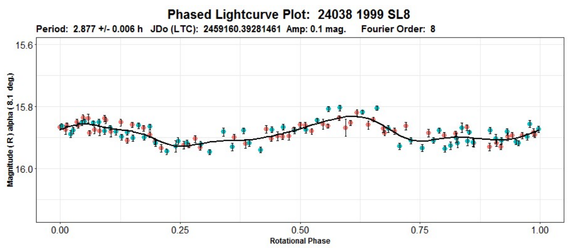
18418 Ujibe. Waszczak et al. (2015) found a rotation period of 3.470 h for this asteroid. Exactly the same value ($P = 3.470 \pm 0.001$ h) associated with a bimodal lightcurve was obtained from the SAO observations carried out on 5 nights in 2020 October.



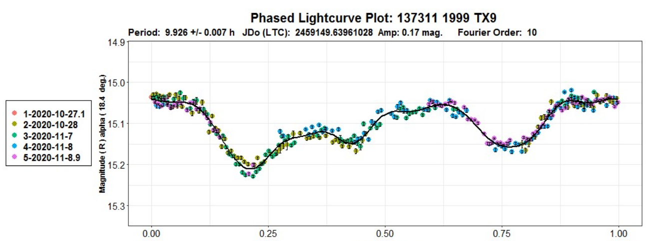
(21242) 1995 WZ41. A Phocaea family asteroid with a previously unknown rotation period observed at the SAO as a program target within the *BinAstPhot Survey* over 3 consecutive nights in 2020 October. A bimodal lightcurve phased to a period of $P = 5.45 \pm 0.02$ h was found as the most plausible solution from the collected data. A rotation period of 5.4535 h was derived by Pravec (2020) by pooling the SAO data with the single-night observations obtained by Marc Deldem in 2020 October.



(24038) 1999 SL8. Another *BinAstPhot Survey* target observed on two consecutive nights at the SAO in early 2020 November. Period analysis performed upon the collected data shows a period of P = 2.877 ± 0.006 h. Using the same dataset Pravec (2020) finds a period value of 2.873 ±0.003 h. These results are in good agreement with what was previously established by Waszczak et al. (2015, 2.880 h).



(137311) 1999 TX9. A Phocaea family asteroid and another *BinAstPhot Survey* target with no previously known rotation period. Photometric observations conducted at the SAO in 2020 October-November on 5 nights indicate a value of P = 9.926 ± 0.007 h as an unambiguous synodic rotation period solution. Pravec (2020) finds a value of 9.921 ± 0.005 h analyzing exactly the same dataset.



Acknowledgements

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