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PHOTOMETRIC OBSERVATIONS OF TEN MINOR PLANETS

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Phased lightcurves and synodic rotation periods are presented for eight main-belt asteroids. Results are: 243 Ida, 4.634 ± 0.002 h; 874 Rotraut, 14.311 ± 0.010 h; 1686 De Sitter, 11.292 ± 0.012 h; 2285 Ron Helin, 52.77 ± 0.07 h; 2302 Florya, 16.557 ± 0.024 h; 3306 Byron, 6.999 ± 0.005 h; 5391 Emmons, 3.029 ± 0.001 h; and 7365 Sejong, 2.579 ± 0.001 h. No period solutions were found for 1466 Mundleria or 5199 Dortmund. All the data have been submitted to the ALCDEF database.

CCD photometric observations of ten 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 2x2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results. All of the images for these ten asteroids were obtained between 2019 August and September.

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, 2019). The 45'x30' 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. The *MPO Canopus* internal star catalogue was useful in 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

Number	Name	2019/mm/dd	Phase	L _{PAB}	B _{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
243	Ida	09/04-09/07	1.5, 2.5	338	0	4.634	0.002	0.63	0.03	KOR
874	Rotraut	08/23-08/28	*3.2, 3.4	330	9	14.311	0.010	0.26	0.03	MB-O
1466	Mundleria	08/19-08/22	2.0, 1.1	328	4	–	–	–	–	MB-I
1686	De Sitter	08/19-08/23	4.4, 2.7	335	0	11.292	0.012	0.18	0.02	MB-O
2285	Ron Helin	08/23-09/07	*1.2, 9.4	331	1	52.77	0.07	0.33	0.05	FLOR
2302	Florya	08/30-09/06	*5.4, 5.9	339	9	16.557	0.024	0.08	0.03	EUN
3306	Byron	08/23-08/28	11.0, 13.4	314	6	6.999	0.005	0.18	0.05	FLOR
5199	Dortmund	08/19-08/22	5.8, 5.5	330	9	–	–	–	–	EUN
5391	Emmons	09/01-09/07	7.6, 3.6	348	1	3.029	0.001	0.14	0.03	MB-I
7365	Sejong	08/30-09/06	*1.6, 3.4	338	0	2.579	0.001	0.07	0.03	FLOR

Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, and marked with an asterisk if it reached a minimum between the two values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

with respect to a color term. In a departure from the method used for the past several years, comp 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.

Comp star magnitudes had been previously derived from a combination of CMC15 (Muñoz et al., 2014), APASS DR9 (Munari et al., 2015), and GAIA2 G catalogues to set the zero-points each night. Magnitudes of the comps using the ATLAS catalog were spot checked against this previous method and typically showed an agreement within 0.010 mag.

This careful adjustment of the 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.

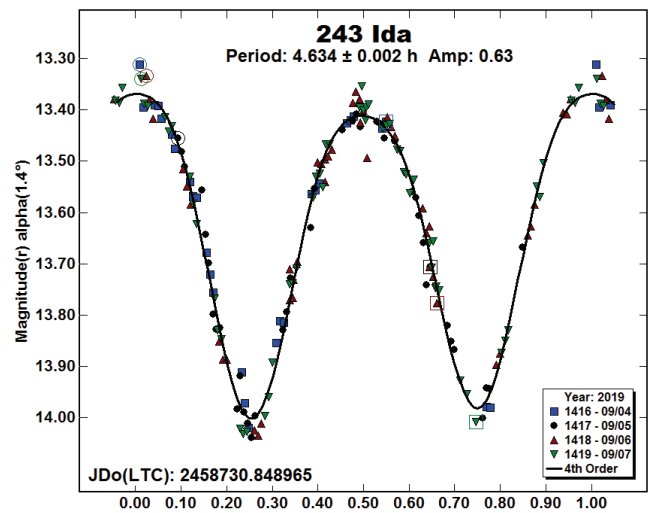
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall 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 asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude $V < 15.0$ and quality of results, U , less than 2+. In this set of observations, three of the ten asteroids had no previous period analysis and two had $U = 1$.

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.

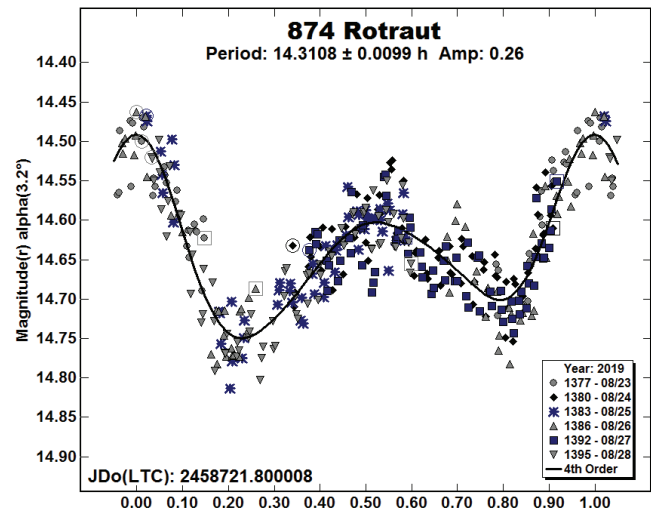
243 Ida is a Koronis-family asteroid in the outer regions of the main-belt. It was discovered by Johann Palisa at Vienna in 1884. Being low-numbered and bright, its rotation period is already well characterized. It was included in this batch only because of its serendipitous presence in the same field as 7365 Sejong for three observing nights. Various sources put the synodic period near 4.634 h, most recently Hanus (2013a), who show a sidereal period of 4.633632 ± 0.000005 h.

Over the course of four observing nights, 177 images were sufficient to obtain a synodic period of 4.634 ± 0.002 h. The amplitude is 0.63 mag and the RMS scatter on the fit shown in the phased plot is 0.027 mag.



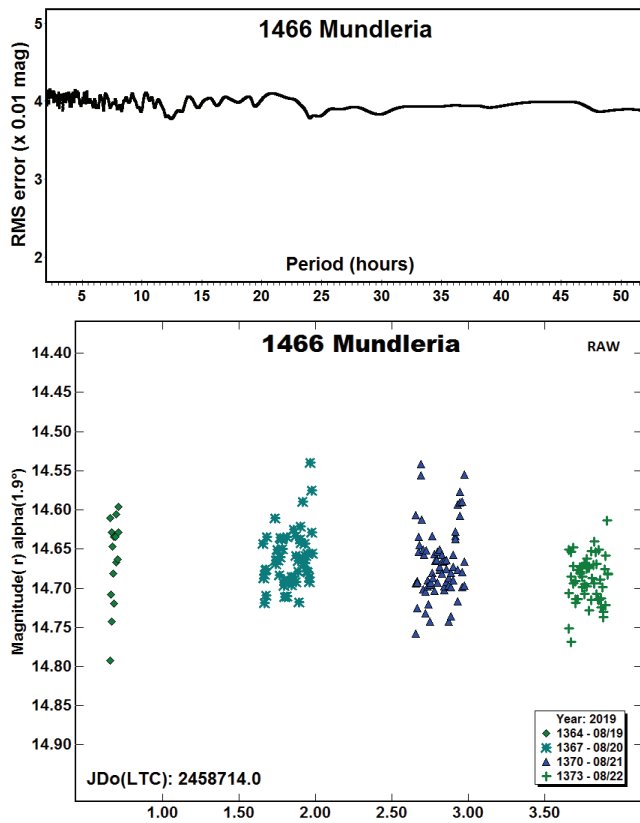
874 Rotraut. This asteroid was discovered at Heidelberg by Max Wolf in 1917. Several similar periods appear in the LCDB. Hanus (2013b) found a period of 14.3007 ± 0.002 h, Ditteon (2018) obtained 14.297 ± 0.006 h, and Polakis (2018) found 14.297 ± 0.009 h.

A total of 379 images were taken during six nights, producing a period of 14.311 ± 0.010 h, in agreement with previous determinations. The lightcurve amplitude is 0.26 mag with an RMS scatter of 0.034 mag.



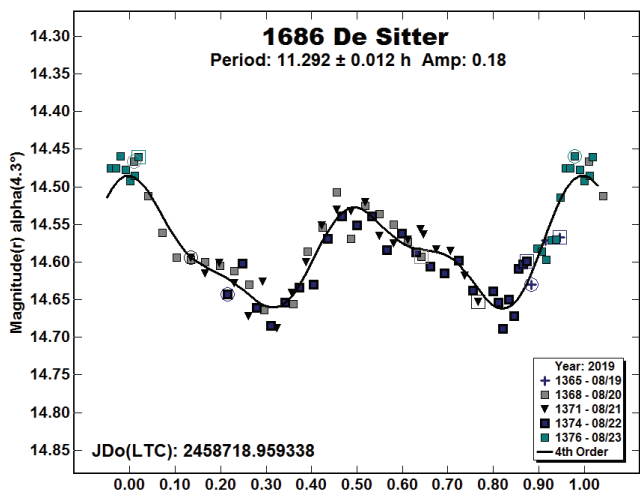
1466 Mundleria. Karl Reinmuth discovered this minor planet from Heidelberg in 1938. No period solutions appear in the LCDB.

During four nights, 193 images were taken, which was sufficient to conclude that a period solution would not become available. The period spectrum showed no significant minima. Raw data from the four nights are presented.



1686 De Sitter was discovered in 1935 by Hendrik Van Gent in Johannesburg. No period solutions appear in the LCDB.

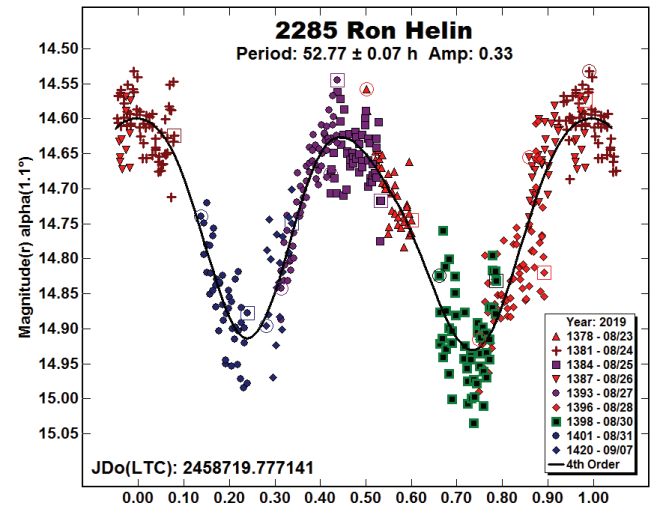
A total of 241 images were taken during five nights. The fit was improved by binning sets of three points, which produced a period solution of 11.292 ± 0.012 h. The amplitude of the phased lightcurve is 0.18 mag, with an RMS error on the fit of 0.021 mag.



2285 Ron Helin was discovered by Schelte Bus at Palomar in 1976; it is named after the husband of prolific asteroid discoverer Eleanor Helin. *The only period published in the LCDB is that of Behrend (2009), who gives >12 h.*

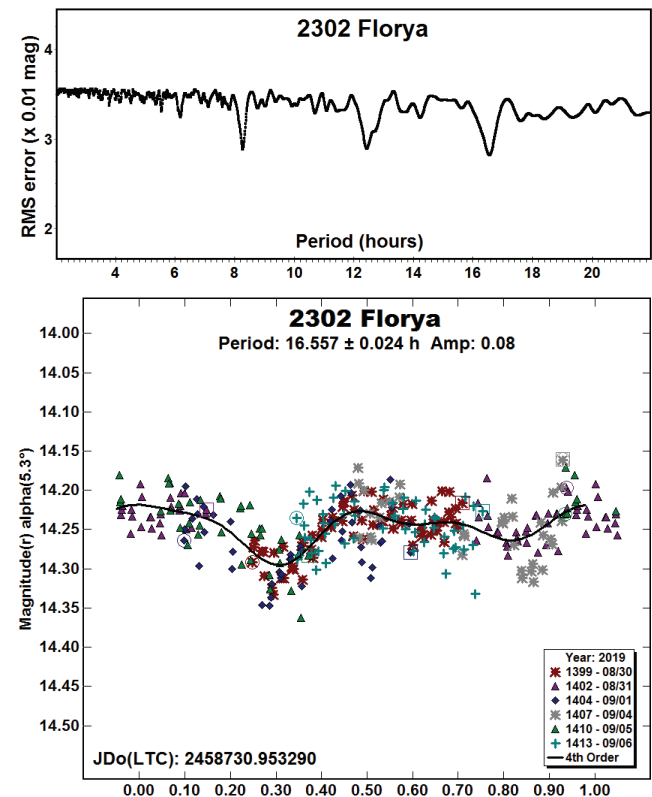
During nine nights around its perihelic opposition, 446 data points were acquired, producing a period solution of 52.77 ± 0.07 h. The RMS scatter on the fit is 0.046 mag. The amplitude is 0.33 mag.

The asteroid will be 2.6 magnitudes fainter during its next opposition in 2021.



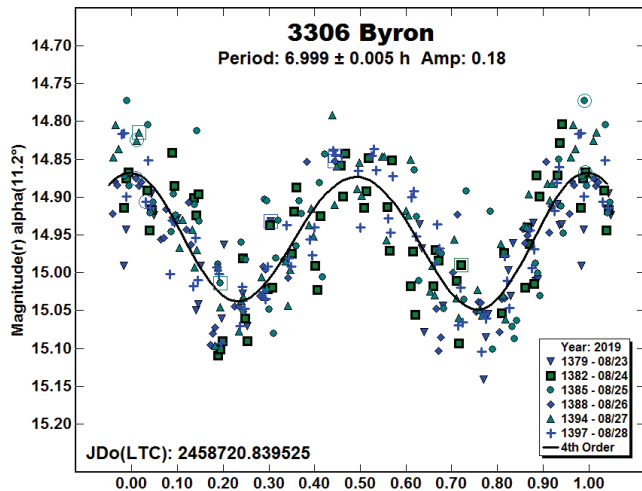
2302 Florya. This Eunomia-family minor planet was discovered at Nauchnyj by N.E. Kurochkin in 1972. Behrend (2006) computed a period >12 h.

A total of 306 images were taken during six nights. The period spectrum has a minimum coinciding with a bimodal solution of 16.557 ± 0.024 h. Due to its small amplitude of 0.08 mag., the RMS error of the Fourier fit is significant (0.028 mag).



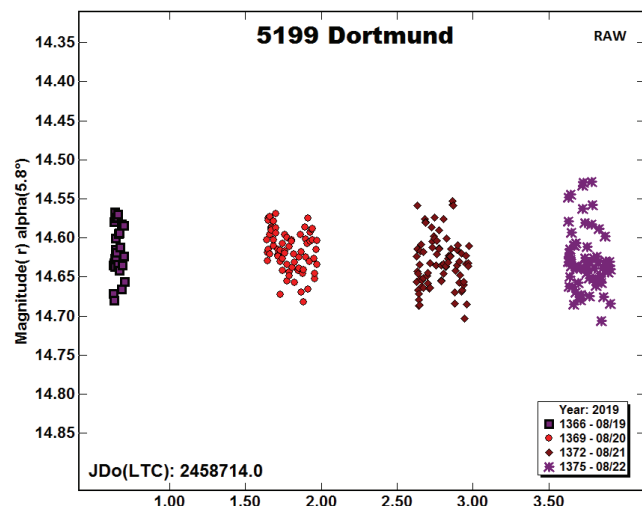
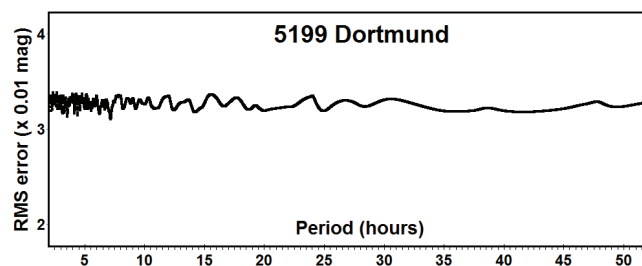
3306 Byron was discovered at Nauchnyj by Nikolai Chernykh in 1979. Two rotation periods appear in the LCDB. Moravec (2013) computed 7.321 ± 0.005 h and Behrend (2019) found 7.013 ± 0.004 h.

During six nights in 2019 August, 294 data points were collected. The rotation period is 6.999 ± 0.005 h, agreeing closely with Behrend's determination. The lightcurve shows an amplitude of 0.18 mag with an RMS error on the fit of 0.049 mag.



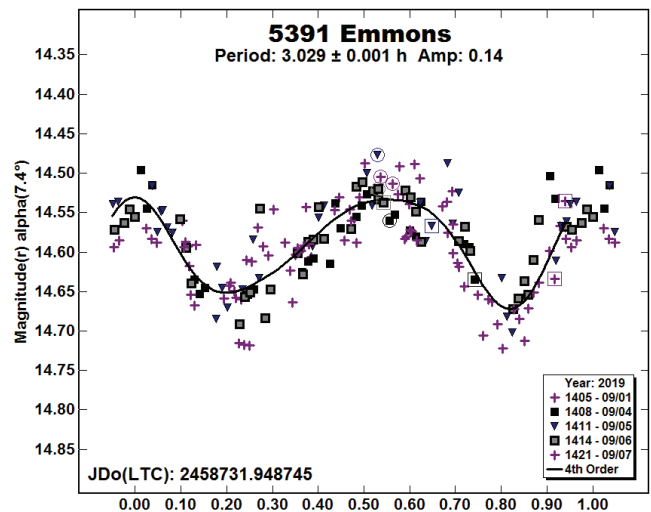
5199 Dortmund was discovered in 1972, also by N.E. Kurochkin at Nauchnyj. No rotation periods appear in the LCDB.

During four nights in 2019 August, 242 images were taken. The period spectrum showed no significant troughs, and the raw lightcurve exhibits no long-term trend. Therefore, a period could not be determined. The next opposition in 2020 will be aphelic, at which time the minor planet will be 1.6 magnitudes fainter.

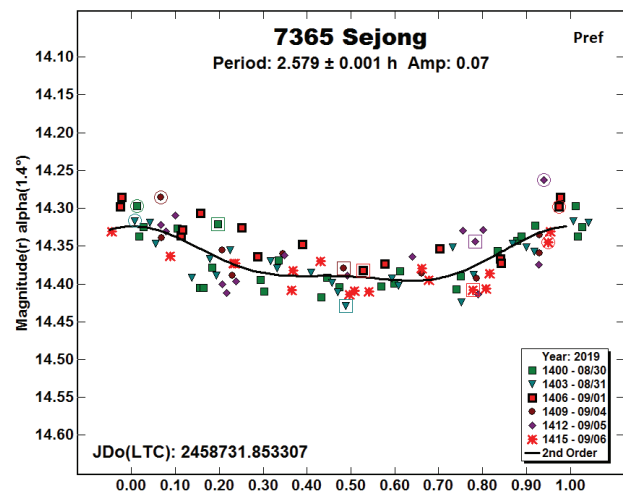
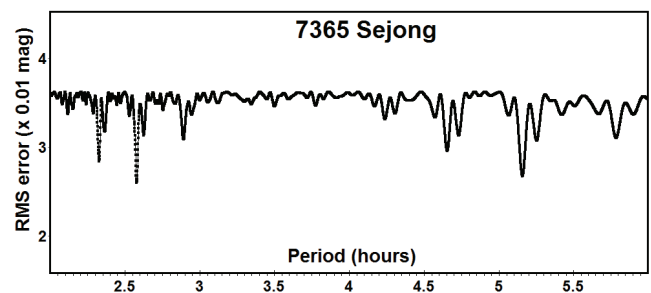


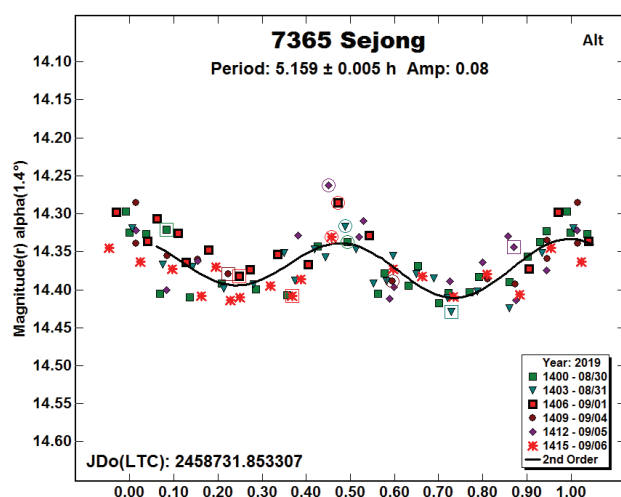
5391 Emmons. Elanor Helin discovered this inner main-belt asteroid at Palomar in 1985. The only period in the LCDB is that of Clark (2003), who published 3.028 ± 0.004 h.

During five nights near the perihelic opposition of 2019 September, 189 images were sufficient to obtain a good period solution of 3.029 ± 0.001 h, agreeing with Clark. The lightcurve amplitude is 0.14 mag, and the RMS error of the curve fit is 0.033 mag.



7365 Sejong. Kazuro Watanabe discovered this Flora-family asteroid in 1996 at Sapporo. Pravec (2019) shows a period of 2.5802 ± 0.0002 h.





During six nights, 269 data points were acquired. The amplitude of the phased lightcurve is small, so binning sets of three points improved the RMS error of the fit. Whereas 4th-order fits are appropriate elsewhere, 2nd-order fits were more appropriate due to the high scatter associated with these points. The derived monomodal period is 2.579 ± 0.001 h, agreeing with Pravec's assessment. However, the bimodal period of 5.159 ± 0.005 h cannot be ruled out. The RMS error for the monomodal fit is 0.026 mag, which is significant relative to the amplitude of 0.07 mag. Due to its highly eccentric orbit, 7365 Sejong will be 2.7 magnitudes fainter during its 2021 opposition.

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