LIGHTCURVES AND SYNODIC ROTATION PERIODS FOR 17 ASTEROIDS FROM SOPOT ASTRONOMICAL OBSERVATORY: 2022 JUNE – 2023 JANUARY

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(Received: 2023 January 15)

This summary report presents the lightcurve and synodic rotation period results derived using photometric data for 17 asteroids obtained at the Sopot Astronomical Observatory in the time span 2022 June - 2023 January.

Photometric observations of 17 asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2022 June through 2023 January 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 ≤ 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, 2022) 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 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:

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

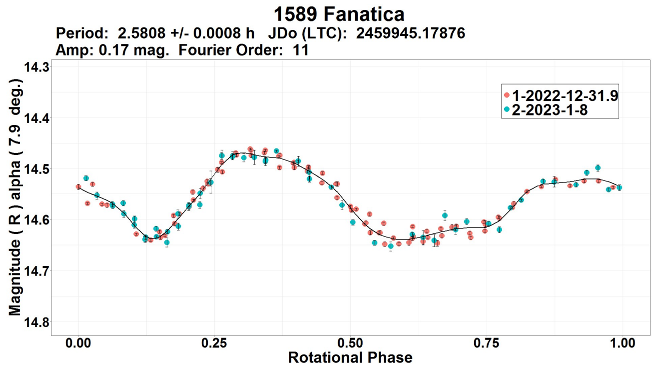
where P and T are the rotational period and the total time span of observations, respectively. Both of these quantities must be expressed in the same units.

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.

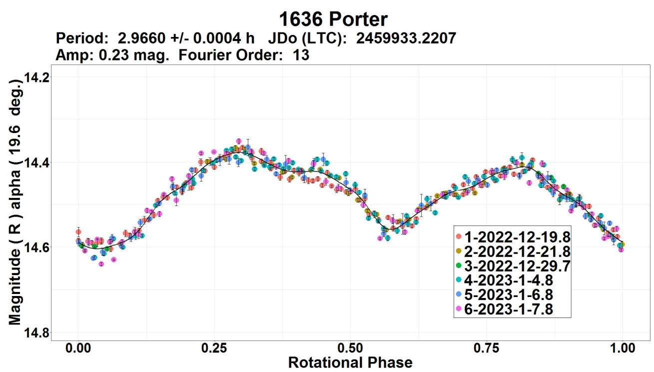
Table I gives the observing circumstances and results.

Observations and results

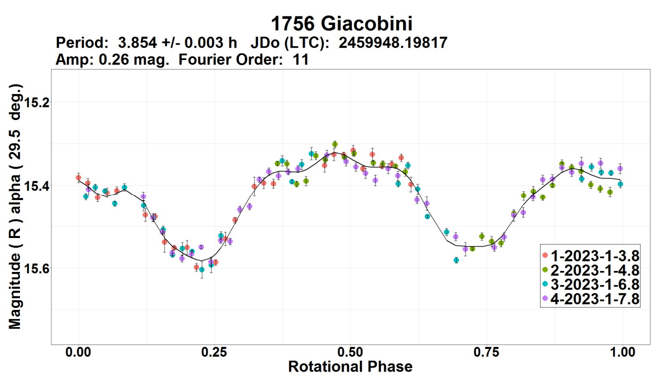
1589 Fanatica. Photometric observations were carried out over two nights in 2022 December - 2023 January at SAO, indicating a bimodal result for the synodic rotational period of *P* = 2.5808 ± 0.0008 h as the statistically most favorable solution. This result is consistent with most previous rotation period determinations: 2.58 h (Warner, 2004), 2.582 h (Stephens, 2015), 2.578 h (Stephens and Warner, 2019), 2.58144 h (Pál et al., 2020), and 2.5832 h (Stephens and Warner, 2020).



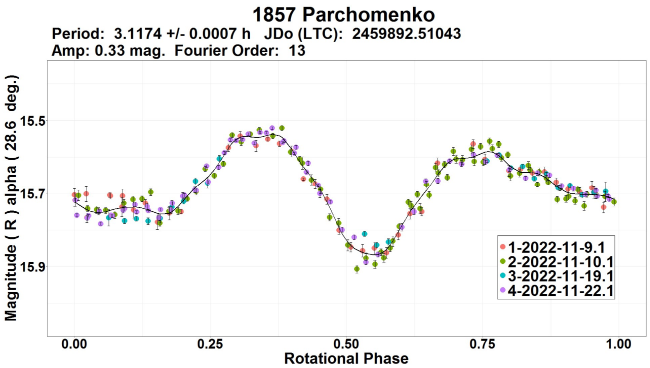
1636 Porter. A bimodal lightcurve phased to a period of *P* = 2.9660 ± 0.0004 h emerges as the most favorable solution in period analysis conducted over 6 datasets obtained in 2022 December - 2023 January. Previously found rotation period results by Albers et al. (2010, 2.9653 h), Behrend (2014web, 2.9658 h), and a sidereal one by Durech et al. (2020, 2.965591 h) are very close to the newly established value.



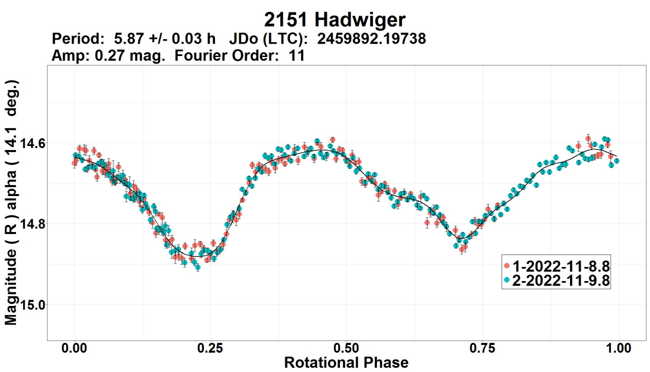
1756 Giacobini. There is no substantial difference between a bimodal period solution (*P* = 3.854 ± 0.003 h) found from the SAO data taken over four nights in 2023 January and previous period determinations by Warner (2007, 3.8527 h), Behrend (2018web, 3.85311 h), and Stephens and Warner (2019, 3.854 h).



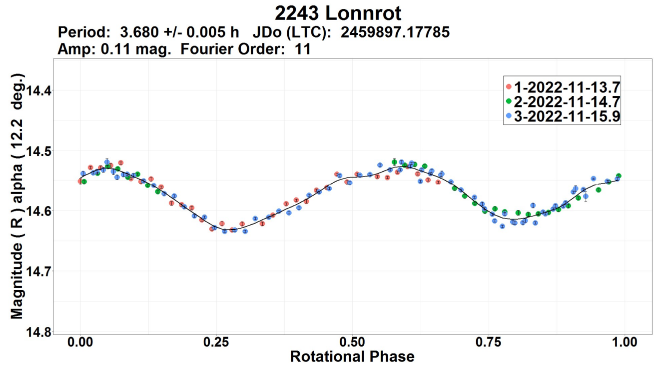
1857 Parchomenko. The four-night 2022 November SAO photometric data yielded a large-amplitude (> 0.3 mag.) bimodal lightcurve phased to a period of P = 3.1174 ± 0.0007 h. Period determinations consistent with the nelwly determined result found in the Asteroid Lightcurve Database (LCDB; Warner et al., 2009) are by Stephens et al. (2006, 3.1177 h), Behrend (2008web, 3.08 h), and a sidereal period value by Durech et al. (2020, 3.117177 h).



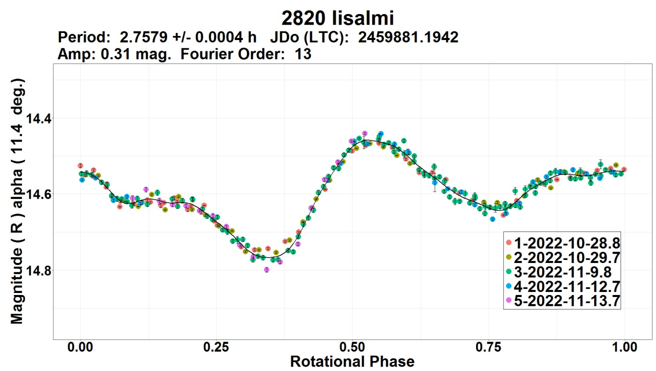
2151 Hadwiger. Photometric datasets obtained over two consecutive nights in 2022 November show a unique bimodal rotation period of P = 5.87 ± 0.03 h. This result is in full accordance with a number of previously obtained rotation periods found in the LCDB: 5.872 h (Sada et al., 2005), 5.87 h (Kim et al., 2014), 5.870 h and 5.871 h (Waszczak et al., 2015), and 5.870 h (Benishek, 2021).



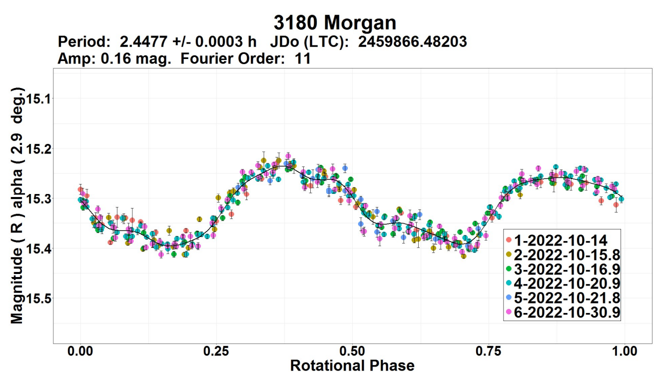
2243 Lonnrot. The only prior rotation period determination is by Marchini et al. (2021, 3.813 h). The relevant bimodal lightcurve associated with this only previous period result is quite noisy and consists of small number of data points obtained over two observing nights. An uncertainty flag of U = 2 has been assigned to this result in the LCDB. A somewhat different value for rotation period of P = 3.680 ± 0.005 h was obtained at SAO using the considerably less scattered photometric data collected on three consecutive nights in 2022 November showing a bimodal lightcurve with an amplitude of 0.11 mag.



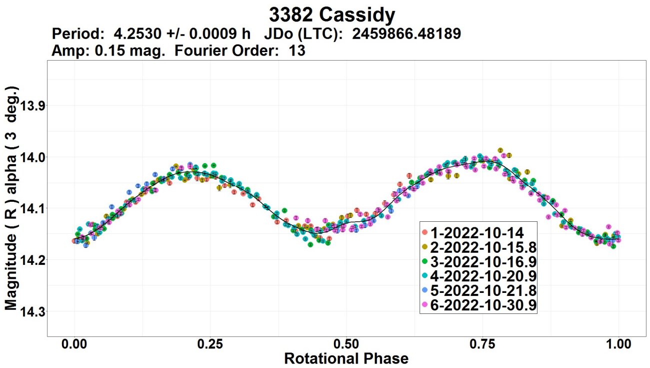
2820 Iisalmi. Behrend (2020web) found a value of 2.7580 h for rotation period, which is the only previously known rotation period determination according to the LCDB. An almost exactly identical result for period (P = 2.7579 ± 0.0004 h) was obtained using the SAO data from five datasets acquired in 2022 October - November.



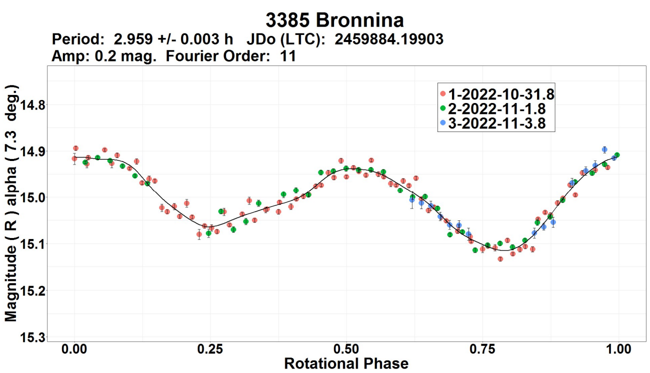
3180 Morgan. According to the LCDB records this is the first rotation period determination for this asteroid. Period analysis conducted upon a dense photometric composite dataset obtained on six nights in 2022 October indicates an unambiguous bimodal solution for a synodic rotation period of P = 2.4477 ± 0.0003 h.



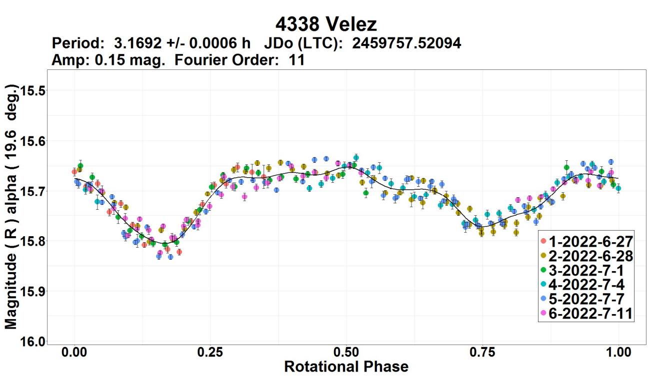
3382 Cassidy. An unequivocal bimodal period solution of $P = 4.2530 \pm 0.0009$ h derived from the dense six-night combined SAO dataset obtained in 2022 October is fully consistent with all previously determined rotation periods found in the LCDB: 4.258 h (Pravec, 2012web), 4.254 h (Risley, 2013), 4.253 h (Waszczak et al., 2015) and a sidereal period of 4.25310 h by Durech et al. (2020).



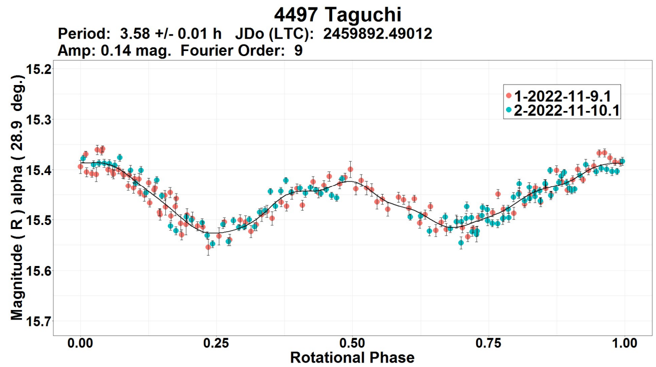
3385 Bronnina. Period analysis of observations obtained over three nights in 2022 October - November led to a unique bimodal period solution of $P = 2.959 \pm 0.003$ h. In this case the obtained result is highly consistent with most of the previous detеminations, as well. Some of these are as follows: 2.95893 h, 2.95897 h, and 2.95877 by Dykhuis et al. (2016), 2.95911 h (Benishek, 2020), 2.959 h (Franco et al., 2021), and a sidereal period by Durech et al. (2020, 2.958806 h).



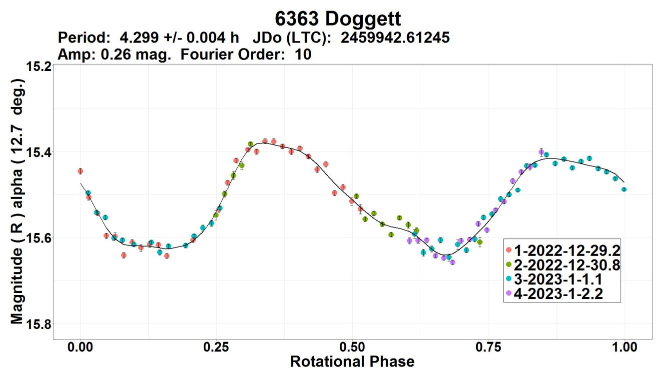
4338 Velez. A search of LCDB records show the only previous period reference by Waszczak et al. (2015, 3.166 h and 3.162 h). These results are in full agreement with the bimodal period solution of $P = 3.1692 \pm 0.0006$ h shown here.



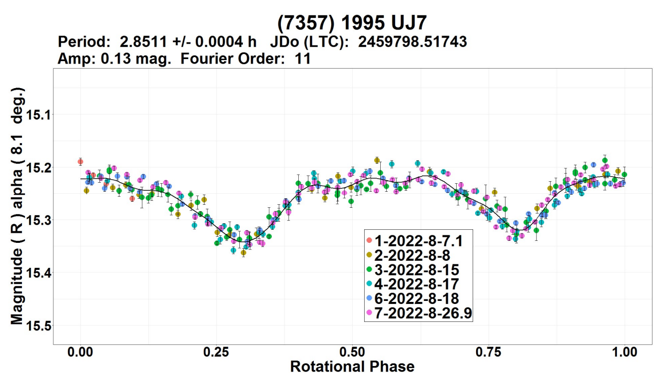
4497 Taguchi. Data obtained on two consecutive nights in 2022 November at SAO indicate a unique bimodal period result of $P = 3.58 \pm 0.01$ h. A comparison with previous period determinations indicates clear agreement with a range of the following results: 3.563 h (Almeida et al., 2004), 3.57 h (Behrend, 2008web), 3.567 h (Behrend, 2012web), 3.563 h (Warner, 2013), and Pál et al. (3.5639 h, 2020).



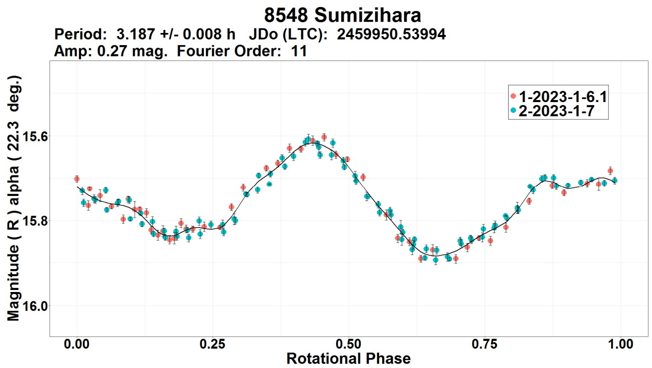
6363 Doggett. No prior rotation period determination records were present in the LCDB. Data taken over four nights in 2022 December - 2023 January yielded a unique period solution of $P = 4.299 \pm 0.004$ h associated with a bimodal lightcurve with a considerable amplitude of 0.26 mag.



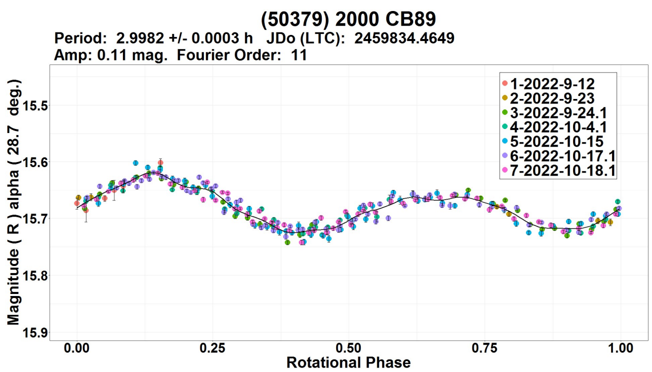
(7357) 1995 UJ7. No records on previous rotation period determinations for this *BinAstPhot Survey* target were found in the LCDB. Photometric observations carried out at SAO on seven nights in 2022 August reveal a bimodal lightcurve phased to a period of $P = 2.8511 \pm 0.0004$ h as a statistically most favorable solution.



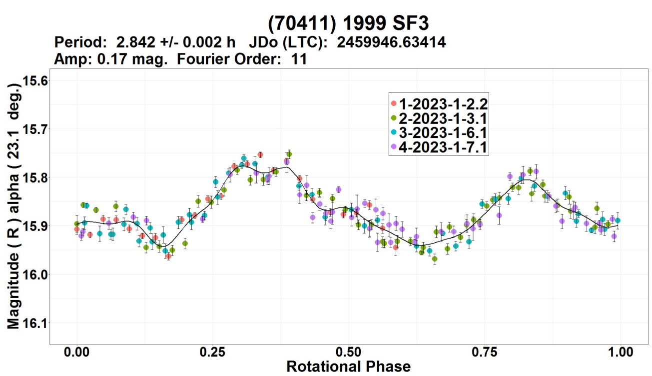
<u>8548 Sumizihara</u>. Waszczak et al. (2015) found a synodic rotation period of 3.192 h, which is fairly close to the bimodal period of P = 3.187 ± 0.008 h obtained from the SAO data obtained on two consecutive nights in early 2023 January.



<u>(50379) 2000 CB89</u>. Pál et al. (2020) reported the only prior result for rotation period of 2.99993 h. A bimodal period solution of P = 2.9982 h obtained from the 2022 September - October SAO data firmly corroborates the previously found result.



<u>(70411) 1999 SF3</u>. A *BinAstPhot Survey* target observed within this survey back in 2014 by Donald Pray, when from the obtained data Pravec (2014web) found a rotation period of 2.8420 h. An exactly identical value for period (P = 2.842 ± 0.002 h) was found from the 2023 January SAO data acquired on four nights.



Acknowledgements

Observational work at Sopot Astronomical Observatory is generously supported by Gene Shoemaker NEO Grants awarded by the Planetary Society in 2018 and 2022.

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Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1589	Fanatica	22/12/31-23/01/08	7.9,11.4	85	0	2.5808	0.0008	0.17	0.02	MB-I
1636	Porter	22/12/19-23/01/07	19.6,25.6	58	-6	2.9660	0.0004	0.23	0.02	FLOR
1756	Giacobini	23/01/03-23/01/07	29.5,29.6	36	5	3.854	0.003	0.26	0.03	MB-I
1857	Parchomenko	22/11/09-22/11/22	28.6,26.4	110	-3	3.1174	0.0007	0.33	0.02	MB-I
2151	Hadwiger	22/11/08-22/11/09	14.1,14.6	14	-2	5.87	0.03	0.27	0.03	MAR
2243	Lonnrot	22/11/13-22/11/15	12.2,13.3	32	3	3.680	0.005	0.11	0.01	FLOR
2820	Iisalmi	22/10/28-22/11/13	11.4,19.6	20	-1	2.7579	0.0004	0.31	0.02	FLOR
3180	Morgan	22/10/13-22/10/31	2.9,12.5	19	4	2.4477	0.0003	0.16	0.02	MB-I
3382	Cassidy	22/10/13-22/10/31	12.4,3.0	19	4	4.2530	0.0009	0.15	0.02	FLOR
3385	Bronnina	22/10/31-22/11/03	7.3,8.8	25	-2	2.959	0.003	0.20	0.02	MB-I
4338	Velez	22/06/27-22/07/11	19.6,13.0	303	9	3.1692	0.0006	0.15	0.02	FLOR
4497	Taguchi	22/08/11-22/11/10	28.9,28.6	101	-1	3.58	0.01	0.14	0.03	MB-I
6363	Doggett	22/12/29-23/01/02	12.7,10.7	116	8	4.299	0.004	0.26	0.02	MB-I
7357	1995 UJ7	22/08/07-22/08/27	*8.1,4.6	326	0	2.8511	0.0004	0.13	0.02	MB-I
8548	Sumizihara	23/01/06-23/01/07	22.3,21.9	142	-2	3.187	0.008	0.27	0.02	MB-I
50379	2000 CB89	22/09/11-22/10/18	28.7,15.3	39	-14	2.9982	0.0003	0.11	0.01	MB-I
70411	1999 SF3	23/01/02-23/01/07	23.1,21.1	140	-11	2.842	0.002	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): FLOR = Flora, MAR = Maria, MB-I = main-belt inner, PHO = Phocaea, EUN = Eunomia.

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