LIGHTCURVES FOR THIRTEEN MINOR PLANETS

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(Received: 2022 January 4)

Photometric measurements were made for 13 main-belt asteroids, based on CCD observations made from 2021 October through December. Phased lightcurves were created for 12 asteroids, while one did not yield a period solution. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 13 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 2021 October and 2021 December.

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.

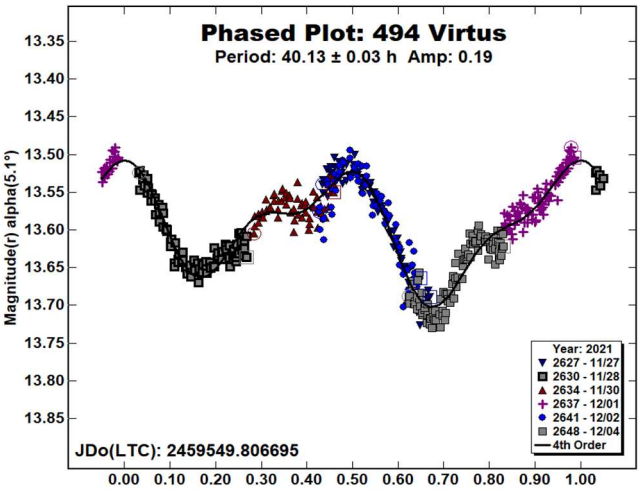
The data reduction and period analysis were done using *MPO Canopus* (Warner, 2020). The 45'×30' field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected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

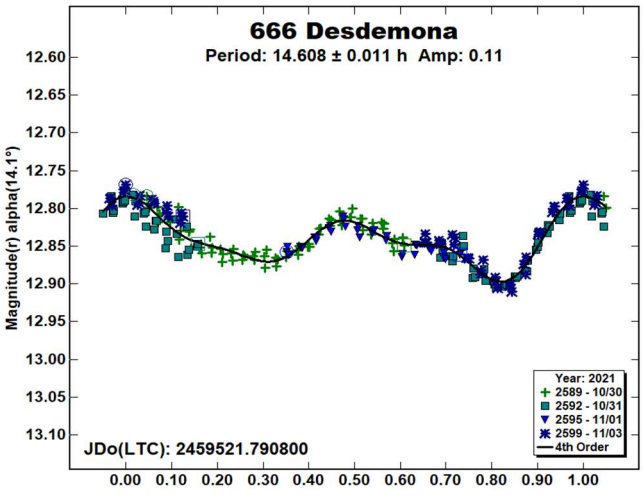
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall 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. In cases where rotation periods could not be determined, raw lightcurves are presented, with "Raw" appearing in the upper right-hand corner of the plots.

Most asteroids were selected from the CALL website (Warner, 2011) In this set of observations, 2 of the 13 asteroids had no previous period analysis, 2 had U = 1, 9 had U = 2, and 1 had 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.

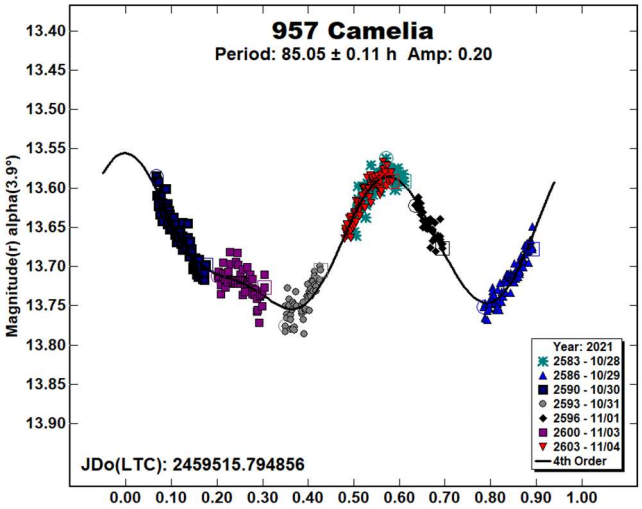
494 Virtus was discovered by Max Wolf at Heidelberg in 1902. Several papers show short rotational periods: Behrend (2008web) 4.9903 ± 0.0004 h; Warner (2006) 5.57 ± 0.01 h; and Hamanowa (2009) 5.570 ± 0.003 h. Polakis (2018) computed a longer period of 49.427 ± 0.022 h. During six nights, 508 images were taken to determine a period of 40.13 ± 0.03 h, disagreeing with previous values. The amplitude of the lightcurve is 0.19 ± 0.02 mag.



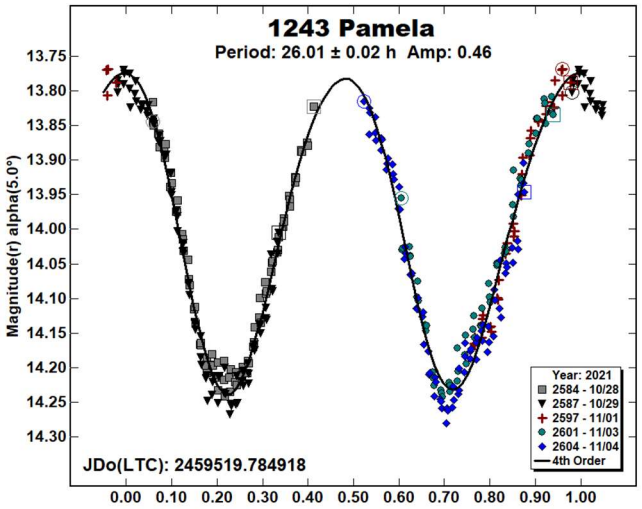
666 Desdemona. This inner main-belt asteroid was discovered by August Kopff at Heidelberg in 1908. The most recent of the many concurring period solutions are Pál et al. (2020) 14.5995 ± 0.0005 h and Dose (2022) 14.612 ± 0.014 h. This asteroid has a very eccentric orbit (e = 0.24), and the 2021 opposition was favorably close. A total of 219 data points were acquired during four nights, producing a period solution of 14.608 ± 0.011 h and an amplitude of 0.11 ± 0.01 mag.



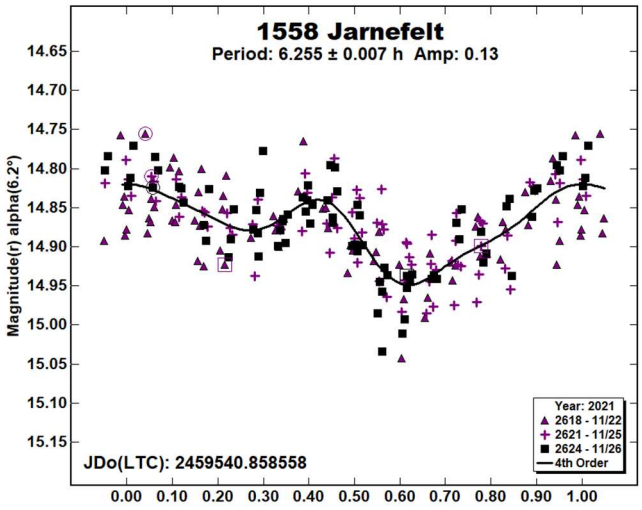
957 Camelia is one of Karl Reinmuth's many discoveries at Heidelberg, having been announced in 1921. Warner (2001) derived a period of 5.391 ± 0.02 h, and Behrend (2020web) shows 8.984 ± 0.004 h. Obtained over seven nights, the 460 data points did not result in any minima in the period spectrum for these short periods, rather the best solution is 85.05 ± 0.11 h. The amplitude of the lightcurve is 0.20 ± 0.12 mag.



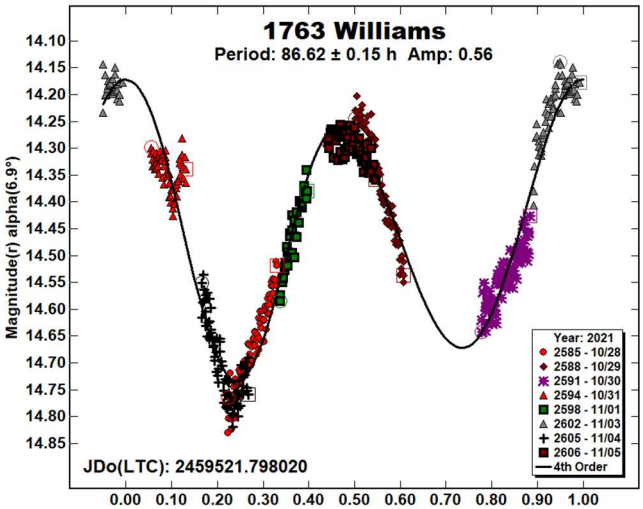
1243 Pamela is an outer main-belt asteroid, discovered by Cyril Jackson at Johannesburg in 1932. The most precise period determinations are those of Warner (2000), who published 26.017 ± 0.013 h and Garceran et al. (2016), who obtained 26.00 ± 0.01 h. During five nights, 348 images were acquired, yielding a solution of 26.01 ± 0.02 h with an amplitude of 0.46 ± 0.02 mag.



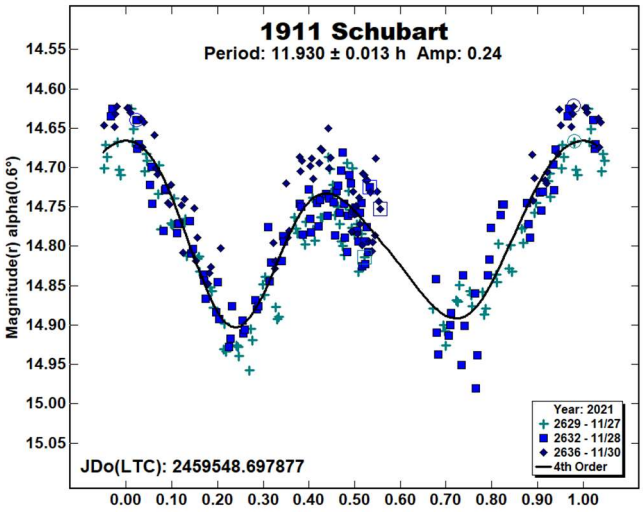
1558 Jarnefelt. Liisi Oterma made the discovery of this minor planet in Turku in 1942. Two period solutions are found in the LCDB: Hawkins and Ditteon (2016; 18.22 ± 0.06 h) and Polakis (2019; 6.252 ± 0.003 h). A total of 216 images were gathered in three nights to produce a period solution of 6.255 ± 0.007 h, in agreement with the more recent solution. The amplitude of the lightcurve is 0.13 mag, and the RMS error is 0.04 mag.



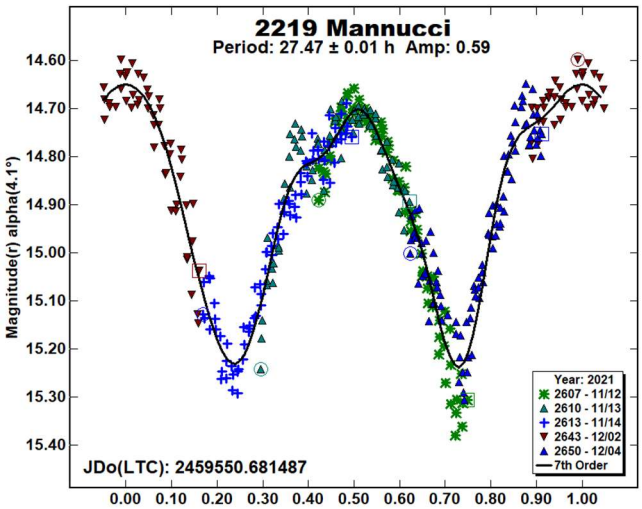
1763 Williams was discovered at Goethe Link Observatory in 1963. Durech et al. (2018) published a sidereal period of 88.030 ± 0.002 h. After eight nights, 533 images were obtained. The resulting period solution is 86.62 ± 0.15 h, in rough agreement with Durech's value. The amplitude is 0.56 ± 0.04 mag. A curious feature resembling that of an eclipse by a companion is apparent at a phase of 0.1. Denser follow-up observations are encouraged.



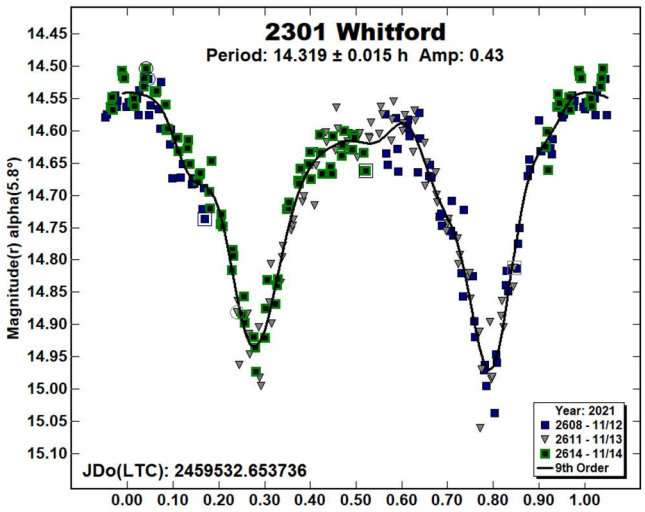
1911 Schubart. This Hilda asteroid was discovered in 1973 by Paul Wild at Zimmerwald. Stephens (2016) found a period of 11.915 ± 0.002 h and Warell (2017) published a value of 7.91 ± 0.02 h. In total, 284 observations were made on three November nights, producing a synodic period of 11.930 ± 0.013 h, which agrees with the solution by Stephens. The lightcurve has an amplitude of 0.24 ± 0.04 mag.



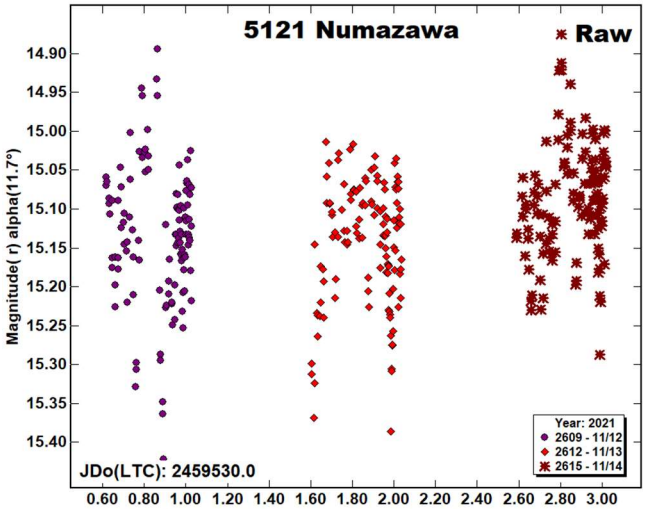
2219 Mannucci. This outer main-belt asteroid was first identified at Felix Aguilar Observatory in 1975. The only period solution in the LCDB is that of Durech et al. (2020), who published 27.4587 ± 0.0003 h. Due to its period being nearly commensurate with earth's rotation, the five observing nights were spaced over a 22-day interval. The synodic period is 27.47 ± 0.01 h, with an amplitude of 0.59 ± 0.05 mag.



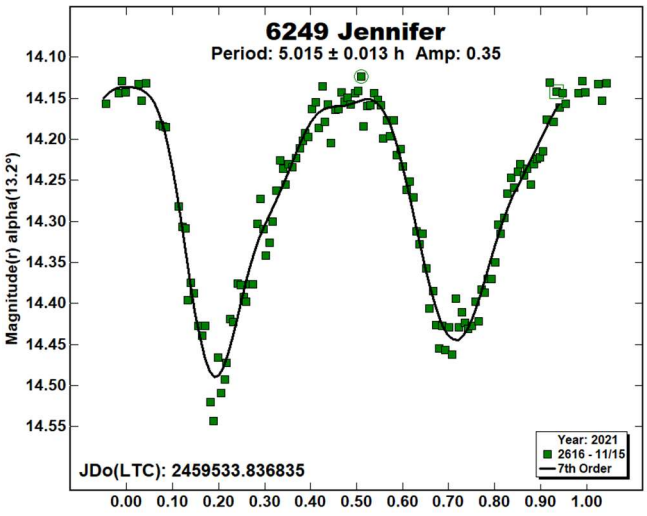
2301 Whitford was discovered at Goethe Link Observatory in 1965. Waszczak et al. (2015) showed a period of 14.275 ± 0.0049 h and Durech et al. (2020) computed 14.30151 ± 0.00006 h. During three nights, 233 images were used to obtain a similar period of 14.319 ± 0.015 h, with an amplitude of 0.43 ± 0.03 mag.



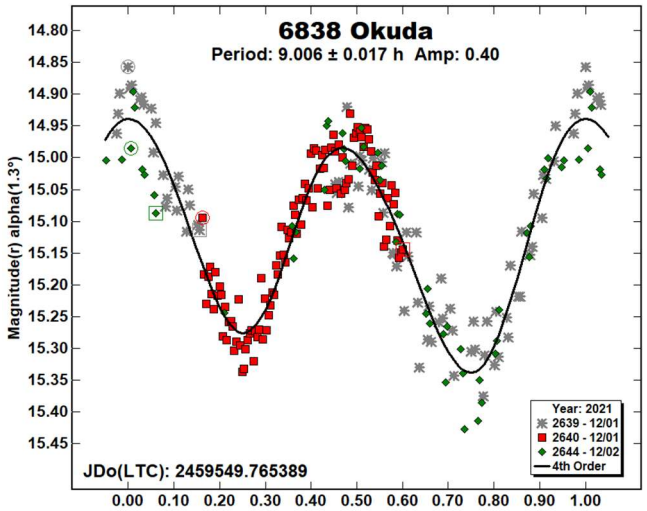
5121 Numazawa is a Flora-family asteroid discovered by Yanai and Watanabe in 1989 at Kitami. No periods appear for it in the LCDB. After three nights, it became apparent that a period would not be easily obtainable at this level of scatter. No period solution was found, and the lightcurve shown is the raw data.



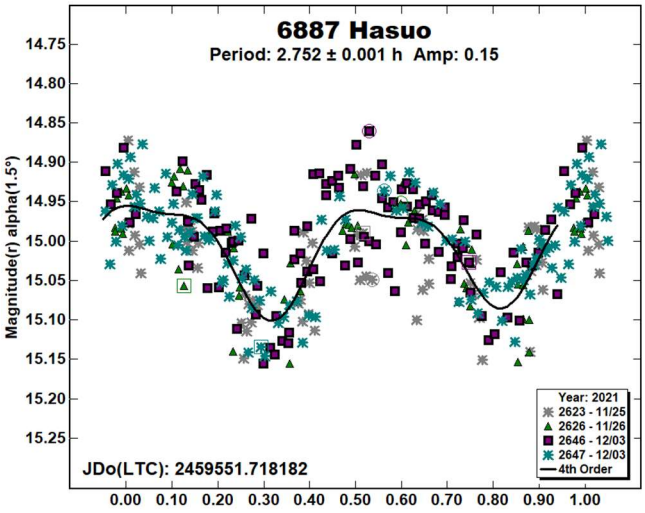
6249 Jennifer is a main-belt asteroid in a highly inclined orbit. It was first identified at Palomar in 1991 by Eleanor Helin. Many concurring period solutions may be found in the LCDB. The most recent of these is Warner (2015), who published a synodic period of 4.957 ± 0.001 h. During a single night, 128 images were gathered, yielding a period of 5.015 ± 0.013 h, with an amplitude of 0.35 ± 0.02 mag.



6838 Okuda. This minor planet's discovery was made by Shiimizu and Urata in 1995 at Nachi-Katsuura. Pligge et al. (2011) found a period of 8.983 ± 0.008 h and Noschese and Vecchione (2018) showed a value of 11.0537 ± 0.0012 h. During two nights, 236 data points were acquired. The resulting period is 9.006 ± 0.017 h, in agreement with Pligge. The amplitude is 0.40 mag, with an RMS error of 0.04 mag.



6887 Hasuo was discovered in 1951 by P.A.E. Laugier at Nice. The sole period solution in the LCDB is that of Waszczak (2015): 2.752 ± 0.0001 h. During three nights, 402 images were gathered. The synodic period is 2.752 ± 0.001 h, matching the published value. The amplitude of the lightcurve is 0.15 ± 0.05 mag.



Acknowledgements

The author would like to express his gratitude to Brian Skiff for his indispensable mentoring in data acquisition and reduction. Thanks also go out to Brian Warner for support of his *MPO Canopus* software package.

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Number	Name	yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
494	Virtus	21/11/27-12/04	5.0,7.5	51	2	40.13	0.03	0.19	0.02	MB-O
666	Desdemona	21/11/30-12/03	25.3,26.0	22	0	14.608	0.011	0.11	0.01	MB-I
957	Camelia	21/10/28-11/04	3.9,6.0	29	7	85.05	0.11	0.20	0.01	MB-O
1243	Pamela	21/10/28-11/04	5.0,6.9	26	10	26.01	0.02	0.46	0.02	MB-O
1558	Jarnefelt	21/11/22-11/26	6.2,7.3	47	-11	6.255	0.007	0.13	0.04	MB-O
1763	Williams	21/10/28-11/05	6.9,10.9	28	6	88.62	0.15	0.56	0.04	MB-I
1911	Schubart	21/11/27-11/30	0.6,1.5	63	1	11.930	0.013	0.24	0.04	SCHU
2219	Mannucci	21/11/12-12/04	4.1,11.8	41	-4	27.47	0.010	0.59	0.05	MB-O
2301	Whitford	21/11/12-11/14	5.8,6.4	41	-9	14.319	0.015	0.43	0.03	MB-O
5121	Numazawa	21/11/12-11/14	11.7,10.6	65	9	--	--	--	--	FLOR
6249	Jennifer	21/11/15-11/15	13.0,13.2	37	-2	5.015	0.013	0.35	0.02	HUN
6938	Okuda	21/12/01-12/02	1.2,1.8	67	0	9.006	0.017	0.40	0.04	MB-M
6887	Hasuo	21/11/25-12/03	1.5,5.8	63	2	2.752	0.001	0.15	0.04	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).

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