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LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2022 JULY-OCTOBER

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CCD photometric observations of eight Hilda asteroids were made at the Center for Solar System Studies between 2022 July and October.

CCD photometric observations of eight Hilda asteroids were carried out at the Center for Solar System Studies (CS3) from 2022 July-October as part of an ongoing study of the family/group that is located between the outer main-belt and Jupiter Trojans in a 3:2 orbital resonance with Jupiter. The goal is to determine the spin rate statistics of the Hildas and to find pole and shape models when possible. We also look to examine the degree of influence that the YORP (Yarkovsky-O'Keefe-Radzievskii-Paddack) effect (Rubincam, 2000) has on distant objects and to compare the spin rate distribution against the Jupiter Trojans, which can provide evidence that the Hildas are more "comet-like" than main-belt asteroids.

Telescopes	Cameras
0.30-m *f*/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m *f*/9.1 Schmidt-Cass	FLI Proline 1001E
0.35-m *f*/11 Schmidt-Cass	SBIG STL-1001E
0.40-m *f*/10 Schmidt-Cass	
0.50-m *f*/8.1 Ritchey-Chrétien	

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

Table I lists the telescopes and CCD cameras that are available to make observations. All the cameras use CCD chips from the KAF 1001 blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel. All lightcurve observations were unfiltered or with a clear filter, even though the latter can result in a 0.1-0.3 magnitude loss. The exposures varied depending on the asteroid's brightness.

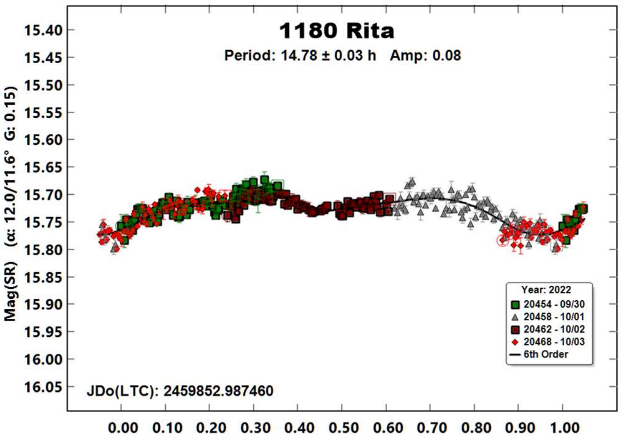
To reduce the number of times and amounts of adjusting nightly zero-points, the ATLAS catalog r´ (SR) magnitudes (Tonry et al., 2018) are used. Those adjustments are usually ≤ ±0.03 mag. The rare greater corrections may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction. Another cause may be selecting what appears to be a single star but is actually an unresolved pair.

The Y-axis values are ATLAS SR "sky" (catalog) magnitudes. The values in the parentheses give the phase angle(s), *a*, and the value of *G* used to normalize the data to the comparison stars used in the earliest session. This, in effect, corrects all the observations so that seem to have been made at a single fixed date/time and phase angle, presumably leaving any variations due only to the asteroid's rotation and/or albedo changes.

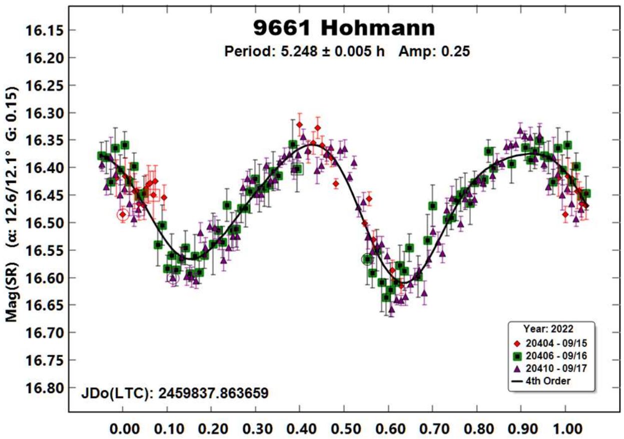
There can be up to three phase angles given. If two, the values are for the first and last night observations. If three, the middle value is the extrema (maximum or minimum) reached between the first and last observing runs. The X-axis shows rotational phase from -0.05 to 1.05. If the plot includes the amplitude, e.g., "Amp: 0.65," this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve.*

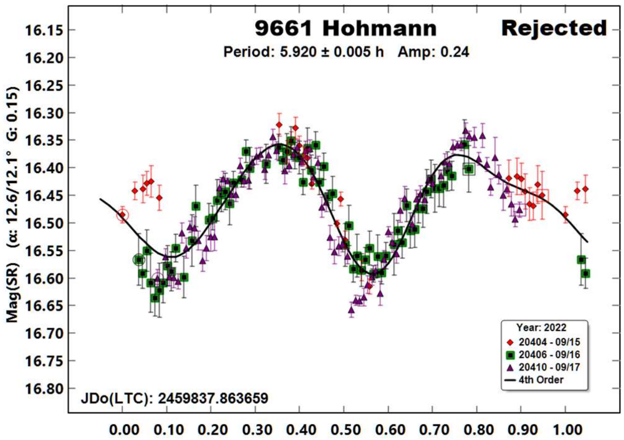
For brevity, only some of the previous results are referenced. A more complete listing is in the asteroid lightcurve database (Warner et al., 2009; "LCDB" from here on).

1180 Rita. Dahlegren et al. (1998) determined a period of 14.902 h for this 78 km Hilda. We had observed it on three previous occasions. In 2017, we found a period of 13.090 h (Warner and Stephens, 2017). After observations in 2018 that led to a period of 14.849 h (Warner and Stephens, 2018), we re-examined the 2017 data and found a period of 14.928 h. In 2021 (Warner and Stephens, 2022) we found a similar period of 14.894 h. As with the 2017 observations, the lightcurve for our most recent data (2022 September and October) has a very low amplitude.



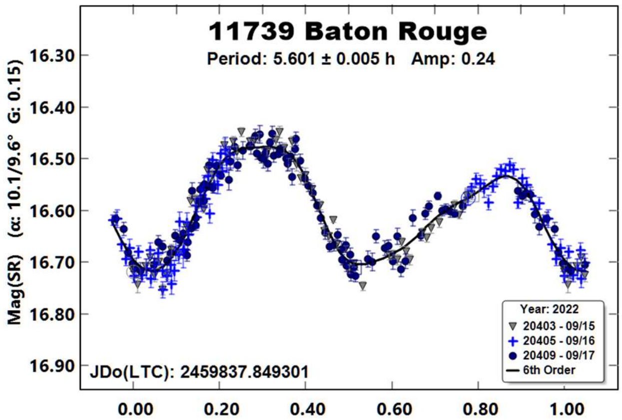
9661 Hohmann. The only previously reported period in the LCDB was from Waszczak et al. (2015), who found a period of 5.920 h. The period spectrum using our 2022 data shows two nearly equal solutions (based on minimum RMS fit to the Fourier curve), one near that by Waszczak et al. and the other at 5.248 h. The two periods differ by one-half rotation over 24-hours.



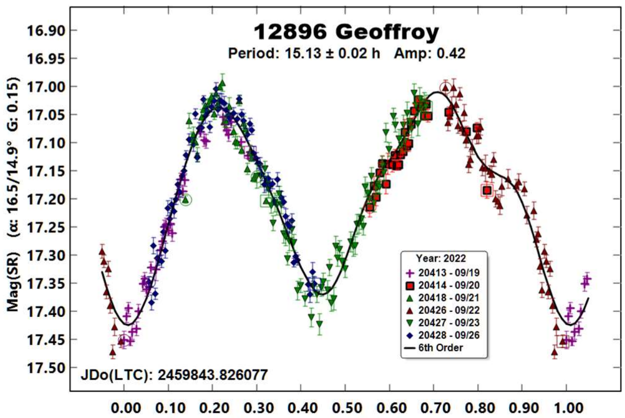


We plotted our data to the two possible solutions. The "Rejected" plot is for the period found by Waszczak et al. and shows significant deviations from the Fourier curve and a gap in coverage. Based on a comparison between the two, we feel confident in adopting 5.248 h as the correct result.

11739 Baton Rouge. Hasegawa et al. (2018) reported a period of 4.8 h for the 22-km Hilda. It is rated U = 2– in the LCDB, meaning rthe solution is barely reliable. Our observations in 2022 September allowed us to find what we believe to be a reliable period of 5.601 h.



12896 Geoffroy. The only previous result in the LCDB was 5.68 h by Chang et al. (2016), but it is considered insufficiently reliable for statistical studies (U = 1+).

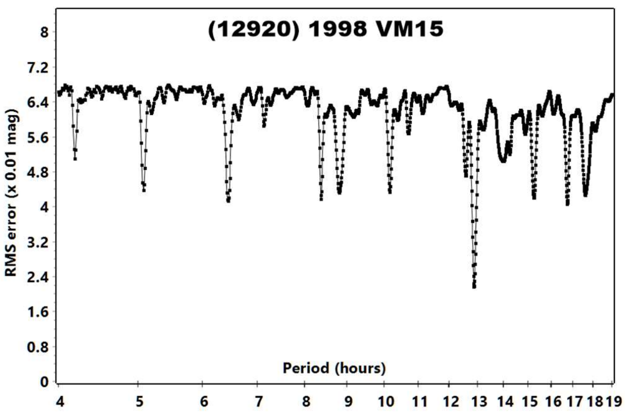


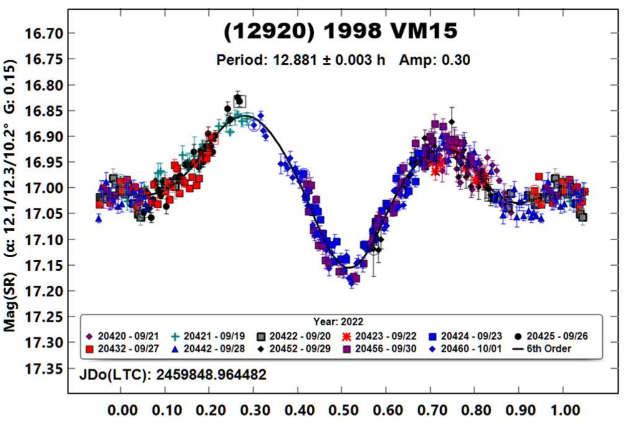
Number	Name	2022/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1180	Rita	09/30-10/03	12.0,11.6	62	-4	14.78	0.03	0.08	0.01
9661	Hohmann	09/15-09/17	12.6,12.1	28	-9	5.248	0.005	0.27	0.02
11739	Baton Rouge	09/15-09/17	10.1,9.5	14	15	5.601	0.005	0.24	0.02
12896	Geoffroy	09/19-09/26	16.5,14.9	43	-1	15.13	0.02	0.42	0.03
12920	1998 VM15	09/19-10/01	12.5,10.2	46	0	12.881	0.003	0.30	0.02
14569	1998 QB32	08/17-08/29	11.2,7.4	354	1	2.5699	0.0005	0.09	0.01
21930	1999 VP61	09/15-09/26	1.7,5.6	348	1	-	-	0.02	0.02
41365	2000 AO98	07/24-08/08	5.5,2.2	315	6	13.148	0.003	0.21	0.03

Table II. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. The asterisk indicates that the phase angle reached an extremum over the span of the observations. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris et al., 1984).

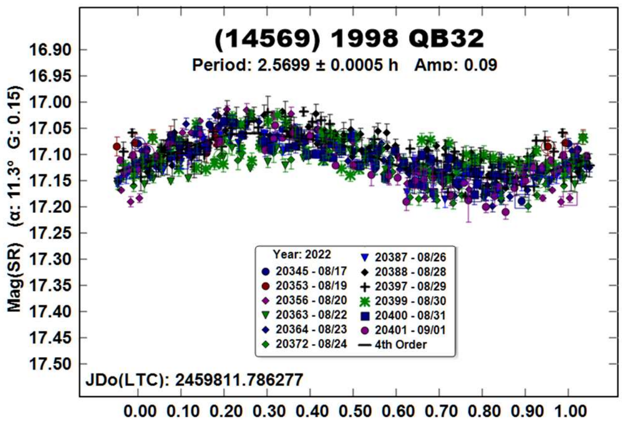
Our observations in 2022 September covered a span of about a week. The resulting data set led to a period of 15.13 h. Given the large amplitude, the lightcurve is almost certainly to be bimodal (Harris et al., 2014), which was confirmed by that being the only solution to fit the data with complete coverage and proper spacing of the maximums and minimums.

(12920) 1998 VM15. Clark (2014) reported a period of 12.885 h for this 35-km Hilda. He subsequently revised it to 9.0511 h after newer observations in 2014 led to $P = 9.1240$ h (Clark, 2015). The period spectrum based on our 2022 data shows only a relatively weak solution for periods near 9 h. Our result and Clark's original period are in close agreement.



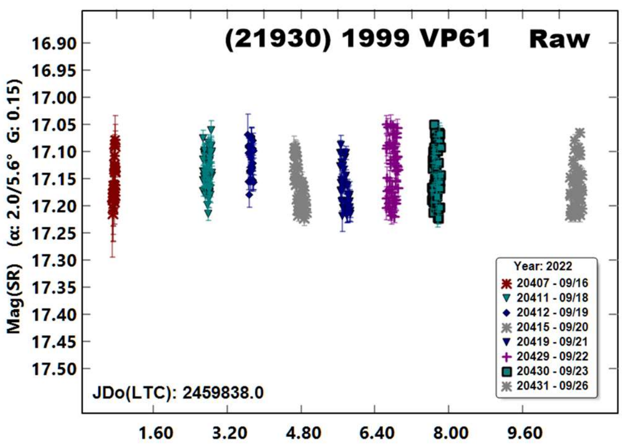


(14569) 1998 QB32. There were no previous period results in the LCDB. The low amplitude led to an ambiguous solution (see Harris et al., 2014).

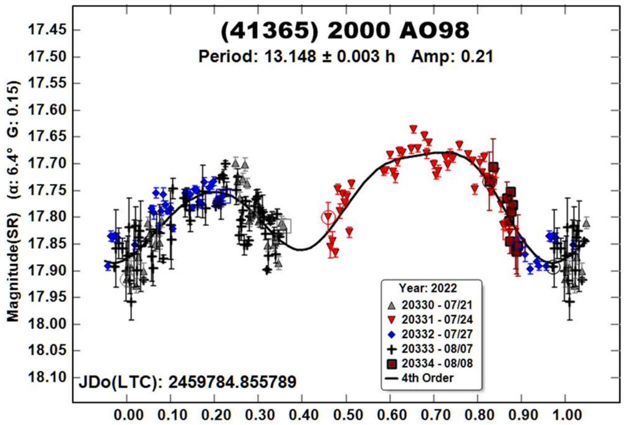


A split-halves plot using a period near 5 hours showed essentially identical halves and so a monomodal solution of 2.57 h was adopted. We note, however, that the double period near 5 h cannot be formally excluded and that both solutions lie below the spin barrier in the LCDB frequency-diameter plot.

(21930) 1999 VP61. There were no previous entries for a period in the LCDB. The estimated diameter is 17 km. A search from 2 to 200 hours, and then from 1 to 10 hours, on the combined and individual data sets found solutions only barely above the noise in the period spectrums. If there is a period to be found, it is well into the noise of the data. It's possible that this apparition was close to a pole-on view. A future apparition, with a more equatorial viewing aspect, might lead to a lightcurve with at least a modest amplitude.



(41365) 2000 AO98. There were no previously reported periods in the LCDB. The period spectrum based on our 2022 data showed a few possibilities.



We adopted a period of 13.148 h since it produced a bimodal lightcurve with a reasonable spacing of the maximums and minimums, e.g., the two maximums were about 0.5 rotation phase apart. In addition, the two halves were significantly different, which made the half-period unlikely.

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