CCD PHOTOMETRY OF 11 ASTEROIDS AT SOPOT ASTRONOMICAL OBSERVATORY: 2021 JULY - 2022 JANUARY

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

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CCD photometric observations carried out at Sopot Astronomical Observatory (SAO) from 2021 July to 2022 January led to establishing the lightcurve and synodic rotation period solutions for 11 asteroids.

Photometric observations of 11 asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2021 July to 2022 January in order to determine their 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 ≤ B-V ≤ 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, 2021) 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.

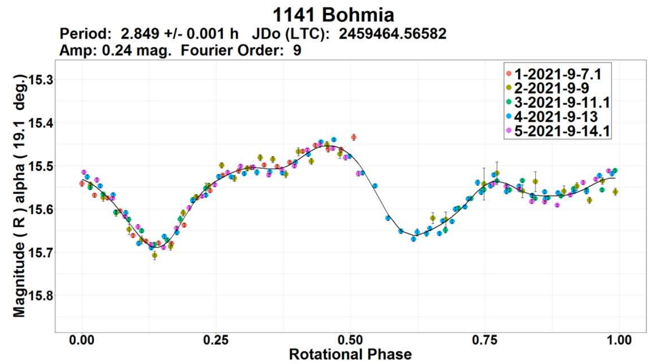
Lightcurve construction and period analysis were performed using *Perfindia* custom-made software developed in the R statistical programming language (R Core Team, 2020) by the author of this paper. The essence of its algorithm is reflected in finding the most favorable solution for rotational period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

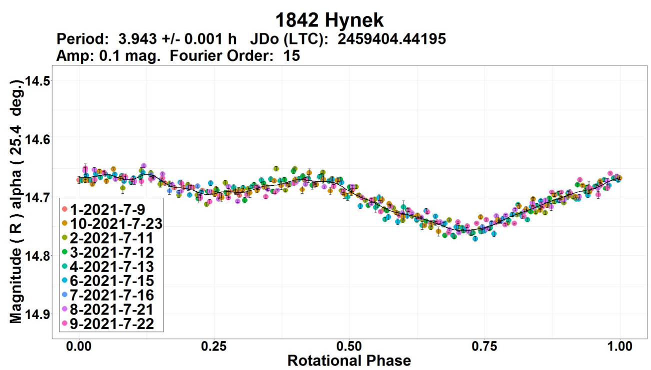
Some of the targets presented in this paper were observed within the Photometric Survey for Asynchronous Binary Asteroids (*BinAstPhot Survey*) under the leadership of Dr. Petr Pravec from Ondřejov Observatory, Czech Republic.

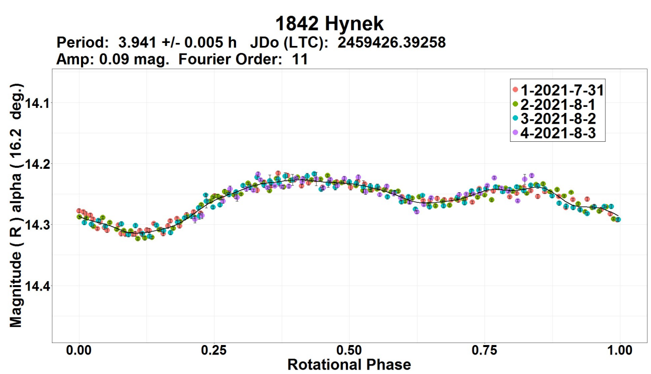
Table I gives the observing circumstances and results.

1141 Bohmia. The only previous rotation period determination was done in the 2018-2019 apparition within the *BinAstPhot Survey* using data obtained by Pray and Benishek in 2019 January. A period of 2.8480 h (Pravec, 2019web) was found. A new period result of $P = 2.849 \pm 0.001$ h, fully consistent with the previously determined result, was derived from the SAO observations acquired on five nights in 2021 September.

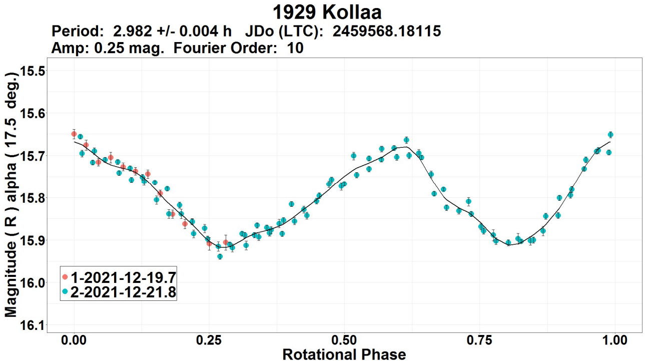


1842 Hynek. There is a significant discrepancy between the rotation period results found by Behrend in several apparitions (3.94 h, 2004web; 3.9410 h, 2007web; 3.94 h, 2014web) and the one of Pal et al. (25.3466 h, 2020). Due to the lightcurve shape changing over the observing time span, the dense SAO photometric data were divided into two groups that were analyzed separately. Rotation period values derived from these two combined data sets are highly consistent with each other (3.943 ± 0.001 h and 3.941 ± 0.005 h), as well as with the results previously found by Behrend.

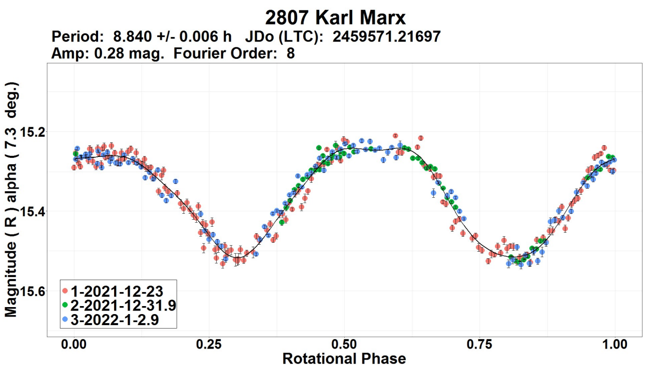




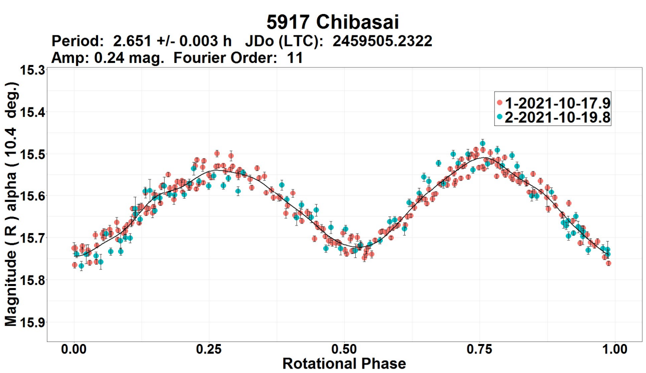
1929 Kollaa. Two previously found rotation periods by Ryan (2.980 h, 2007web) and Behrend (2.9887 h, 2008web) are in complete agreement with the rotation period value of $P = 2.982 \pm 0.004$ h, found from the SAO observations carried out on two nights in 2021 December.



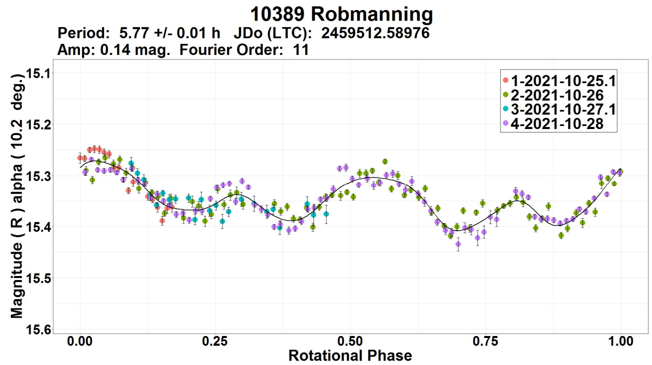
<u>2807 Karl Marx</u>. Period analysis using the 2021 December - 2022 January dense photometric combined data set obtained on three nights led to a bimodal lightcurve and an unambiguous period solution of P = 8.840 ± 0.006 h. The difference from the only previous period determination by Pal et al. (8.81893 h, 2020) is not substantial, but apparently is not exactly negligible.

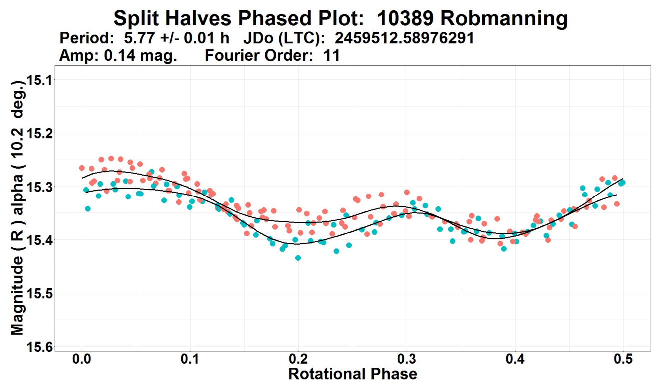


<u>5917 Chibasai</u>. A bimodal period solution of P = 2.651 ± 0.003 h resulting from the dense SAO photometric data collected on two nights in 2021 October shows very good match with all previously found results: 2.645 h (Behrend, 2004web), 2.65 h (Stephens, 2005) and Pal et al. (2.65032 h, 2020).

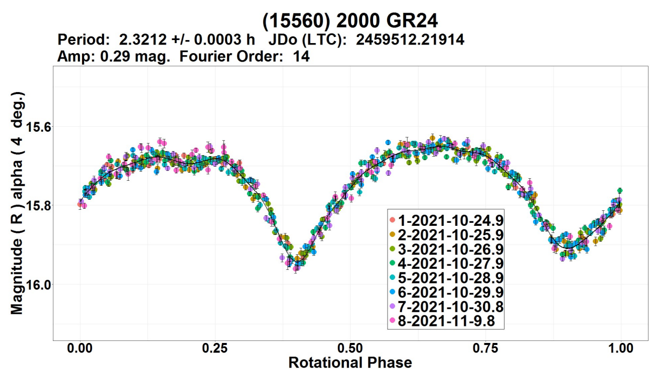


<u>10389 Robmanning</u>. The LCDB (Warner et al., 2009) records show two previous significantly different rotation period determinations: Hasegawa et al. (2.75 h, 2014) and Pal et al. (5.76754 h, 2020). The more recent one of these shows a close proximity to the period of P = 5.77 ± 0.01 h derived from the dense SAO data obtained over four consecutive nights in 2021 October. This statistically plausible result corresponds to a quadramodal lightcurve (four minima and four maxima per rotational cycle) of a relatively low amplitude (0.14 mag). A “split-halves” test shows a significant mismatch between two halves of the 5.77-hour period quadramodal lightcurve, well beyond the data scatter level; this rules out the possibility for the half-period reported by Hasegawa et al.





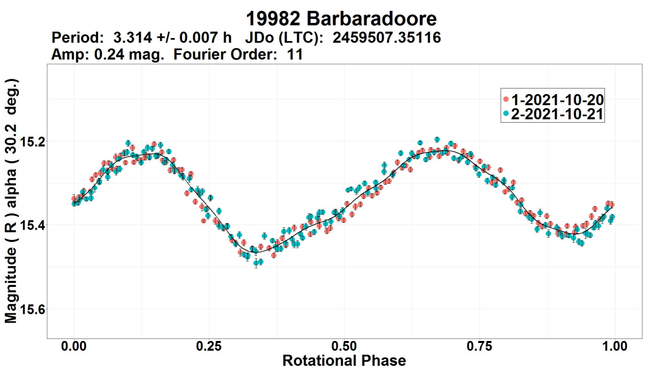
<u>(15560) 2000 GR24</u>. The only previously determined rotation period by Pal et al. (28.8446 h, 2020) substantially differs from the bimodal period of P = 2.3212 ± 0.0003 h found from the 2021 October-November SAO dense photometric data acquired on eight nights.

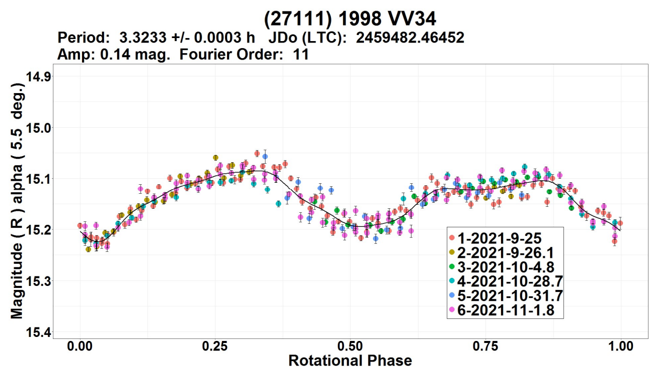


<u>19982 Barbaradoore</u>. The period found from the two consecutive nights 2021 October SAO data (P = 3.314 ± 0.007 h) is consistent with two previous result by Pravec (3.3162 h; 2010web) and Pal et al. (3.31528 h; 2020).

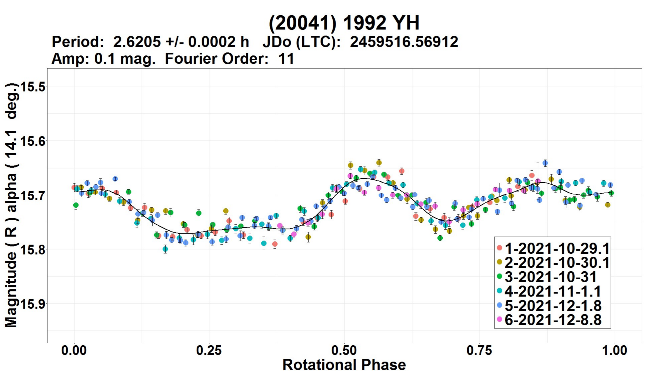
Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1141	Bohmia	21/09/07-21/09/14	19.1,15.8	13	-6	2.849	0.001	0.24	0.02	FLOR
1842	Hynek	21/07/08-21/07/23	25.4,20	329	2	3.943	0.001	0.10	0.02	MB-I
1842	Hynek	21/07/30-21/08/03	16.2,14.5	332	1	3.941	0.005	0.09	0.02	MB-I
1929	Kollaa	21/12/19-21/12/21	17.5,18.2	52	-1	2.982	0.004	0.25	0.03	V
2807	Karl Marx	21/12/22-22/01/03	*7.3,5.6	100	10	8.840	0.006	0.28	0.03	DOR
5917	Chibasai	21/10/17-21/10/19	10.4,9.8	38	16	2.651	0.003	0.24	0.03	MAR
10389	Robmanning	21/10/25-21/10/28	10.2,8.4	45	-5	5.77	0.01	0.14	0.03	FLOR
15560	2000 GR24	21/10/24-21/11/09	4.0,11.8	25	-2	2.3212	0.0003	0.29	0.03	MB-O
19982	Barbaradoore	21/10/19-21/10/21	30.2,29.9	57	31	3.314	0.007	0.24	0.02	PHO
20041	1992 YH	21/10/29-21/12/08	*14.1,9.2	60	-4	2.6205	0.0002	0.10	0.02	MB-I
27111	1998 VV34	21/09/24-21/11/01	*5.5,17.5	10	4	3.3233	0.003	0.14	0.03	MB-I
46304	2001 OZ62	21/09/24-21/09/26	2.1,1.8	3	-3	2.664	0.006	0.09	0.02	MB-I

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): FLOR = Flora, MB-I/O = main-belt inner / outer, MAR = Maria, DOR = Dora, PHO = Phocaea, V = Vestoid.



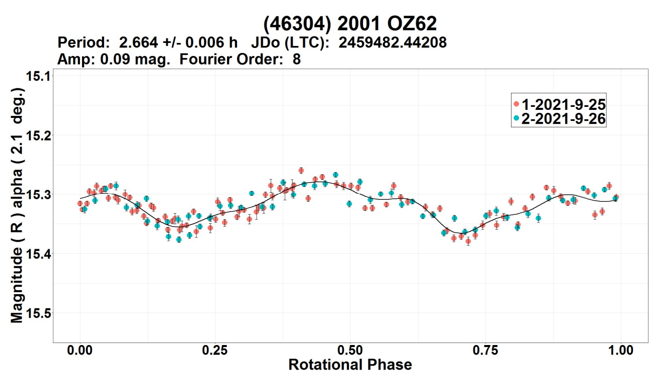


(20041) 1992 YH. No prior rotation period reports were found for this asteroid. Photometric observations at SAO were performed in a somewhat longer time span from late 2021 October until early 2021 December over a total of six nights. There was no significant change of the lightcurve shape during that time. Period analysis shows a rotation period of $P = 2.6205 \pm 0.0002$ h to be the most likely result.



(27111) 1998 VV34. A rotation period result of $P = 3.3233 \pm 0.0003$ h was found from the six-night data obtained over a longer time span (2021 September - November). It is associated with an bimodal lightcurve with a consistent shape over the time of the observations. This result is fully consistent with the only previous result of $P = 3.323$ h Strabla et al. (2012).

(46304) 2001 OZ62. Data taken with a dense cadence in late 2021 September led to a bimodal period solution of $P = 2.664 \pm 0.006$ h. There is good agreement with the rotation period reported by Waszczak et al. (2015) of 2.655 h, but it differs somewhat more from that found by Fauerbach and Brown (2.73 h; 2019).



Acknowledgments

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2022 APRIL-JUNE

Brian D. Warner
Center for Solar System Studies (CS3)
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Alan W. Harris
Center for Solar System Studies (CS3)
La Cañada, CA 91011-3364 USA

Josef Ďurech
Astronomical Institute
Charles University
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance.benner@jpl.nasa.gov

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 2022 April through June. The "Radar-Optical Opportunities" section provides an expanded list of potential NEA targets, many of which are planned 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 $V \leq 18.0$ 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