PHOTOMETRIC OBSERVATIONS OF EIGHT MINOR PLANETS FOR SHAPE MODELING

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Phased lightcurves and synodic rotation periods for eight main-belt asteroids are presented, based on CCD observations made in 2020 October. The purpose of obtaining these particular lightcurves is to augment shape modeling efforts. All the data have been submitted to the ALCDEF database.

CCD photometric observations of eight main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe, AZ. Images were taken using a 0.32-m f/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a 'clear' glass filter. Exposure time for all the images was 2 minutes. The image scale after 2×2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results. All of the images for these eight asteroids were obtained in 2020 October.

Images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel. Image calibration and alignment was performed using MaxIm DL software.

The data reduction and period analysis were done using MPO Canopus (Warner, 2020). The 45′×30′ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B\text{-}V < 0.95$ to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. MPO Canopus plots instrumental vs. catalog magnitudes for solar-colored stars, which is useful for selecting comp stars of suitable color and brightness.

Since the sensitivity of the KAF-6303 chip peaks in the red, the clear-filtered images were reduced to Sloan r´ to minimize error with respect to a color term. Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into MPO Canopus. 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 or shifts of only a few hundredths of a magnitude in a series.

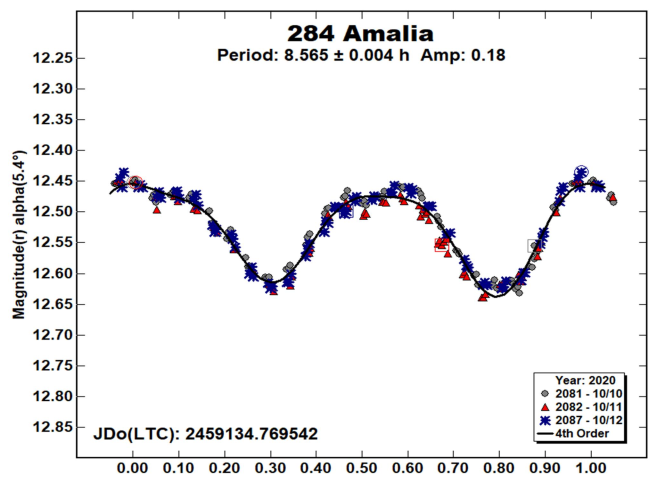
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comp stars, the asteroid itself, and the period-fit. Period determination was done using the MPO Canopus Fourier-type FALC fitting method (cf. Harris et al., 1989). Phased lightcurves show the maximum at phase zero. Magnitudes in these plots are apparent and scaled by MPO Canopus to the first night.

Most issues of the *Minor Planet Bulletin* provide a table of candidates for photometry opportunities to perform or improve shape modeling. These eight asteroids were selected based on criteria that they are rated better than U = 3-, and have at least three entries in the LCDB with U ≥ 2, preferably all with different phase angle bisectors.

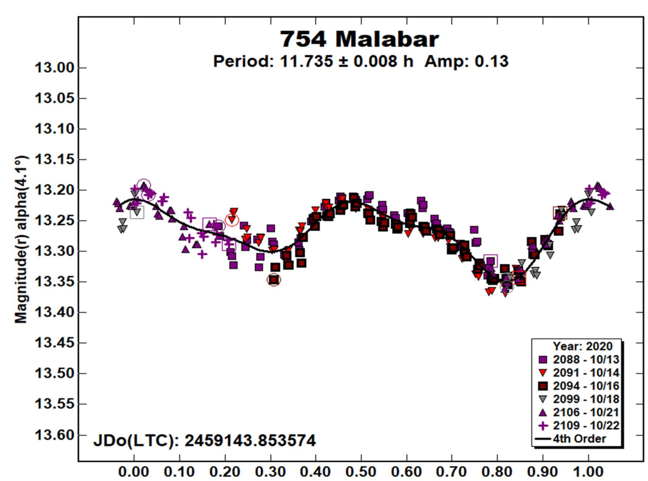
Three of the eight asteroids already have shape models at the DAMIT web site (Ďurech et al., 2010). They are 754 Malabar, 911 Agamemnon, and 1590 Tsiolkovskaja.

The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All the new data for these asteroids can be found in the ALCDEF database.

<u>284 Amalia</u>. Auguste Charlois discovered this asteroid in a highly eccentric orbit from Nice in 1889. Harris and Young (1989) found a period of 8.545 ± 0.015 h. Behrend (2004, 2006) shows periods of 8.56 ± 0.05 h and 8.559 ± 0.001 h, respectively. More recently, Pál et al. (2020) computed 8.5599 ± 0.0005 h. A total of 233 images were taken during three nights, yielding a period solution of 8.565 ± 0.004 h, and an amplitude of 0.18 ± 0.008 mag.



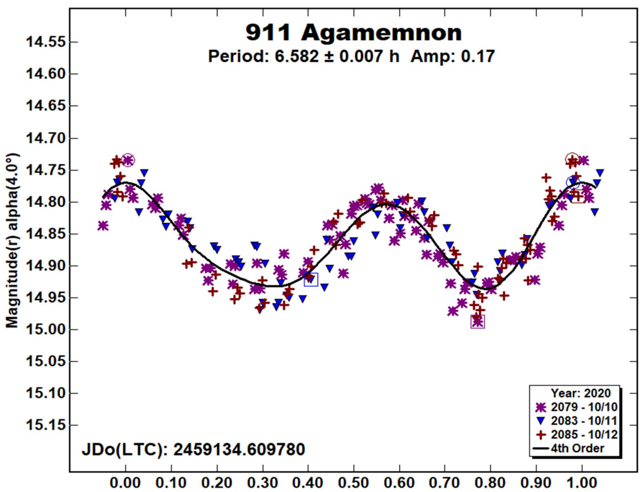
<u>754 Malabar</u>. August Kopff discovered this outer main-belt asteroid at Heidelberg in 1906. Behrend (2004, 2005, 2019) shows synodic period solutions of 11.7267 ± 0.0005 h, 11.732 ± 0.001 h, and 11.7314 ± 0.0006 h. Stephens (2003) computed 11.740 ± 0.005 h. During six nights, 271 data points were obtained to compute a rotational period of 11.735 ± 0.008 h. The amplitude is 0.13 mag., and the RMS error on the fit is 0.011 mag.



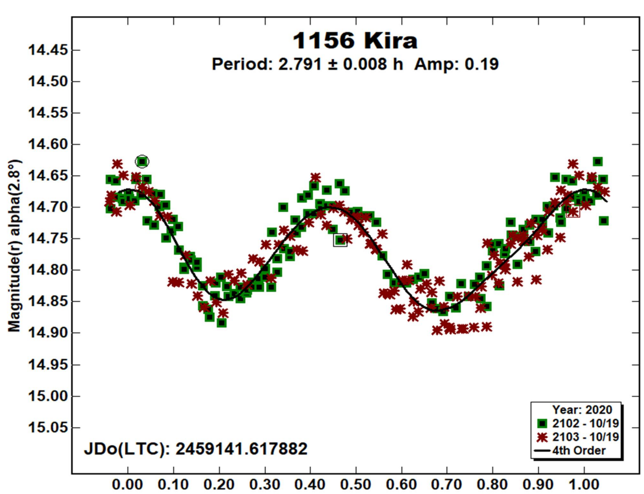
Number	Name	2020/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
284	Amalia	10/10-10/12	5.4,6.0	12	7	8.565	0.004	0.18	0.01	MB-I
754	Malabar	10/13-10/22	4.1,6.8	14	-9	11.735	0.008	0.13	0.01	MB-O
911	Agamemnon	10/10-10/12	4.0,4.3	1	11	6.582	0.007	0.17	0.03	TR-J
1156	Kira	10/19-10/19	2.6,2.6	22	-2	2.791	0.008	0.19	0.03	MB-I
1314	Paula	10/10-10/12	8.3,9.2	7	8	5.948	0.001	0.84	0.01	FLOR
1590	Tsiolkovskaja	10/13-10/17	3.8,5.8	14	3	6.728	0.001	0.36	0.02	FLOR
2346	Lilio	10/18-10/20	3.6,3.8	24	6	3.029	0.001	0.19	0.01	ERI
8256	Shenzhou	10/13-10/17	8.9,11.2	10	-5	3.396	0.001	0.34	0.03	MC

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. L_{PAB} and B_{PAB} 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).

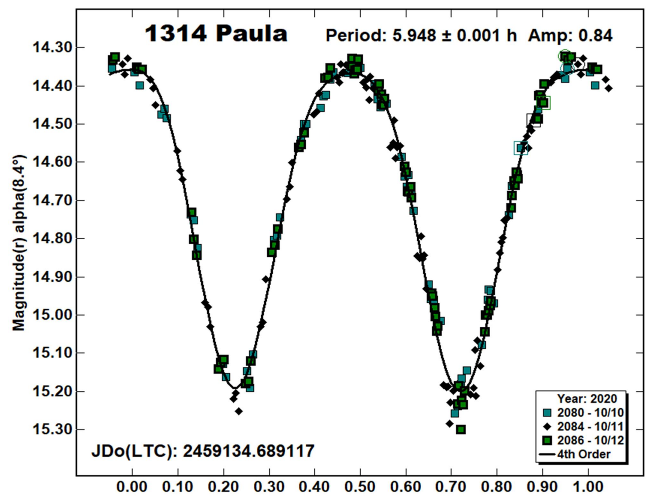
911 Agamemnon. This Trojan was discovered in 1918 by Karl Reinmuth at Heidelberg. Stephens (2009) first determined a period of 6.592 ± 0.004 h, and Mottola et al. (2011) published 6.5819 ± 0.0007 h. Stephens et al. (2014a) again observed the asteroid, determining a period of 6.59 ± 0.001 h. During three nights at V02, 196 images were gathered. The rotational period is 6.582 ± 0.007 h, with an amplitude of 0.17 ± 0.027 mag.



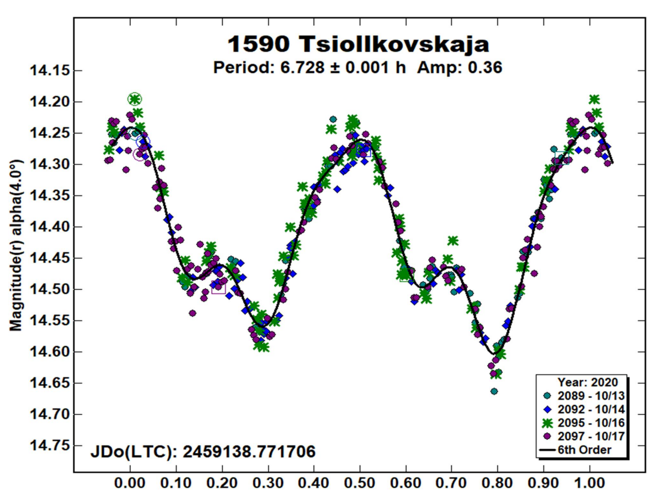
1156 Kira. Karl Reinmuth discovered this minor planet at Heidelberg in 1928. Synodic periods are as follows. Pravec et al. (2012), 2.9710 ± 0.0005 h; Dykhuis et al. (2016), 2.79103 ± 0.00004 h and 2.79113 ± 0.00008 h. During a single night, 233 images were taken, producing a period of 2.791 ± 0.008 h. The amplitude of the lightcurve is 0.19 mag, with an RMS error on the fit of 0.028 mag.



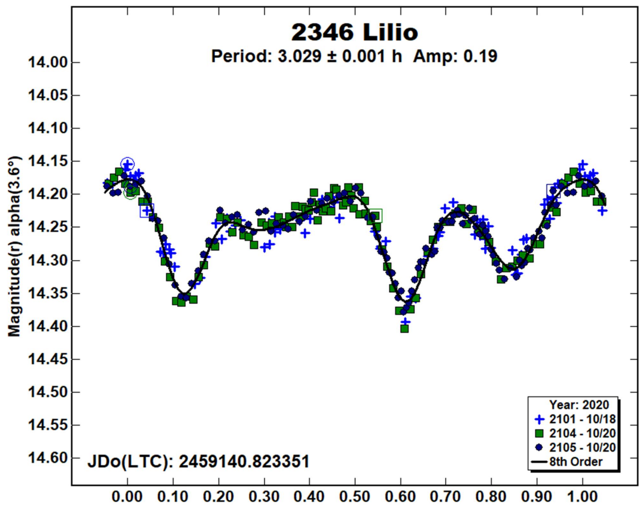
1314 Paula. This Flora-family asteroid was discovered by Sylvain Arend in 1933 at Uccle. Rotational periods with U = 3 are listed: Pravec et al. (2006), 5.9498 ± 0.0003 h; Stephens (2014b), 5.949 ± 0.001 h; and Behrend (2018), 5.95 ± 0.05 h. A total of 222 images taken over the course of three nights were used to determine a synodic period of 5.948 ± 0.001 h, with an amplitude of 0.84 ± 0.003 mag.



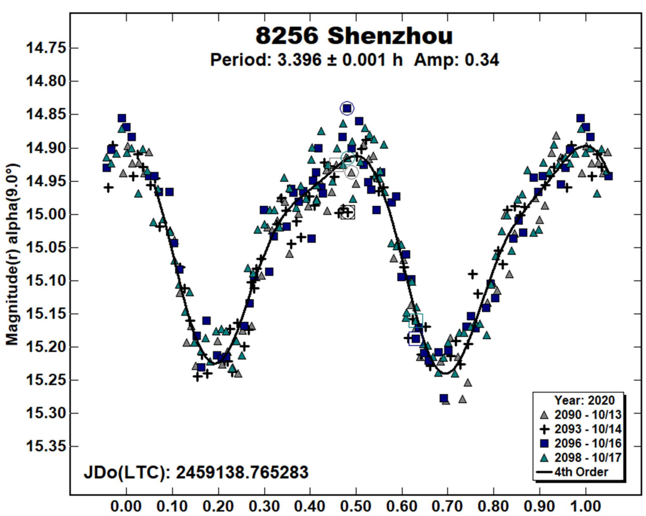
1590 Tsiolkovskaja was discovered by Grigory Neujmin at Siemis in 1933. Photometric results with unique position angle bisectors include: Warner (2008), 6.737 ± 0.004 h; Carbo et al. (2009), 6.731 ± 0.002 h; and Klinglesmith III and Hendrickx (2018), 6.729 ± 0.001 h. During four nights, 376 images were taken. The computed synodic period is 6.728 ± 0.001h, and the amplitude is 0.36 ± 0.022 mag.



2346 Lilio. Karl Reinmuth discovered this Erigone-family minor planet in 1934 at Heidelberg. Unfortunately for shape modeling, the published U = 3 periods share roughly the same position angle bisector: Behrend (2005), 3.02883 ± 0.0003 h; Warner (2006), 3.029 ± 0.002 h; and Behrend (2016), 3.0285 ± 0.0002 h. During three nights, 280 images were obtained, and the derived period is 3.029 ± 0.001 h. The amplitude of the lightcurve is 0.19 mag., with an RMS error on the fit of 0.001 mag.



8526 Shenzhou is a Mars crosser, discovered at Purple Mountain Observatory in 1981. Crawford (2008) published a period of 3.395 ± 0.001 h, Pravec et al. (2015) shows 3.3960 ± 0.0003 h, Benishek (2018) computed 3.394 ± 0.001 h, and Stephens (2018) published 3.397 ± 0.001 h. Using 299 images taken during four nights, the calculated synodic period is 3.396 ± 0.001 h, with an amplitude of 0.34 ± 0.033 mag.



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ROTATIONAL PERIOD AND LIGHTCURVE DETERMINATION OF 4625 SHCHEDRIN, (8823) 1987 WS3, (15010) 1998 QL92, (19755) 2000 EH34, AND 21082 ARAIMASARU

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Photometric observations of five asteroids were performed in order to acquire lightcurves and to determine the rotational periods. The synodic period and lightcurve amplitude were found for 4625 Shchedrin, (8823) 1987 WS3, (15010) 1998 QL92, (19755) 2000 EH34, and 21082 Araimasaru.

This asteroid photometry campaign was done from Amateur Astronomers belonging to AstroCampania Association. The targets were selected mainly in order to acquire lightcurves to determine rotational periods not reported before. All the images reported here were unbinned with no filter and had master flats and darks applied. The exposure time depended upon various experimental conditions such as magnitude of the target, sky motion, and Moon illumination. Image processing, measurement, and period analysis were done using *MPO Canopus* (Warner, 2019), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the ATLAS catalog (Tonry et al., 2018). Observations of 4625 Shchedrin was carried out at ‘Nastro Verde’ observatory (C82) located at Sorrento (Naples), Italy by means of a 0.35-m Schmidt-Cassegrain telescope operating at f/6.3 using a SBIG ST-10 XME CCD camera with 2148×1472 array of 6.8-micron pixels with a clear filter.

Observations of (15010) 1998 QL92 and (19755) 2000 EH34 were carried out by means of Elianto observatory (K68) located in the south of Italy (Pontecagnano) using a 0.3-m Newton telescope operating at f/4 equipped with a Moravian KAF1603 ME CCD camera (1536×1024 array of 9-micron pixels) with a clear filter.