# PERIOD DETERMINATIONS FOR TWENTY MINOR PLANETS

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Phased lightcurves and synodic rotation periods for 20 main-belt asteroids are presented, based on CCD observations made from 2020 December through 2021 February. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 20 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 2020 December and 2021 February.

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.

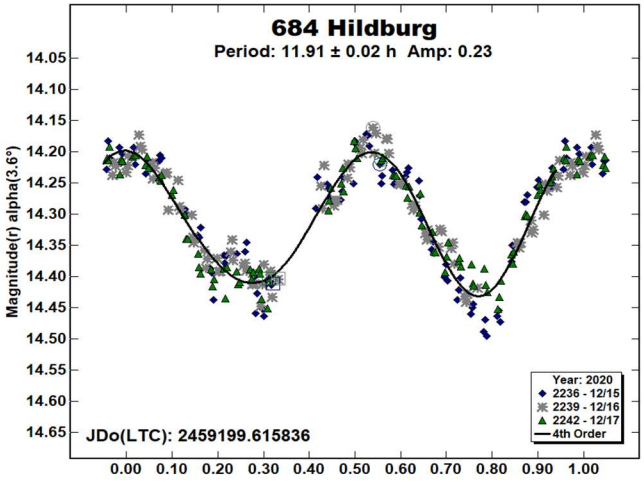
The data reduction and period analysis were done using *MPO Canopus* (Warner, 2020). The 45′×30′ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of 0.5 < B-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.

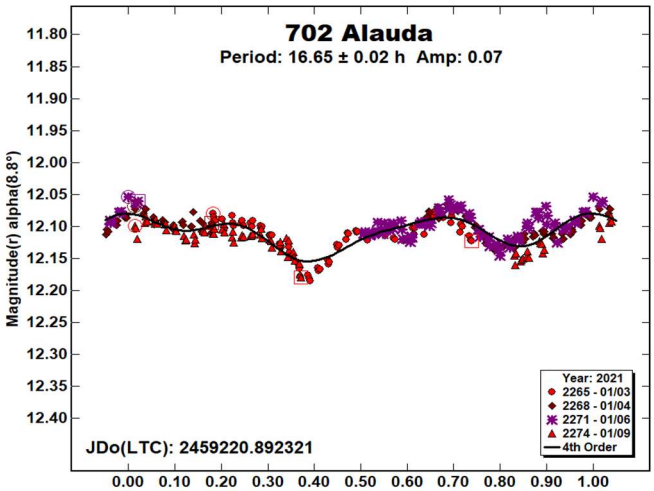
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall 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.

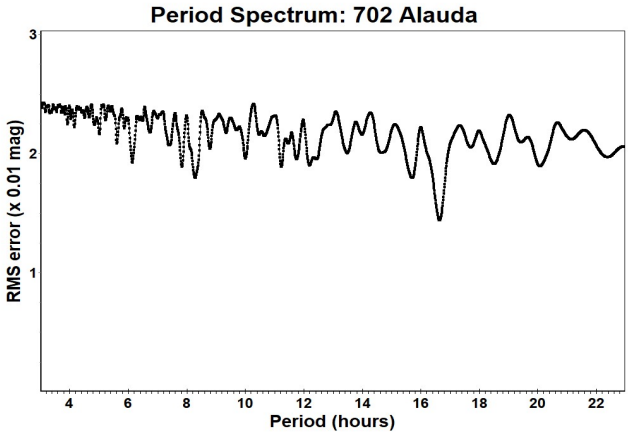
Most asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude brighter than 15.5 and quality of results, U, less than 2+. In this set of observations, 5 of the 21 asteroids had no previous period analysis, 14 had U = 2, and one was U = 3. The Asteroid Lightcurve Database (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.

684 Hildburg lies in the inner main belt. It was discovered by August Kopff at Heidelberg in 1909. Binzel (1987) published a rotational period of 11.92 h, Ferrero (2014) computed 15.89 ± 0.01 h, and Behrend (2018) shows 14.2 ± 0.1 h. A total of 277 images were gathered over the course of three nights, producing a period of 11.91 ± 0.02 h, agreeing with Binzel's value. The lightcurve has an amplitude of 0.23 mag. with an RMS error of 0.026 mag.

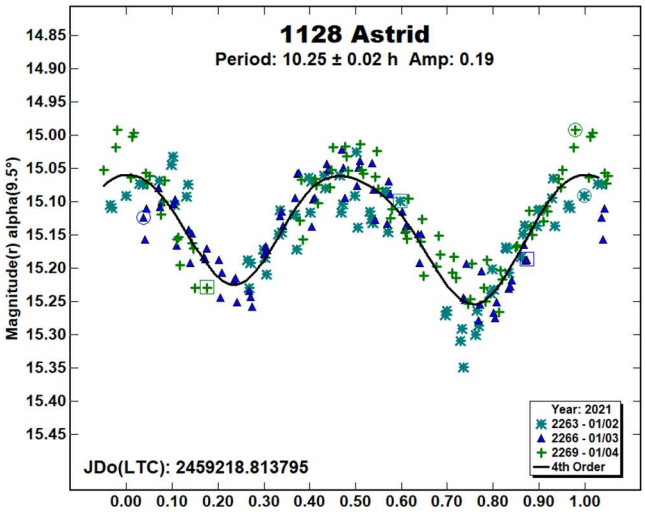



702 Alauda. This outer main-belt asteroid was discovered at Heidelberg in 1922 by Joseph Helffrich. Multiple, similar period solutions have been published. They include Benishek and Protitch-Benishek (2008), 8.3539 ± 0.0007 h; Alkema (2014), 8.3531 ± 0.0004 h; and Polakis (2020), 8.333 ± 0.006 h. Behrend (2019) indicates double this period: 16.7072 ± 0.0003 h. In four nights, 315 data points were used to calculate a period of 16.65 ± 0.02 h, with an amplitude of 0.07 ± 0.014 mag. This agrees with Behrend's solution, although the small amplitude results in some uncertainty. The period spectrum is presented to show the fit error for both periods. Note the weak signal at the half period.

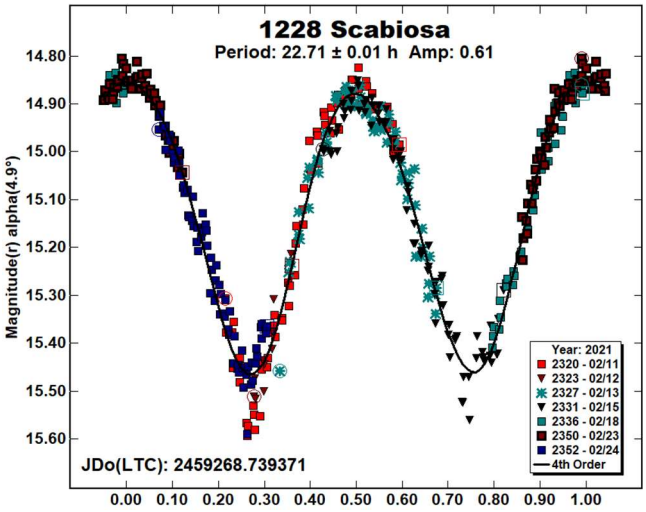




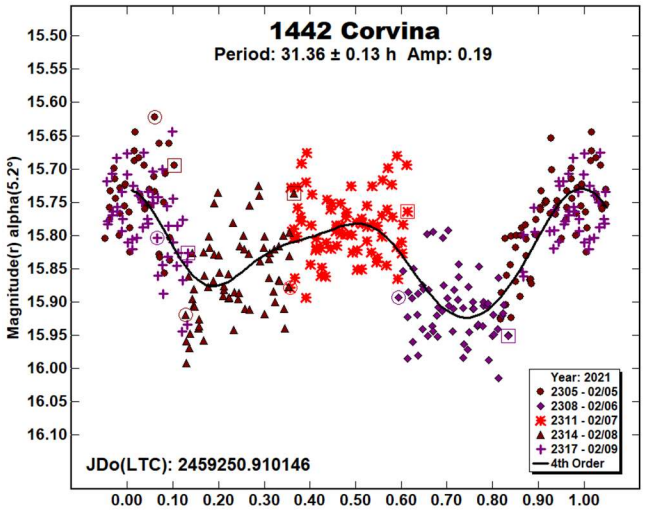

1128 Astrid was discovered in 1929 by Eugène Delporte. Among the period solutions in the LCDB are that of Behrend (2005), 10.228 ± 0.002 h; Waszczak et al. (2015), 10.229 ± 0.0031 h, and Ditteon et al. (2018), 14.552 ± 0.011 h. A total of 206 data points obtained during three nights were used to calculate a period solution of 10.25 ± 0.02 h, agreeing with Behrend and Waszczak. The amplitude of the lightcurve is 0.19 ± 0.034 mag.




1228 Scabiosa. This outer main belt asteroid was discovered at Heidelberg in 1931 by Karl Reinmuth. The LCDB shows no period solutions. Data was gathered on seven nights, but a 13-day interval was required due to its rotation period being nearly commensurate with that of the earth. The 417 images were used to compute a period solution of 22.71 ± 0.01 h, and an amplitude of 0.61 ± 0.037 mag.



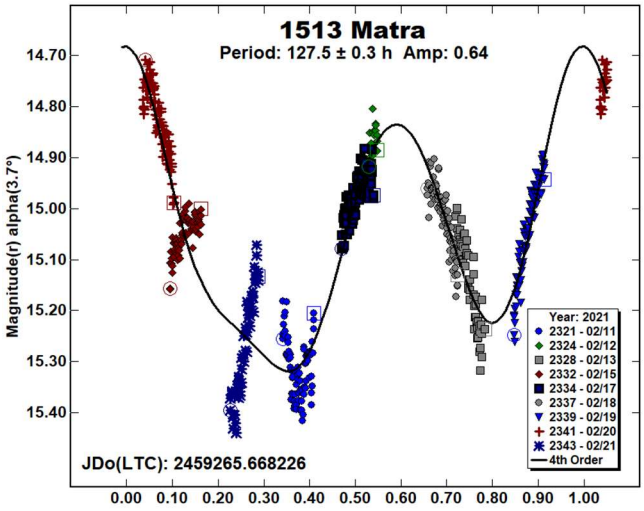

1442 Corvina is a member of the Koronis family. It was discovered at Budapest in 1937 by György Kulin. No periods are shown in the LCDB. During four nights, 339 images were gathered, producing a period solution of 31.36 ± 0.13 h. The RMS scatter on the fit of 0.056 mag. is high relative to the amplitude of 0.19 mag.

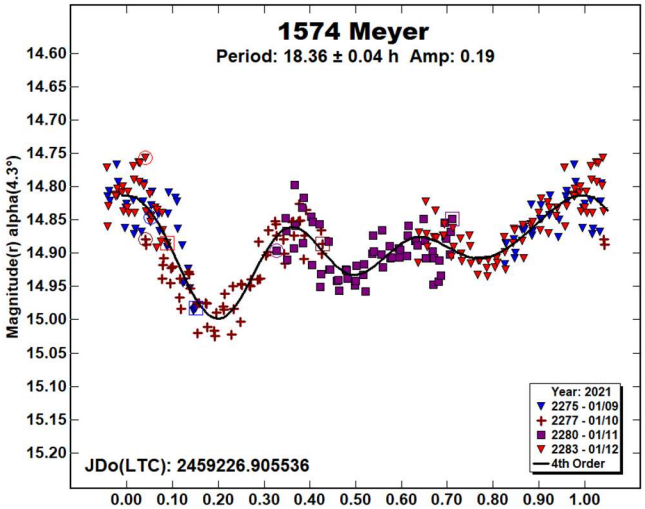



1513 Matra is a Flora-family asteroid, discovered at Budapest in 1940, also by György Kulin. Rowe (2019) published a period of 34.48 ± 0.02 h. During a nine-night interval, 607 images were obtained, yielding a synodic period of 127.5 ± 0.3 h, which disagrees with Rowe's period. The amplitude is 0.54 mag., and the RMS error on the fit is 0.061 mag. Misaligned points against the Fourier fit indicate tumbling.

| Number | Name | yy/mm/dd | Phase | $L_{PAB}$ | $B_{PAB}$ | Period(h) | P.E. | Amp | A.E. | Grp |
|---|---|---|---|---|---|---|---|---|---|---|
| 684 | Hildburg | 20/12/15-12/17 | 3.6,4.0 | 81 | 7 | 11.91 | 0.02 | 0.23 | 0.03 | MB-I |
| 702 | Alauda | 21/01/03-01/09 | 8.8,10.4 | 79 | 11 | 16.65 | 0.02 | 0.07 | 0.01 | MB-O |
| 1128 | Astrid | 21/01/02-01/04 | 9.5,10.2 | 78 | 1 | 10.25 | 0.02 | 0.19 | 0.03 | MB-O |
| 1228 | Scabiosa | 21/02/11-02/24 | *4.9,1.4 | 153 | -2 | 22.71 | 0.01 | 0.61 | 0.04 | MB-O |
| 1442 | Corvina | 21/02/05-02/09 | 5.2,6.7 | 123 | -2 | 31.36 | 0.13 | 0.19 | 0.06 | KOR |
| 1513 | Matra | 21/02/11-02/21 | *3.7,2.8 | 148 | 1 | 127.5 | 0.3 | 0.64 | 0.06 | FLOR |
| 1574 | Meyer | 21/01/09-01/12 | 4.3,4.9 | 101 | -11 | 18.36 | 0.04 | 0.19 | 0.03 | MB-O |
| 1612 | Hirose | 21/02/07-02/13 | 2.3,0.7 | 144 | -2 | 12.28 | 0.01 | 0.27 | 0.03 | MB-O |
| 1844 | Susilva | 21/01/13-01/14 | 2.1,2.5 | 101 | 3 | 5.423 | 0.011 | 0.18 | 0.03 | EOS |
| 2035 | Stearns | 21/01/02-01/12 | 15.3,19.7 | 75 | 5 | 132.7 | 1.1 | 0.22 | 0.04 | H |
| 2045 | Peking | 21/02/07-02/20 | 5.1,10.3 | 133 | 8 | 158.7 | 0.3 | 0.83 | 0.06 | V |
| 2437 | Amnestia | 20/12/15-12/22 | 5.9,9.3 | 75 | -3 | 82.7 | 0.2 | 0.51 | 0.05 | FLOR |
| 2533 | Fechtig | 21/01/10-01/14 | 0.9,2.3 | 109 | -2 | 15.41 | 0.04 | 0.16 | 0.04 | THM |
| 2655 | Guangxi | 21/02/05-02/06 | 9.5,9.8 | 117 | 12 | 11.06 | 0.04 | 0.34 | 0.06 | MB-O |
| 2746 | Hissao | 21/01/13-01/14 | 5.3,5.7 | 106 | -5 | 3.185 | 0.003 | 0.34 | 0.06 | FLOR |
| 2950 | Rousseau | 20/12/18-12/22 | 4.5,5.8 | 83 | -6 | 36.27 | 0.12 | 0.12 | 0.02 | MB-O |
| 3935 | Toatenmongakkai | 20/12/15-12/23 | 5.1,7.1 | 83 | 8 | 104.6 | 0.69 | 0.69 | 0.05 | MB-I |
| 3955 | Bruckner | 21/01/15-01/17 | 5.9,6.2 | 110 | 13 | 7.566 | 0.008 | 0.25 | 0.04 | EOS |
| 4612 | Greenstein | 21/02/05-02/06 | 5.3,5.7 | 129 | 6 | 3.006 | 0.002 | 0.24 | 0.04 | MB-I |
| 4632 | Udagawa | 21/02/05-02/06 | 3.6,4.5 | 112 | 4 | 3.572 | 0.001 | 0.64 | 0.06 | FLOR |

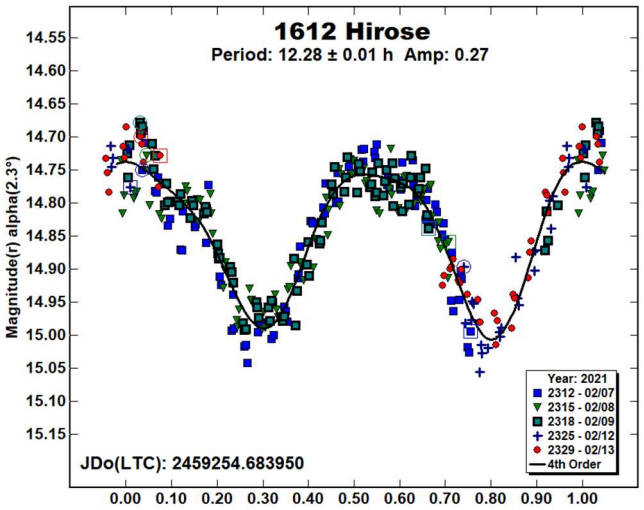
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. $L_{PAB}$ and $B_{PAB}$ are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



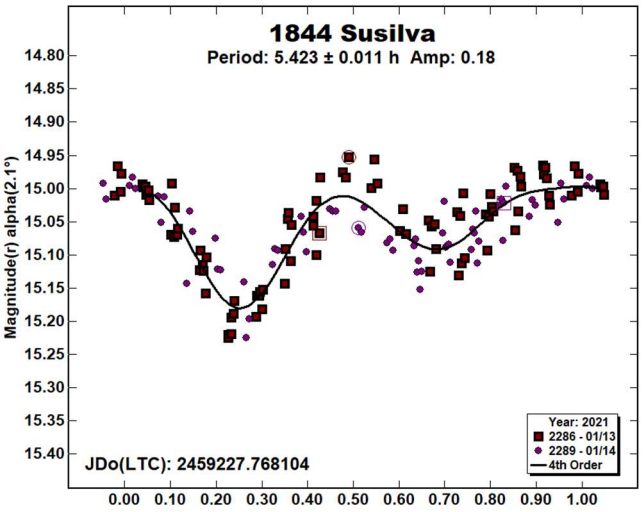




1574 Meyer, an outer main belt minor planet, was discovered by Louis Boyer at Algiers in 1949. The only entry in the LCDB is that of Carbo (2009), who shows a period of 12.64 ± 0.05 h. The asteroid was observed on four nights, and 259 images were obtained. The period spectrum showed a deep minimum at 18.36 ± 0.04 h, disagreeing with Carbo's result. The amplitude is 0.19 mag., with an RMS error on the fit of 0.029 mag.

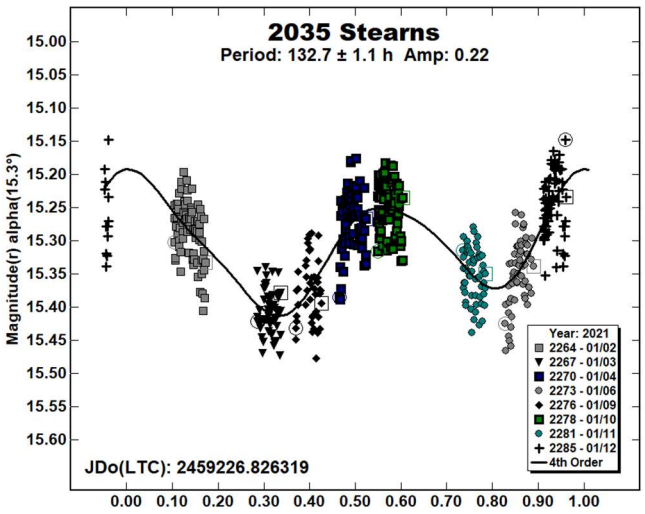
1612 Hirose. Karl Reinmuth discovered this asteroid at Heidelberg in 1950. Waszczak et al. (2015) produced the only period solution, 12.295 ± 0.0028 h. After five nights, 321 images were sufficient to produce a period solution of 12.28 ± 0.01 h, agreeing with Waszczak's analysis. The lightcurve has an amplitude of 0.27 ± 0.031 mag.



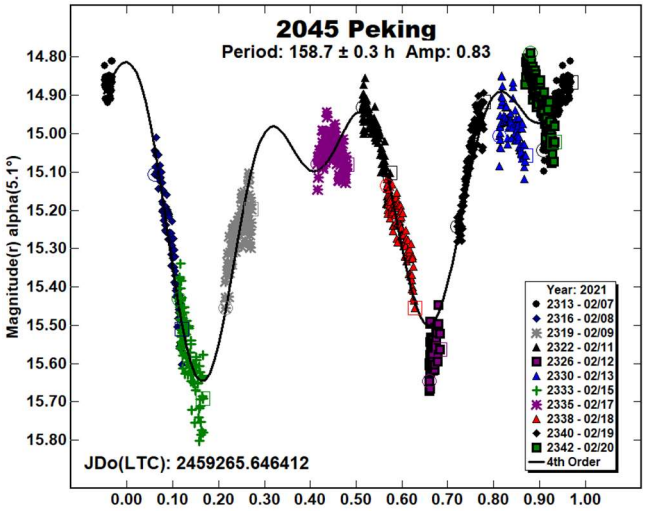

1844 Susilva. This EOS-family minor planet was discovered in 1972 by Paul Wild at Zimmerwald. Pál et al. (2020) shows a synodic period of 5.39557 ± 0.00005 h. During two nights, 143 images were secured, resulting in a period solution of 5.423 ± 0.011 h, and an amplitude of 0.18 ± 0.033 mag.



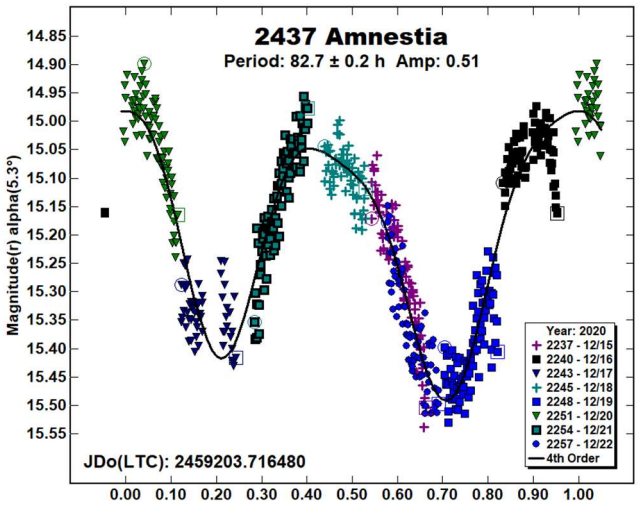

2035 Stearns is a Hungaria asteroid in a highly inclined orbit, discovered by James Gibson at El Leoncity in 1973. Among the discordant period solutions are Warner et al. (2010), 51.89 ± 0.20 h; Stephens (2014), 93 ± 1 h; and Behrend (2019), 20.79 ± 0.06 h. A total of 517 observations were made in eight nights, yielding a period of 132.7 ± 1.1 h. The amplitude is 0.22 ± 0.041 mag.



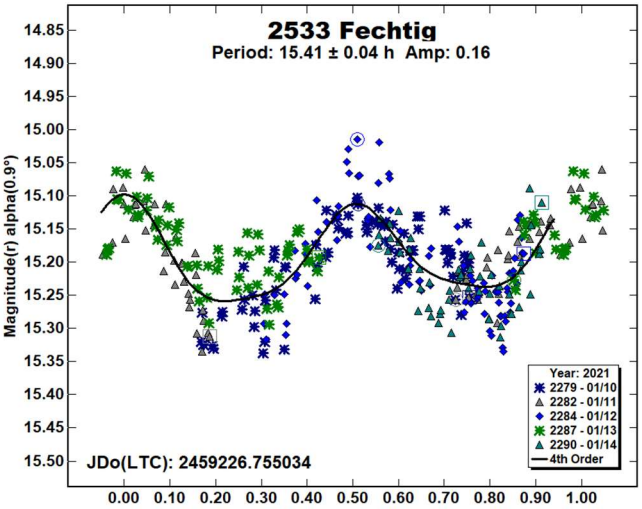

2045 Peking was discovered at Purple Mountain Observatory in Nanking in 1964. Stephens (2017) computed a period of 82.4 ± 1.0 h, and Behrend (2019) calculated 52.43 ± 0.05 h. During 13 nights, 239 images were taken. While the fit is crude, the two deep minima indicate a period of 158.7 ± 0.7 h, disagreeing with previous results. The lightcurve has an amplitude of 0.83 mag., and an RMS error on the fit of 0.064 mag.



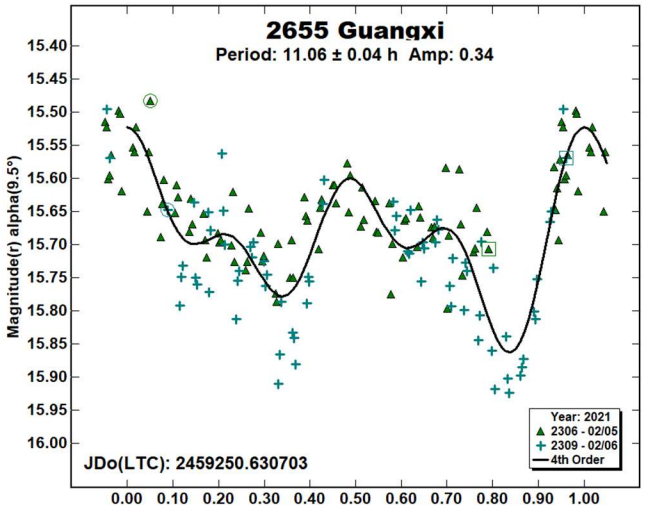

2437 Amnestia. Yrjö Väisälä discovered this Flora-family asteroid from Turku in 1942. Ruthroff (2011) calculated a period of 85 ± 5 h. It was observed on eight consecutive nights, and 615 images were taken. The best solution appears at 82.7 ± 0.2 h. The lightcurve has an amplitude of 0.51 ± 0.052 mag. The stray points are an indication of tumbling.



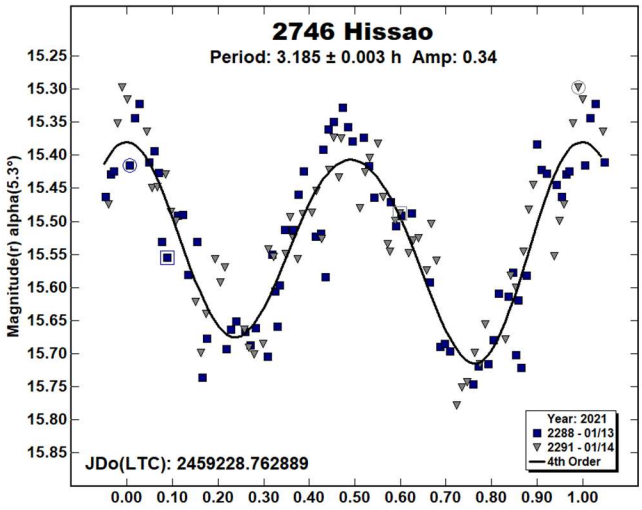

2533 Fechtig was discovered in 1905 by Max Wolf at Heidelberg. The LCDB shows no period solutions. A total of 353 images were taken during three nights. The synodic period is 15.41 ± 0.04 h, and the amplitude is 0.16 ± 0.042 mag.



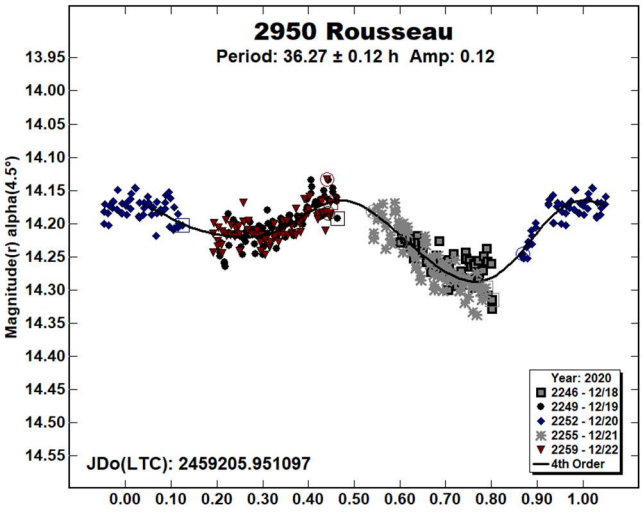

2655 Guangxi. This outer main-belt minor planet was discovered in 1974 at Purple Mountain Observatory in Nanking. No period solutions have been published. During two nights, 160 images were obtained, which produced a synodic period solution of 11.06 ± 0.04 h, and an amplitude of 0.34 ± 0.056 mag.



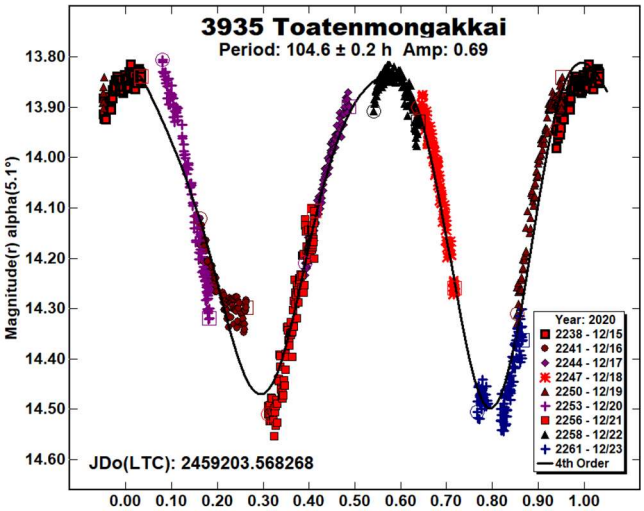

2746 Hissao. Nikolai Chernykh discovered this Flora-family asteroid at Nauchnyj in 1979. Three similar period solutions are in the LCDB: Loera-Gonzalez et al. (2019), 3.1848 ± 0.0015 h; Zeigler et al. (2019), 3.18 ± 0.01 h, and Erasmus et al. (2020), 3.185 ± 0.001 h. Two nights and 130 images provided sufficient coverage to calculate a period of 3.185 ± 0.003 h, agreeing with previous assessments. The lightcurve has an amplitude of 0.34 mag, and an RMS fit error of 0.056 mag.



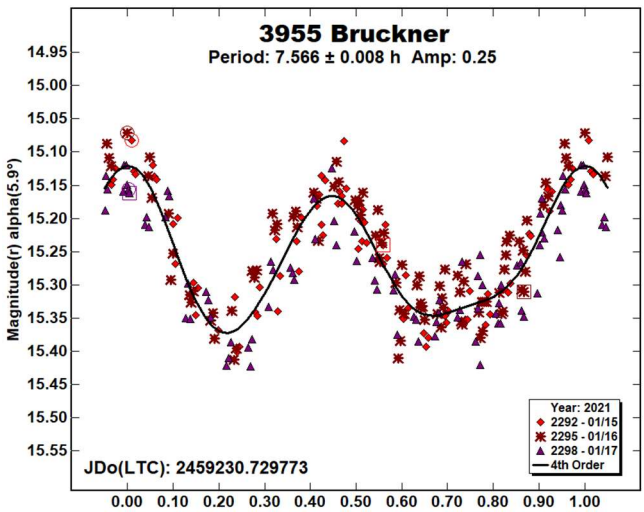

2950 Rousseau is an outer main-belt asteroid, discovered by Paul Wild at Zimmerwald in 1974. Its highly eccentric orbit brought it to a favorable 2020 opposition. Behrend (2012) shows a period of 18.228 ± 0.003 h. After five nights, 383 data points were used to determine a period of 36.27 ± 0.12 h, and an amplitude of 0.12 ± 0.018 mag.



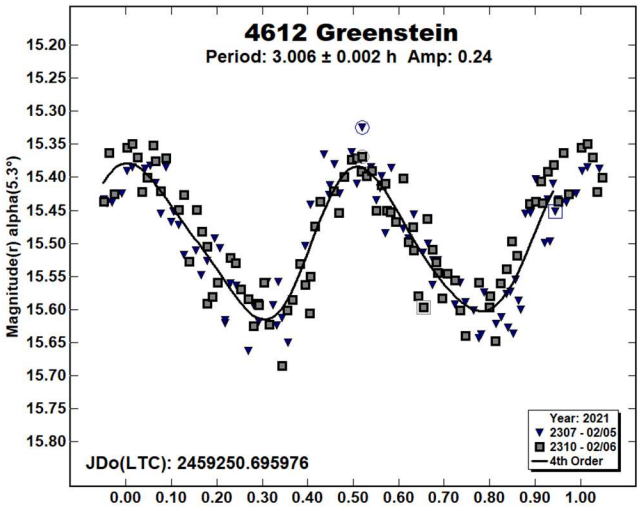

3935 Toatenmongakkai. Is an inner main-belt asteroid in an eccentric orbit. Its discovery was made by Tsutomu Seki in 1987 at Geisei. Behrend (2005) shows a rotational period of 106.3 h. The asteroid was observed on nine consecutive nights, and 875 data points were acquired. A period solution of 104.6 ± 0.2 h was obtained, agreeing with Behrend. The amplitude is 0.69 mag, and the RMS error is 0.049 mag.



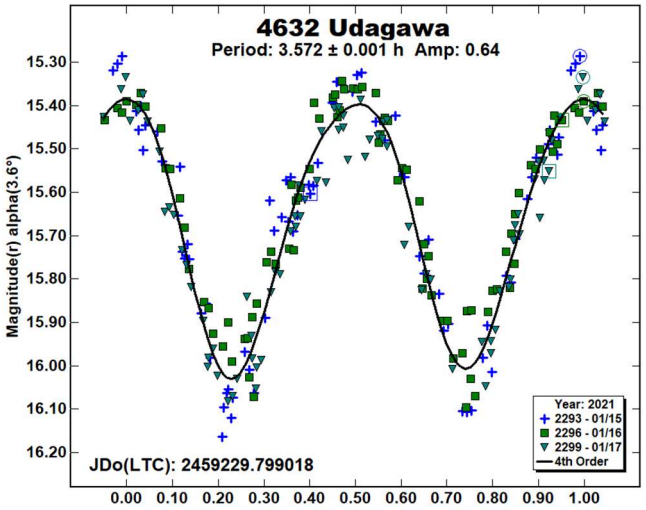

3955 Bruckner was discovered by Freimut Börngen in 1988 from Tautenberg. No period solutions for it appear in the LCDB. During three nights, 246 images were sufficient to determine a rotation period of 7.566 ± 0.008 h. The amplitude of the lightcurve is 0.25 ± 0.039 mag.




4612 Greenstein. This inner main-belt minor planet was discovered in 1989 at Palomar by Eleanor Helin. No period solutions for it have been published. A total of 167 images were taken in two nights, yielding a synodic period of 3.006 ± 0.002 h, and an amplitude of 0.24 ± 0.038 mag.




4632 Udagawa is a Flora-family asteroid, discovered at Chiyoda by Takuo Kojima in 1987. Erasmus et al. (2020) shows a period of 3.570 ± 0.001 h. It was observed for three nights, during which 243 images were acquired. The computed synodic period is 3.572 ± 0.001 h, and the amplitude is 0.64 ± 0.061 mag.

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