

LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2022 MARCH-MAY

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CCD photometric observations of four Hilda asteroids were made at the Center for Solar System Studies between 2022 March and May. Of those, 3561 Devine and 8551 Daitarabochi had distinct secondary periods.

CCD photometric observations of four Hilda asteroid were carried out at the Center for Solar System Studies (CS3) from 2022 March-May 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.

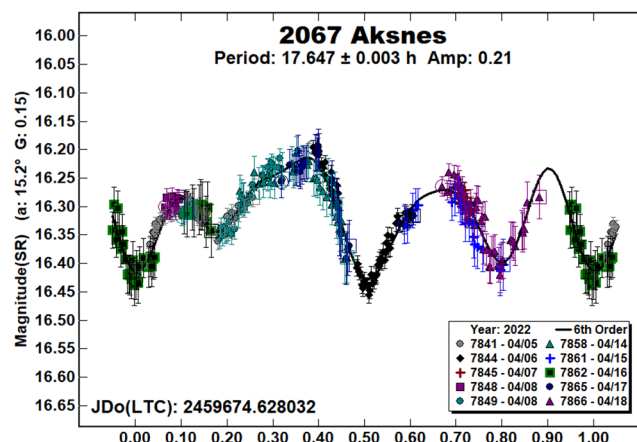
To reduce the number of times and amounts of adjusting nightly zero-points, the ATLAS catalog r' (SR) magnitudes (Tonry et al., 2018) are used. Those adjustments are usually $\leq \pm 0.03$ mag. The rare greater corrections may have been related in part to using unfiltered observations, poor centroiding 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 two values in the parentheses are the phase angle (α) and the value of G used to normalize the data to the comparison stars used in the earliest session. This, in effect, made all the observations seem to be made at a single fixed date/time and phase angle, leaving any

variations presumably due only to the asteroid's rotation and/or albedo variations. 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*.

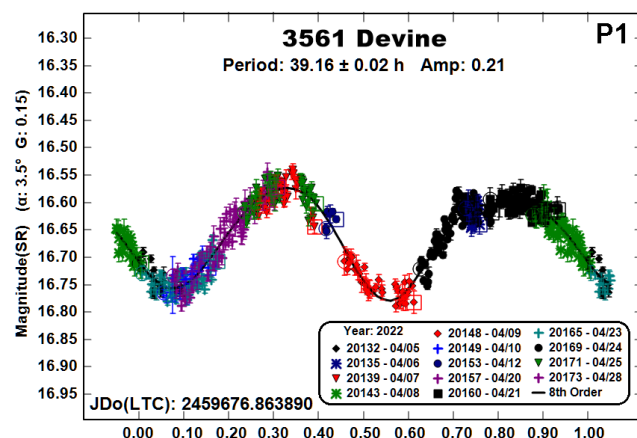
For brevity, only some of the previous results are referenced. A more complete listing is in the asteroid lightcurve database (Warner et al, 2009; “LCDB” from here on).

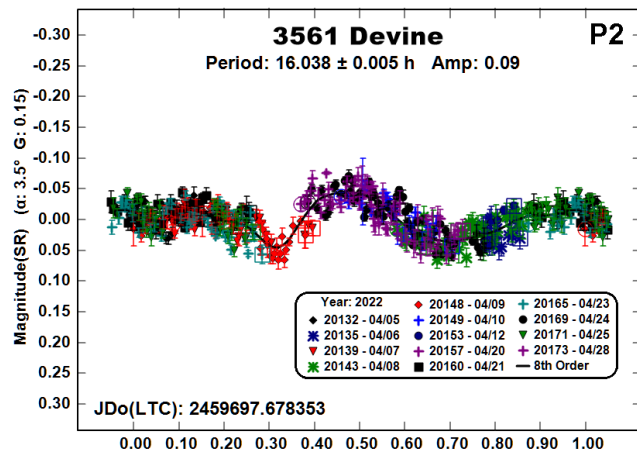
2067 Aksnes. Dahlgren et al. (1998) reported a period of 17.75 h and amplitude of 0.24 mag. From observations in 2021, we (Warner and Stephens, 2021) found a similar period of 17.677 h and an identical amplitude. Our 2022 results are consistent with the previous results. We note the unusual shape of the lightcurve.



3561 Devine. Our previous results include Stephens (2016; 4.376 h), Warner et al. (2018; 9.61 h), and Warner et al. (2021; 4.7985 h). In very sharp contrast, Pál et al. (2020) reported a period of 108.068 h using data from TESS. Reviewing their frequency spectrum, there were much less prominent solutions at 3.077 h, 3.840 h, and 4.948 h, the last being somewhat close to our 2021 result.

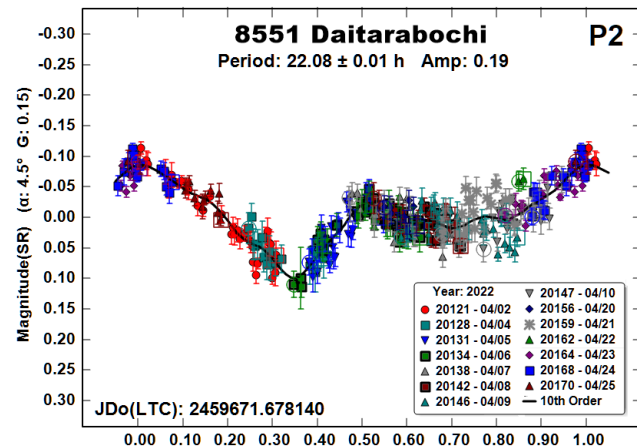
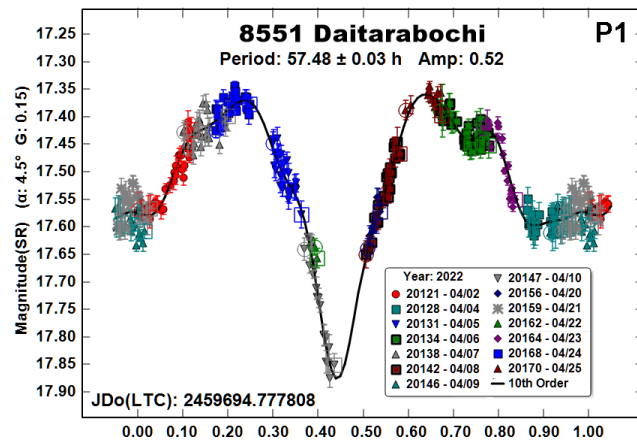
Our 2022 observations unexpectedly showed a primary period of 39.16 h and a secondary period of 16.038 h that were found with the dual-period search in *MPO Canopus*. Those two periods do not have a simple integer ratio, which helps remove the possibility, but not completely, that they are harmonically related. On the other hand, the Pál et al. and our primary period have a close to 11:4 ratio (11.039). Allowing for uncertainties in one or both periods, it's possible that two are harmonically tied to one another.





Given the shape of the P2 lightcurve, it seems unlikely that it is due to a satellite. Instead, it may be one of the byproducts of *MPO Canopus* doing what it *not* designed to do: find the periods of rotation and precession of a tumbling asteroid. The most optimistic estimate of the tumbling damping time for the asteroid (0.2 Gyr) requires a period of 101 h (Pravec et al., 2014; 2005), which is close to the period from Pál et al. (2020). Future observations are highly recommended.

8551 Daitarabochi. Our previous result of $P = 6.62$ h (Warner et al., 2018) was the only one listed in the LCDB. The results from the 2022 data are dramatically different, the most significant being a much longer dominate period and finding a secondary period.

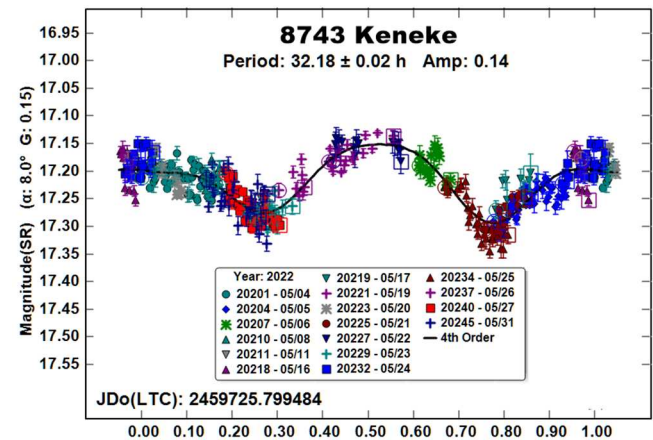
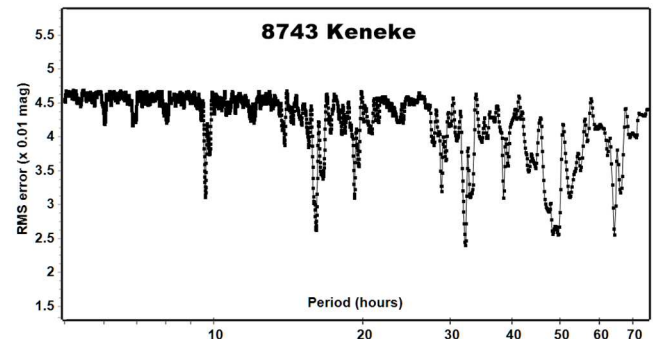


As with 3561 Devine, there were two distinct periods extracted from the data, the periods don't have a simple integral ratio, and the secondary period is unlikely due to a satellite. "More Data!"

A side note: the data from the first night, March 30, were inexplicably 0.7 mag too bright even after confirming that SR magnitudes were being used and the asteroid correctly identified. As a result, the data were not used in period analysis since they were an obvious outlier compared to the rest of the data set, even if considering the possibility of tumbling.

8743 Keneke. Pál et al. (2020) found a period of 99.3073 h. In our previous work (Warner and Stephens, 2021), we found a period of 46.74 h based on 2021 observations and, after remeasuring the original images from 2016, a revised period of 63.7 h. Instead of our 2022 data analysis removing ambiguities it only added to them.

The period spectrum indicates several possible solutions, including some close to those in Warner and Stephens (2021). None of the four periods given here has a simple integer period ratio with the other three.



Acknowledgements

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Number	Name	2022/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
2067	Aksnes	04/05-04/18	15.2, 16.3	137	0	17.647	0.003	0.21	0.02
3561	Devine	04/05-04/28	3.5, 8.3	189	11	39.16	0.02	0.21	0.02
						16.038	0.005	0.09	0.01
8551	Daitarabochi	03/30-04/25	4.1, 8.9	179	12	57.48	0.03	0.52	0.02
						22.08	0.01	0.19	0.02
8743	Keneke	05/04-05/31	8.1, 13.3	201	16	32.18	0.02	0.14	0.02

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).

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