

ROTATIONAL PERIOD AND LIGHTCURVE DETERMINATION OF FOUR ASTEROIDS

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Photometric observations were conducted of four main-belt asteroids. The results of lightcurve analysis gave synodic rotation periods and amplitudes shown in the table below.

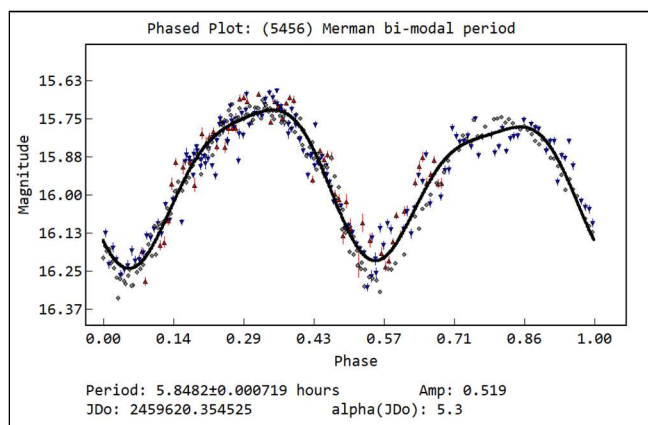
I report lightcurve and period of rotation of asteroids studied in 2022 February with Marina Sky Observatory 17-inch robotic telescope (Marina Sky, 2022). All images were taken with a Planewave CDK 0.432-m *f*/6.8 telescope and Finger Lake Instruments Proline 16803 CCD camera using Sloan *r* filter. The images were binned at 2×2 yielding an image scale of 1.28 arcsec/pixel and the field of view 43 × 43 arcmin.

The exposure time of each image was 150 seconds. To remove Residual Bulk Image (RBI), the NRI pre-flash was applied before each exposure. Images were calibrated with bias, dark for -20°C, and sky flat frames.

Astrometric plate solving of acquired images was achieved using *PinPoint* (DC3 Dreams, 2022) with star positions from ATLAS catalogue (Tonry et al., 2018). In photometry analysis, a couple dozen of carefully selected comparison stars sourced from ATLAS catalogue were used having SLOAN *r* magnitudes in range 12 - 16, B-V color index in range 0.45 - 0.9, and SNR usually between 50 and 450.

Tycho Tracker software (Parrot, 2022) and *Photometric Workflow* (Dose, 2020; 2021) were used for data processing and photometric analysis.

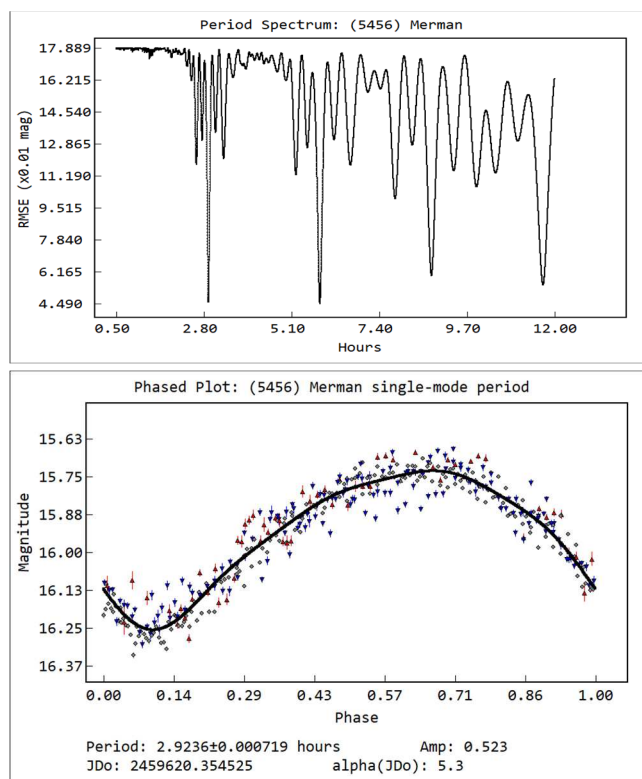
(5456) Merman 1979 HH3. This Vesta family (410) asteroid was discovered at Nauchnyj on 1979 April 25 by N. S. Chernykh. The determined orbit (MPC, 2022) has a semi-major axis of 2.3572709 au, eccentricity of 0.0513055, and inclination of 7.03068 degrees. According to JPL Small-Body Database (JPL, 2022), the asteroid diameter is 4.220 km, absolute magnitude *H* = 13.38, and geometric albedo 0.626. The asteroid sky motion during imaging was 0.66 arcsec/minute.



Observations were made on 2022 February 9-11. The number of images taken during first, second and third night respectively used in analysis were 187, 61 and 163.

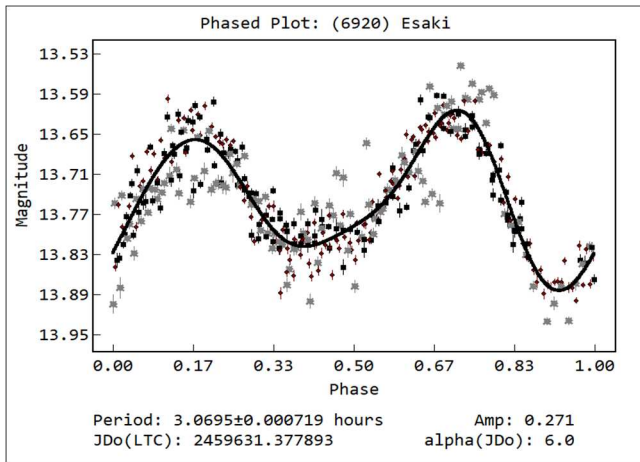
The three observational nights allowed establishing for asteroid (5456) Merman a Sloan *r* magnitude range 15.72 - 16.24 and a bi-modal period of rotation of 5.8482 ± 0.0007 h that is in agreement with period of 5.85286 h calculated by (Ďurech et al., 2020).

The periodogram shows that a single-mode lightcurve rotational period of 2.9236 ± 0.0007 h, being exactly half of a bi-modal period, gives an equally good match. The amplitude and shape of both parts of bi-modal lightcurve are very similar, which allows the possibility of a single-mode solution. However, given the amplitude of 0.52 mag and low phase angle, the true solution is almost certain to be near 5.8 h (Harris et al., 2014).



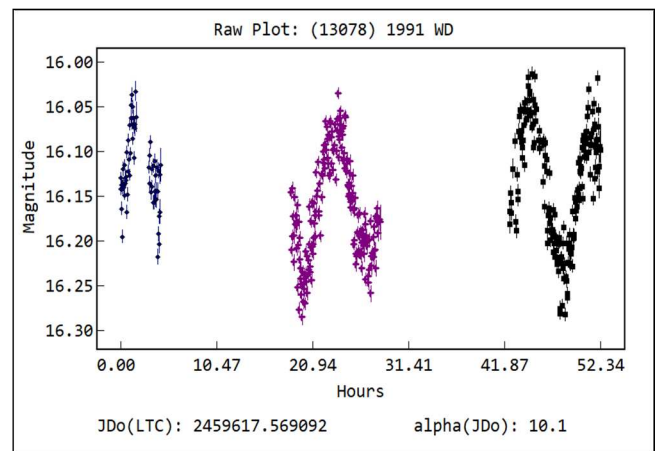
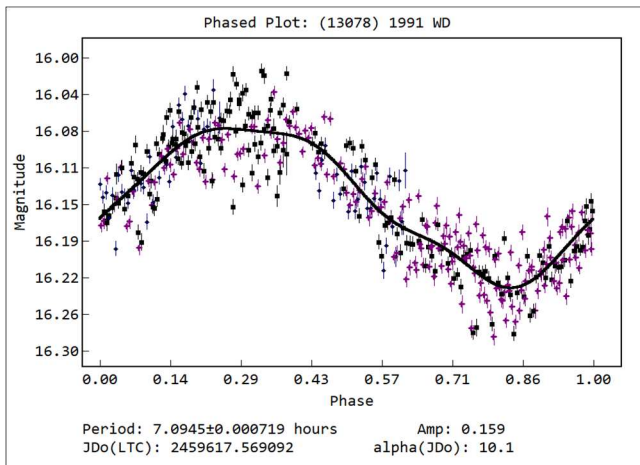
(6920) Esaki 1993 JE. This Vesta family (410) asteroid was discovered at Kitami on 1993 May 14 by K. Endate and K. Watanabe. The determined orbit (MPC, 2022) has a semi-major axis of 2.3873927 au, eccentricity of 0.0801087, and inclination of 6.71374 degrees. According to the JPL Small-Body Database (JPL, 2022), the diameter is 4.962 km, absolute magnitude *H* = 13.36, and the geometric albedo is 0.413. Asteroid speed during imaging was 0.64 arcsec/minute. The rotational period for this body has not been found in previously published data (Warner et al., 2009).

I report lightcurve and period of rotation of asteroid (6920) Esaki as studied on 2022 February 20, 21, and 28. The number of images taken and used in the analysis for the three nights were 116, 138, and 156, respectively. The three observational nights allowed establishing a period of rotation of 3.0695 ± 0.0007 h and Sloan *r* magnitude range 13.62 - 13.89.



(13078) 1991 WD. This main-belt (LCDB orbital group 9105) asteroid was discovered at Kiyosato on 1991 Nov 17 by S. Otomo. The determined orbit (MPC, 2022) has a semi-major axis of 2.6161104 au, eccentricity of 0.2200691, and inclination of 13.87726 degrees. According to the JPL Small-Body Database (JPL, 2022), the diameter is 5.091 km, the absolute magnitude is $H = 13.89$, and the geometric albedo = 0.247. The sky motion during imaging was 0.64 arcsec/minute.

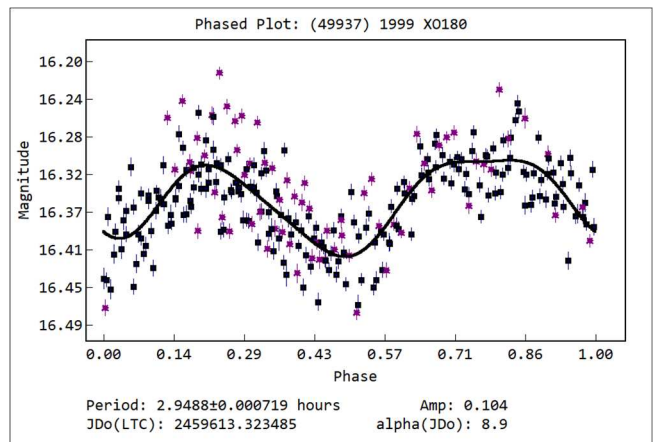
The rotational period for this body has not been found in previously published data (Warner et al., 2009). I report a lightcurve and period of rotation for the asteroid as studied on 2022 February 6-8. The number of images taken and used in analysis for the three nights were 74, 187, and 196, respectively. Analysis of the data found a period of rotation of 7.0945 ± 0.0007 h and Sloan r magnitude range 16.08 - 16.24.



(49937) 1999 XO180. This inner main-belt (LCDB orbital group 9104) asteroid was discovered at Socorro on 1999 December 10 by LINEAR. The determined orbit (MPC, 2022) has a semi-major axis of 2.3806048 au, eccentricity of 0.1701859, and inclination of 9.73216 degrees. According to JPL Small-Body Database (JPL, 2022), the diameter is 3.421 km, absolute magnitude $H = 14.23$, geometric albedo 0.456. The sky motion during imaging was 0.63 arcsec/minute.

The rotational period for this body has not been found in previously published data (Warner et al., 2009). I report lightcurve and period of rotation based on data obtained on 2022 February 2 and 3. During the first and second night, 212 and 82 images were taken, while 207 and 71 observations, respectively, were used in analysis.

The two observational nights allowed establishing a period of rotation of 2.9488 ± 0.0007 h and Sloan r magnitude range 16.31-16.41.



Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
5456	Merman	2022 02/09-02/11	5.30, 5.39	141	10	5.8482	0.0007	0.52	0.03	401
6920	Esaki	2022 02/20-02/28	6.01, 5.52	157	9	3.0695	0.0007	0.27	0.03	401
13078	1991 WD	2022 02/06-02/08	10.12, 9.99	142	16	7.0945	0.0007	0.16	0.03	MB-M
49937	1999 XO180	2022 02/02-02/03	8.88, 8.85	135	14	2.9488	0.0007	0.10	0.03	MB-I

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).

Acknowledgments

Marina Sky Observatory uses, with thanks, the Top 50 Asteroids website and associated database (Kluwak, 2022) as asteroid ephemeris generator during planning and observing.

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LIGHTCURVES FOR SIXTEEN MINOR PLANETS

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Photometric measurements of CCD observations on 16 main-belt asteroids were made from 2022 April through May. Phased lightcurves were created for twelve asteroids, while four did not yield period solutions. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 16 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 asteroids were obtained between 2022 April and May.

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.

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 $0.5 < B-V < 0.95$ 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 usually allowed the separate nightly runs to be linked with no zero-point shifts and occasionally only a few hundredths of a magnitude.

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*