

LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 SEPTEMBER-DECEMBER

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(Received: 2019 Jan 13)

Lightcurves for four Hilda asteroids were obtained at the Center for Solar System Studies (CS3) from 2018 September-November: 3514 Hooke, 3557 Sokolsky, 4495 Dassanowsky, and 10331 Peterblum. 4495 Dassanowsky appears to be a binary asteroid with a primary period of either 2.6314 hr or 5.263 hr and an orbital period of 18.516 hr. The secondary-to-primary ratio of the effective diameters is 0.26 ± 0.02 .

CCD photometric observations of four Hilda asteroids were made at the Center for Solar System Studies (CS3) from 2018 September-November. This is another installment of an on-going series of papers on this group of asteroids, which 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 group and 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.

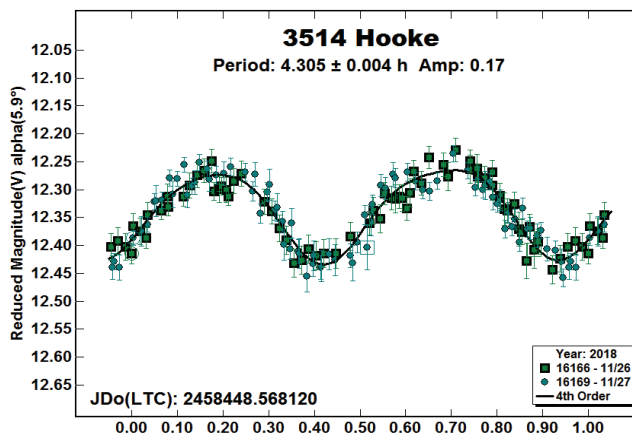
Table I lists the telescopes and CCD cameras that are combined to make observations. Up to nine telescopes can be used for the campaign, although five is most common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24–1.60 arcsec/pixel. All lightcurve observations were unfiltered since a clear filter can result in a 0.1–0.3 magnitude loss. The exposures varied depending on the asteroid’s brightness and sky motion.

Photometric measurements were made using *MPO Canopus*. The Comp Star Selector (CSS) utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs. Period analysis was done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris et al., 1989).

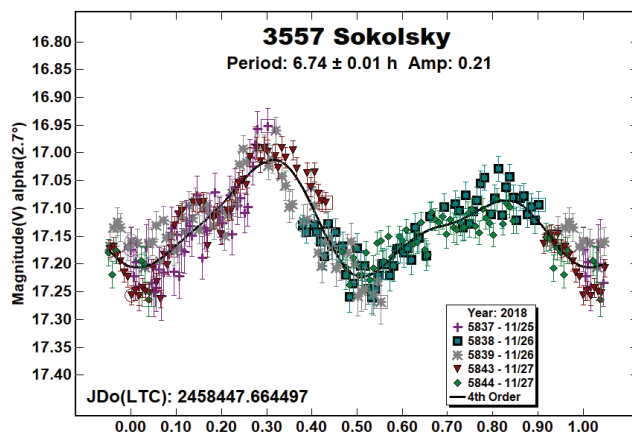
In the plots below, the “Reduced Magnitude” is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5 \cdot \log(r\Delta)$ with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle in parentheses using $G = 0.15$. The X-axis is the rotational phase ranging from -0.05 to 1.05 . If the plot includes an amplitude, e.g., “Amp: 0.65”, this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

Only some of previous works may be referenced. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner et al., 2009). The on-line version at <http://www.minorplanet.info/lightcurvedatabase.html> allows direct queries that can be filtered a number of ways and the results saved to a text file. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

3514 Hooke. The estimated size of this Hilda is 34 km if assuming a visual albedo of 0.057 (Warner et al., 2009). Waszczak et al. (2015) found a rotation period of 4.307 hr and amplitude of 0.17 mag, which is in good agreement with our denser data set.



3557 Sokolsky. Dahlgren et al. (1998) reported a rotation period of 6.725 hr and amplitude of 0.19 mag. Analysis of our data obtained in 2018 November found similar results: 6.74 ± 0.01 hr and 0.21 ± 0.02 mag.



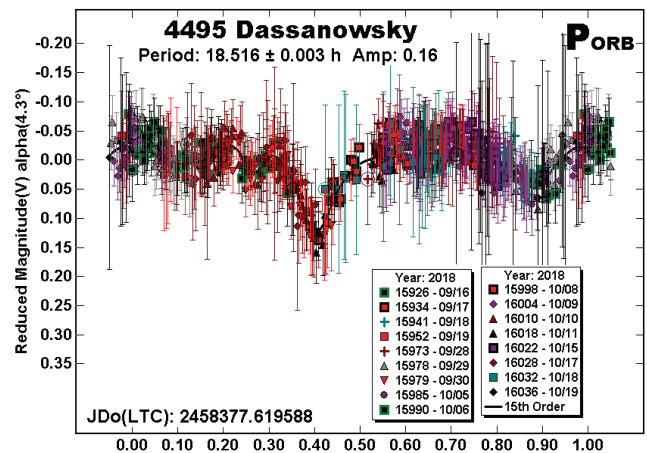
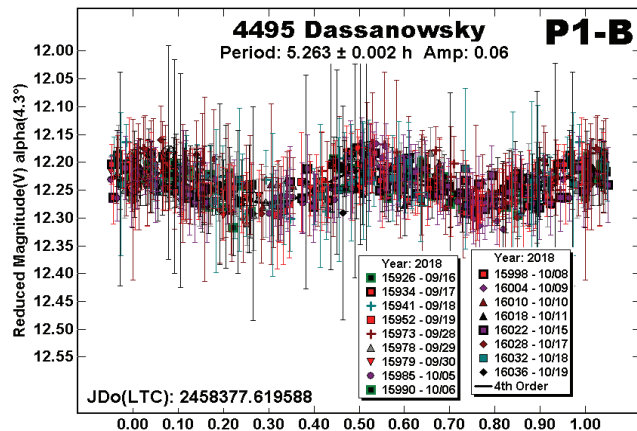
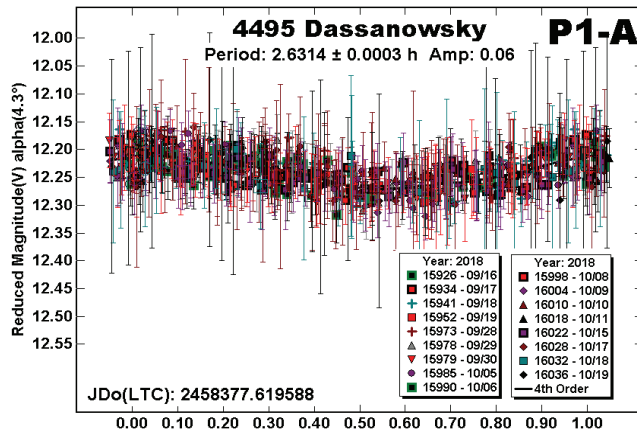
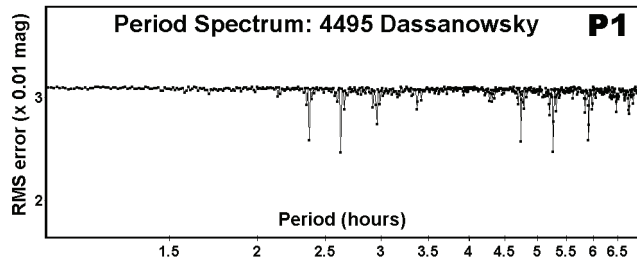
4495 Dassanowsky. The LCDB did not list any rotation periods for Dassanowsky. Mainzer et al. (2016) used data from the WISE mission to find $D = 24.43 \pm 0.26$ km and visual albedo $p_V = 0.082 \pm 0.014$ when using $H = 11.4$.

Number	Name	2018/mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
3514	Hooke	11/26-11/27	151	6.0, 6.3	46	2	4.305	0.004	0.17	0.02
3557	Sokolsky	11/25-11/27	280	2.8, 3.2	54	-5	6.74	0.01	0.21	0.02
4495	Dassanowsky	09/16-10/19	548	4.3, 5.9	326	3	2.6314	0.0003	0.06	0.01
							5.263	0.002	0.06	0.01
							18.516	0.003	0.13	0.01
10331	Peterbluhm	09/16-10/31	763	13.7, 1.8	38	-5	379	5	1.1	0.1

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). For 4495 Dassanowsky, the first line gives the preferred rotation period for the primary of a binary system. The second line gives an alternate primary period. The third line is the orbital period of the presumed satellite.

We observed the asteroid for more than a month, from 2018 Sep 16 through Oct 19. After the first few nights, the data showed attenuations that were consistent with the system being binary.

The amplitude of the purported primary lightcurve had a low amplitude of only 0.06 mag; this was nearly overshadowed by the large photometric error bars on some nights. The period spectrum shows two distinct possibilities, 2.63 hr (P1-A) or 5.26 hr (P1-B). Harris *et al.* (2014) have shown that either one could be right because of the low amplitude.



We used both solutions when looking for the lightcurve of the suspected satellite. The final plot (P_{ORB}) is based on using $P_J = 2.6314 \pm 0.0003$ hr. Using $P_J = 5.623 \pm 0.002$ hr produced an identical solution for the orbital period.

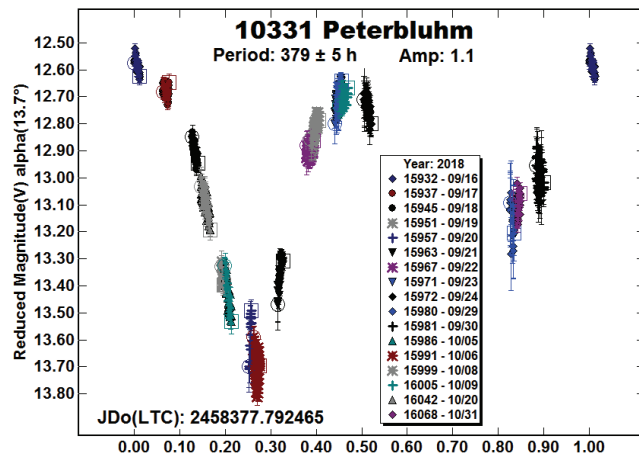
The depth of the mutual eclipses/occultations led to an estimate of the ratio of the secondary-to-primary effective diameters of 0.26 ± 0.02 . This is a lower limit since the secondary (shallower) event was not total. The lightcurve outside the events showed an amplitude of about 0.07 mag. After accounting for dilution of the satellite's lightcurve by the primary, the satellite has an ellipsoidal a/b ratio of about 1.5:1.0

10331 Peterbluhm. After following this Hilda for almost six weeks, we still did not have enough data to produce a fully-covered lightcurve. Some sessions were after one rotation and so covered a part of the lightcurve more than once.

A solution based on a half-period (monomodal lightcurve) was used to find a likely solution. That period was doubled to give our final result of 379 ± 5 hr. This makes this the fourth longest period listed in the LCDB for a Hilda.

The combined diameter and period make this a good candidate for tumbling (Pravec *et al.*, 2014; 2005). However, there were no obvious signs of tumbling seen in the data. One indicator would be sessions at the same point in the phased curve not fitting a relatively smooth model curve (one is significantly high or low). Another is when two sessions at the same point in the phased curve have opposing trends, i.e., one shows a steady rise over the run and the other shows a steady decline.

Mainzer *et al.* (2016) found $D = 19.57 \pm 0.40$ km and $p_V = 0.127 \pm 0.044$ when using $H = 11.4$. This is brighter than the average Hilda (0.057; Warner *et al.*, 2009) but not unrealistic since WISE albedos for the Hilda population range from 0.012 to 0.371.



Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database Warner et al., 2009) and ALCDEF database (*alcdef.org*) are supported by NASA grant 80NSSC18K0851.

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (<http://svo2.cab.inta-csic.es/vocats/cmc15/>).

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These allowed purchasing some of the telescopes and CCD cameras used in this research.

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