

LIGHTCURVES OF NINE ASTEROIDS

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We present lightcurves and synodic rotation periods for nine asteroids. A trimodal interpretation is proposed for the lightcurve of Hungaria-family 4142 Dersu-Uzala.

We present asteroid lightcurves obtained via the workflow process described by Dose (2020) and later improved (Dose, 2021). This workflow applies to each image an ensemble of typically 15-60 nearby comparison (“comp”) stars selected from the ATLAS refcat2 catalog (Tonry et al., 2018). Custom diagnostic plots and the abundance of comp stars allow for rapid identification and removal of outlier, variable, and poorly measured comp stars.

The product of this custom workflow is one night’s time series of absolute magnitudes, on Sloan r’ (SR) catalog basis, for one target asteroid. These magnitudes are corrected for instrument transforms, sky extinction, and image-to-image (“cirrus”) fluctuations and thus represent magnitudes at the top of earth’s atmosphere. These magnitudes are imported directly into *MPO Canopus* software (Warner, 2021) where they are adjusted for distances and phase-angle dependence, fit by Fourier analysis including identifying and ruling out of aliases, and plotted.

Phase-angle dependence is corrected with a H-G model, using the G value minimizing best-fit RMS error across all nights’ data; when we cannot estimate an asteroid’s G value, usually due to a campaign’s narrow range of phase angles, we apply the Minor Planet Center’s default value of 0.15. No nightly zero-point adjustments (Delta Comps in *MPO Canopus* terminology) were made to any session herein, other than by estimating G, which practice we note introduces only one new fitting term vs many more terms (number of nights - 1) when applying non-zero Delta Comps.

Lightcurve Results

Nine asteroids were observed from New Mexico Skies observatory at 2310 meters elevation in southern New Mexico. Images were acquired with a 0.35-meter SCT reduced to f/7.7; a SBIG STXL-6303E camera cooled to -35 C and fitted with an Exoplanet/Blue Blocker (BB) filter (Astrodon); and a PlaneWave L-500 mount. The equipment was operated remotely via *ACP software* (DC-3 Dreams, version 8.3), running plan files generated for each night by the author’s python scripts (Dose, 2020).

Exposures were autoguided, and exposure times targeted 2-5 millimagitudes uncertainty in asteroid instrumental magnitude, subject to a minimum exposure of 150 seconds to ensure suitable comp-star photometry, and to a maximum of 900 seconds.

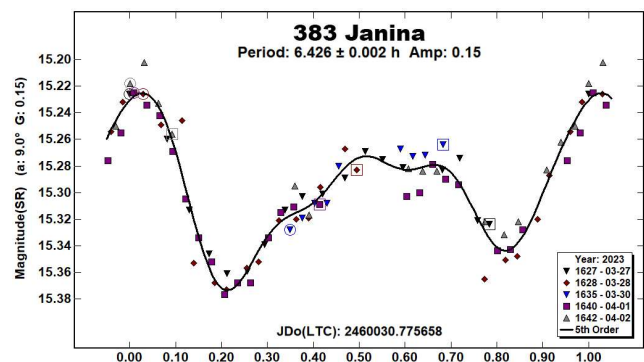
FITS images were plate-solved by *PinPoint* (DC-3 Dreams) or *TheSkyX* (Software Bisque) and were calibrated using temperature-matched, median-averaged dark images and recent flat images of a flux-adjustable flat panel. Every photometric image was visually inspected; the author excluded images with poor tracking, obvious interference by cloud or moon, or having stars, satellite tracks, cosmic ray artifacts, or other apparent light sources within 12 arcseconds of the target asteroid’s signal centroid. Images passing these screens were submitted to the workflow.

The BB filter, a yellow filter with relatively sharp wavelength cut-off, requires only a modest first-order transform to the standard Sloan r’ passband. In our hands, using this filter rather than a clear filter or no filter improves night-to-night reproducibility to a degree outweighing loss of signal-to-noise ratio from loss of flux.

Comparison stars from the ATLAS refcat2 catalog were selected if they had: distance from image boundaries and other catalogued flux sources of at least 15 arcseconds, no catalog VARIABLE flag, Sloan r’ magnitude within [-2, +1] of the target asteroid’s r’ magnitude on that night (except that very faint asteroids used comp stars with magnitudes in the range 14 to 16), Sloan r’-i’ color value within [0.10, 0.34], and absence of variability as seen in session plots of each comp star’s instrumental magnitude vs time.

In this work, “period” refers to an asteroid’s synodic rotation period, “SR” denotes the Sloan r’ passband, and “mmag” denotes millimagitudes (0.001 magnitude).

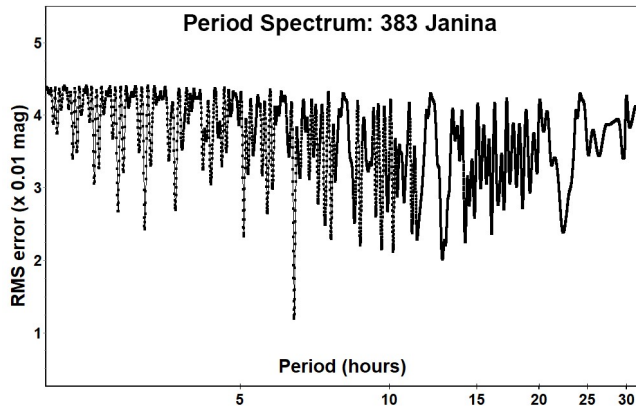
383 Janina. Our synodic period estimate of 6.426 ± 0.002 h for this Themis-family asteroid confirms all previous estimates (6.4 h, Tedesco, 1979; 6.42943 h, Āurech et al., 2020; 6.429 h, Erasmus et al., 2020; 6.4298 h, Pilcher, 2021) but one (4.636 h, Clark, 2006).



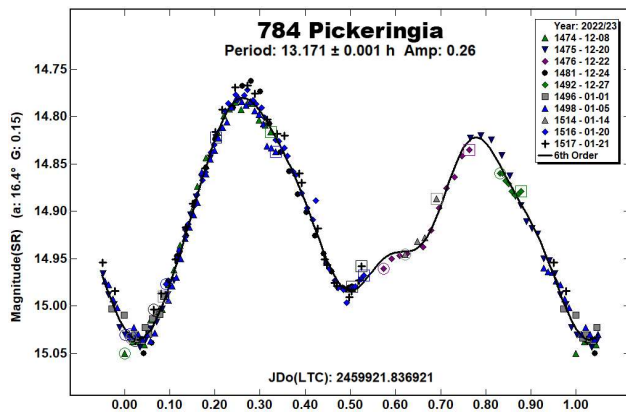
Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
383	Janina	2023 03/27-04/02	9.1, 7.5	215	3	6.426	0.002	0.15	0.02	THEM
784	Pickeringia	2022-3 12/08-01/21	16.4, 8.5	141	12	13.171	0.001	0.26	0.03	MB-O
845	Naema	2023 02/05-03/14	18.3, 18.8	76	9	13.378	0.002	0.13	0.04	NAEM
1493	Sigrid	2022-3 11/07-02/07	*20.0, 15.9	96	3	43.193	0.005	0.69	0.10	MB-O
1558	Jarnefelt	2023 01/21-01/28	*2.2, 1.4	125	3	6.257	0.001	0.24	0.04	MB-O
1639	Bower	2023 01/07-04/12	*18.7, 19.7	150	-1	22.165	0.001	0.32	0.05	MB-I
2301	Whitford	2023 02/03-03/26	*13.2, 9.4	166	15	14.302	0.001	0.42	0.05	MB-O
4142	Dersu-Uzala	2023 01/08-04/07	*30.7, 33.6	142	36	411.22	0.28	0.85	0.15	HUNG
4635	Rimbaud	2023 01/12-03/14	*5.6, 24.3	121	7	118.510	0.045	1.38	0.12	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, 2009a).

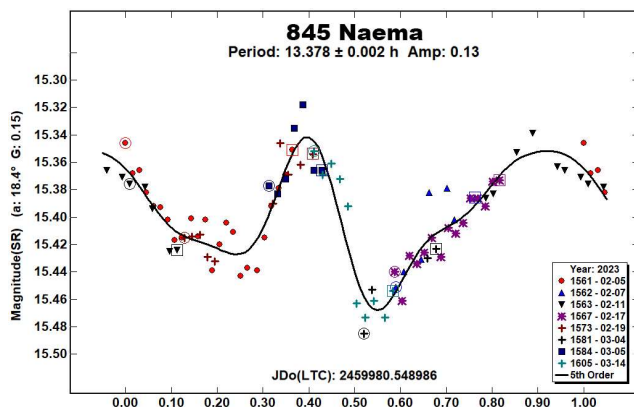
The lightcurve shape for 383 Janina is clearly bimodal. Our Fourier fit RMS error is 12 mmag; given our narrow phase angle range, we applied the Minor Planet Center's default G value of 0.15. Our period spectrum supports the consensus period.



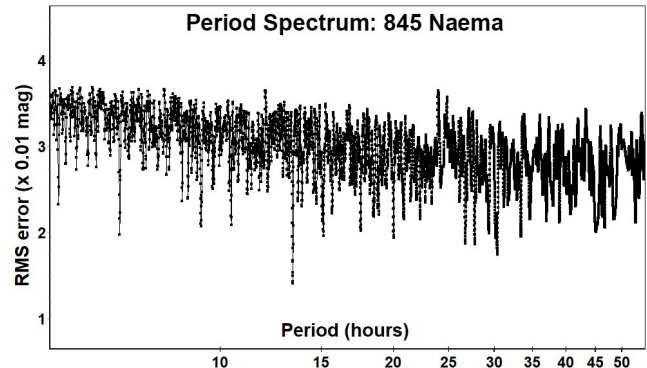
784 Pickeringia. For this outer main-belt asteroid, we estimate the period as 13.171 ± 0.001 h, in agreement with known previous estimates (13 h, Hainaut-Rouelle et al., 1995; 13.17 h, Behrend, 2004web; 13.1699 h, Hanuš et al., 2011; 13.16995 h, Āurech et al., 2016; 13.16998 h, Hanuš et al., 2016; 13.16999 h, Martikainen et al., 2021; 13.144 h, Mas et al., 2018; 13.169 h, Pilcher, 2022). Our Fourier fit RMS error is 9 mmag, and the lightcurve shape is clearly bimodal. Given our narrow range of phase angles, we applied G value of 0.15.



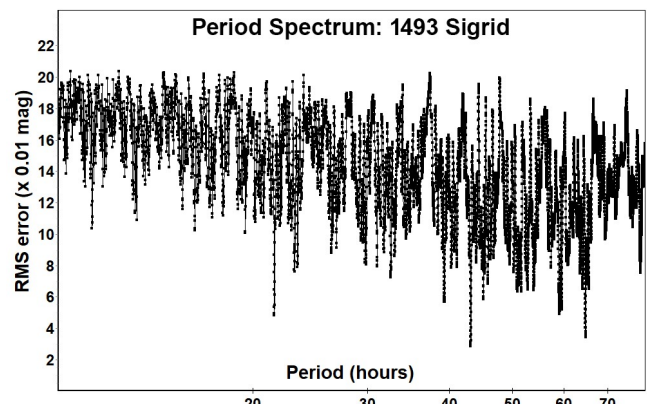
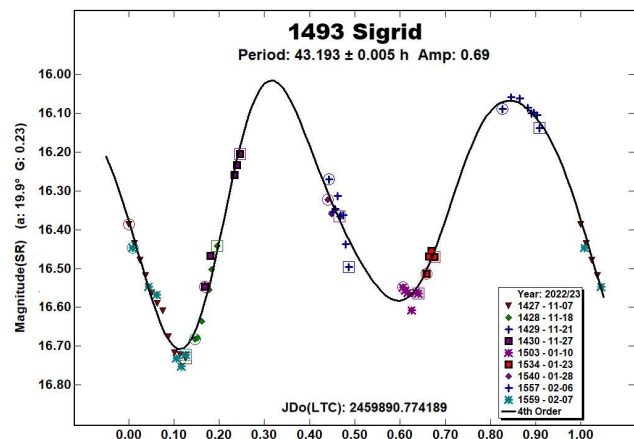
845 Naema. Our period estimate for this primary asteroid of the Naema family is 13.378 ± 0.002 h, at variance from both known published estimates (20.892 h, Bembrick et al., 2008; 12.1 h, Behrend, 2017web). Our lightcurve is bimodal.



Our Fourier fit RMS error is 14 mmag; given our very narrow phase angle range, we applied G value of 0.15. Our period spectrum disfavors both previously published period estimates. We cannot explain differences in these estimates from ours either by multiples of half-period or by sidereal aliases.

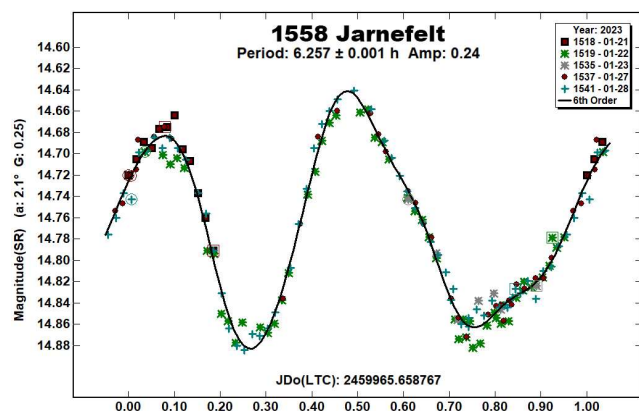


1493 Sigrid. Our period estimate of 43.193 ± 0.005 h for this Nysa-Polana family asteroid agrees with most (43.296 h, Bembrick and Byron, 2007; 43.179 h, Hanuš et al., 2013; 43.1795 h, Āurech et al., 2016) but not all (22.68 h, Behrend, 2010web) published estimates. The Behrend estimate appears to be a monomodal interpretation, but the other estimates and the lightcurve offered here suggest a bimodal interpretation. While our phase coverage is incomplete, the difference in brightness between the two minima is significant and leaves little doubt that a bimodal interpretation is superior to monomodal. Our Fourier fit RMS error is 29 mmag; G of 0.23 minimized the fit error, though the improvement over a value of 0.15 was marginal.

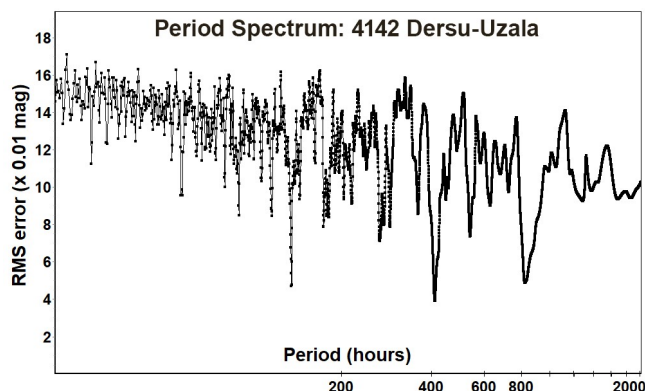


1558 Jarnefelt. For this outer main-belt asteroid, we find a synodic period of 6.257 ± 0.001 h, agreeing with two published estimates (6.252 h, Polakis, 2019; 6.255 h, Polakis, 2022) but differing from one other (18.22 h, Hawkins and Diteon, 2008). The latter lightcurve suffered incomplete coverage as phased to 18.22 h; phased lightcurves of 2019 and 2022 were heavily covered with over 200 data points each and were more clearly bimodal in shape.

Our lightcurve benefited from three sessions each covering more than one period. Our Fourier fit RMS error is 10 mmag; a G value near 0.25 strongly minimized the fit error. We suggest that a bimodal-basis period near 6.25 h appears secure.

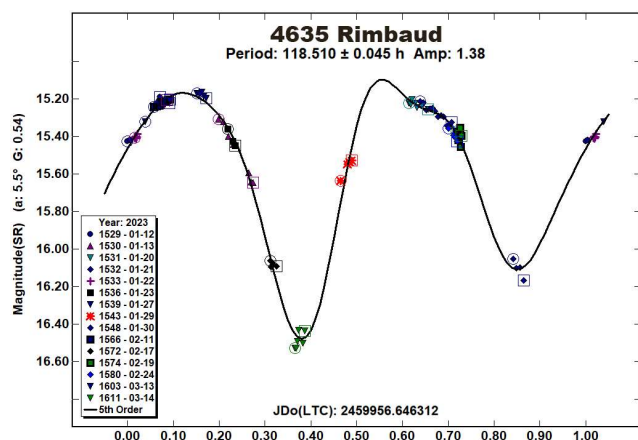


Our period spectrum favors our proposed period over periods near 276, 140, and 71 h.

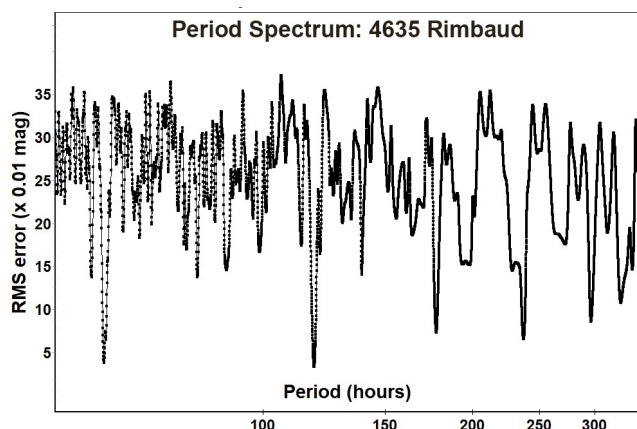


4635 Rimbaud. For this very high-amplitude, inner main-belt asteroid, we report a period of 118.510 ± 0.045 h, in agreement with one previous report (117.91 h, Stephens and Warner, 2019) and in approximate agreement with one other (125 h, Podlewska-Gaca et al., 2021). Our Fourier fit RMS error is 34 mmag; G value of 0.54 strongly reduced fit error relative to MPC's default of 0.15.

Though our campaign continued for 15 nights over 9 weeks, our phase coverage remains incomplete. Even so, our lightcurve shape is clearly bimodal, especially in the difference between the two brightness minima.



Our period spectrum favors only period estimates of multiples of one-half of our own estimate.



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