PHOTOMETRIC ANALYSIS AND ROTATION PERIOD DETERMINATION FOR ASTEROIDS 5445 WILLIWAW, (8823) 1987 WS3 AND (26568) 2000 ET49

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Photometric observations of three main-belt asteroids were conducted in order to determine their synodic rotation periods. For 5445 Williwaw we found P = 10.65 ± 0.02 h, A = 0.29 ± 0.05 mag; for (8823) 1987 WS3, a slow rotator, we found a rough period of P = 86.0 ± 1.0 h, A = 0.24 ± 0.02 mag; for (26568) 2000 ET49 we found P = 7.171 ± 0.003 h, A = 0.71 ± 0.04 mag

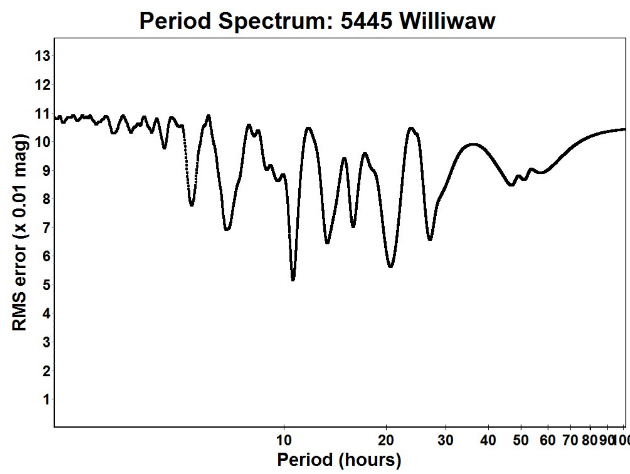
CCD photometric observations of three main-belt asteroids were carried out in 2020 October - December at three Italian observatories. At the Astronomical Observatory of the University of Siena (K54), a facility inside the Department of Physical Sciences, Earth and Environment (DSFTA, 2020), we used a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E NABG CCD camera, and clear filter; the pixel scale was 2.30 arcsec when binned at 2×2 pixels and all exposures were 300 seconds. At the Wild Boar Remote Observatory (K49) data were obtained with a 0.235-m f/10 (SCT) telescope, a SBIG ST8-XME NABG CCD camera unfiltered; the pixel scale was 1.60 arcsec in binning 2×2 and all exposures were 300 seconds. At the Iota Scorpii Observatory (K78) we used a 0.40-m f/6 Ritchey- Chretién telescope, SBIG STXL 6303E NABG CCD camera, and R filter; the pixel scale was 1.55 when binned 2×2 and all exposures were 180 seconds.

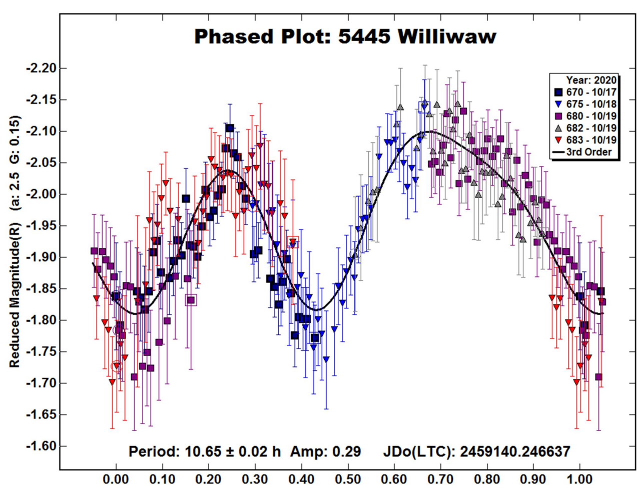
Data processing and analysis were done with *MPO Canopus* (Warner, 2018). All images were calibrated with dark and flat-field frames and the instrumental magnitudes converted to R magnitudes using solar-colored field stars from a version of the CMC-15 catalogue distributed with *MPO Canopus*. Table I shows the observing circumstances and results.

A search through the asteroid lightcurve database (LCDB; Warner et al., 2009) indicates that our results may be the first reported lightcurve observations and results for these asteroids.

5445 Williwaw. (1991 PA12) was discovered on 1991 August 7 by H.E. Holt at Mount Palomar and named after a dramatic mountain on the skyline of Anchorage. Mount Williwaw stands 5445 feet above sea level and it's the highest point in the Campbell Creek drainage. [Ref: Minor Planet Circ. 34341] It is a main-belt asteroid with a semi-major axis of 2.552 AU, eccentricity 0.223, inclination 6.115°, and an orbital period of 4.08 years. Its absolute magnitude is H = 12.4 (JPL, 2020). The WISE/NEOWISE satellite infrared radiometry survey (Masiero et al., 2014) found a diameter D = 8.797 ± 0.107 km using an absolute magnitude H = 12.2.

Observations were conducted over three nights and collected 213 data points. The period analysis shows a solution for the rotational period of P = 10.65 ± 0.02 h with an amplitude A = 0.29 ± 0.05 mag.



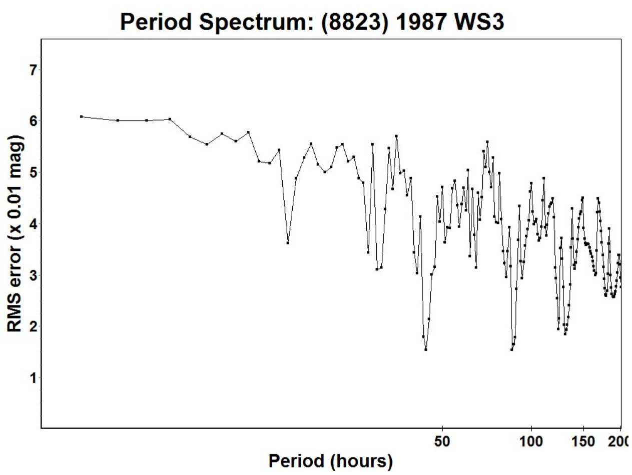


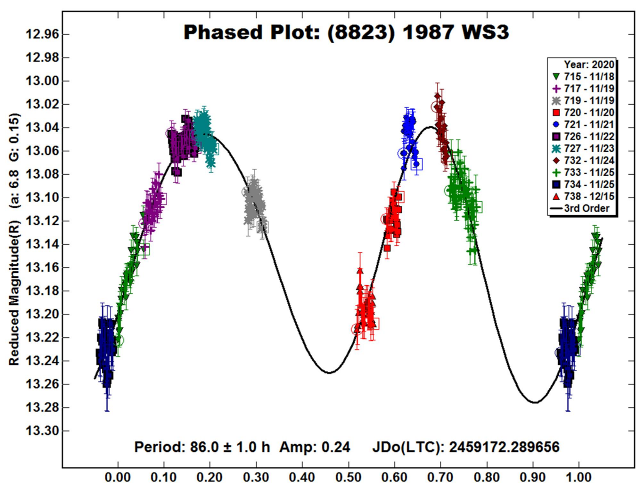
Number	Name	2020/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
5445	Williwaw	10/17-10/20	2.4,2.6	24	6	10.65	0.02	0.29	0.05	MB
8823	1987 WS3	11/18-12/15	*6.8,10.0	68	-2	86.0	1.0	0.24	0.02	MB
26568	2000 ET49	11/06-11/10	4.4,5.3	41	-8	7.171	0.003	0.71	0.04	MB

Table I. Observing circumstances and results. The first line gives the results for the primary of a binary system. The second line gives the orbital period of the satellite and the maximum attenuation. 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).

(8823) 1987 WS3. (1981 QC1) was discovered on 1987 November 24 by S. McDonald at Anderson Mesa. It is a main-belt asteroid with a semi-major axis of 2.570 AU, eccentricity 0.240, inclination 13.557°, and an orbital period of 4.12 years. Its absolute magnitude is H = 12.8 (JPL, 2020). The WISE/NEOWISE satellite infrared radiometry survey (Masiero et al., 2011) found a diameter D = 10.652 ± 0.108 km using an absolute magnitude H = 12.6.

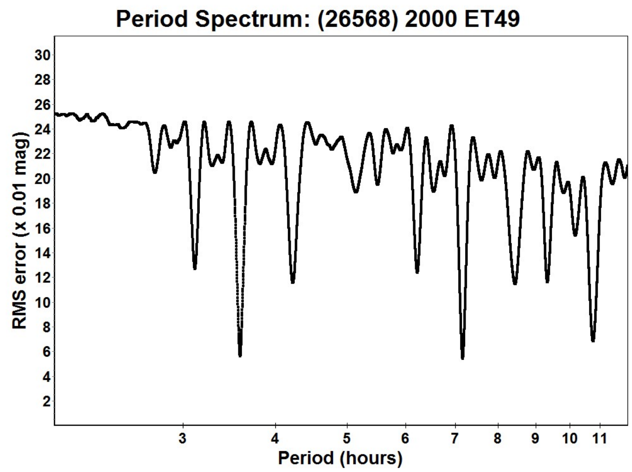
Observations over seven nights collected 351 data points. The period analysis shows a possible bimodal solution for the rotational period of P = 86.0 ± 1.0 h with an amplitude A = 0.24 ± 0.02 mag. This target revealed to be a very slow rotator and the result is based on less than full coverage, so that the true period may differ a few hours.

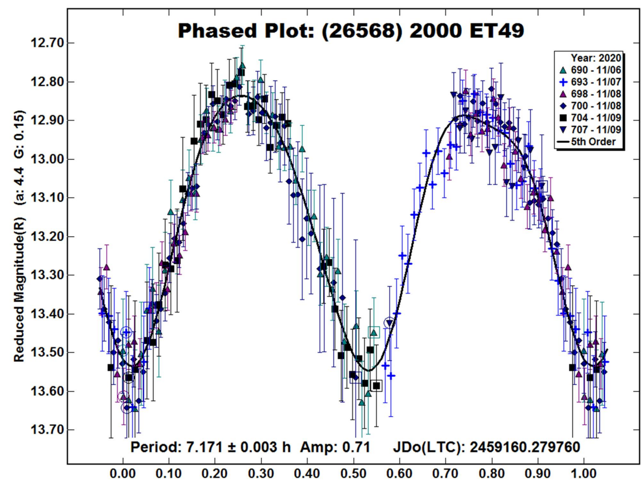




(26568) 2000 ET49 was discovered on 2000 March 9 by LINEAR at Socorro. It is a main-belt asteroid with a semi-major axis of 3.155 AU, eccentricity 0.208, inclination 14.842°, and an orbital period of 5.60 years. Its absolute magnitude is H = 13.0 (JPL, 2020). The WISE/NEOWISE satellite infrared radiometry survey (Masiero et al., 2011) found a diameter D = 16.708 ± 0.160 km using an absolute magnitude H = 13.0.

Observations were conducted over three nights and collected 245 data points. The period analysis shows a result for the rotational period of P = 7.171 ± 0.003 h with an amplitude A = 0.71 ± 0.04 mag as the most likely bimodal solution for this asteroid.





Acknowledgements

Minor Planet Circulars (MPCs) are published by the International Astronomical Union's Minor Planet Center. *https://www.minorplanetcenter.net/iau/ECS/MPCArchive/MPCArchive_TBL.html*

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ROTATION PERIOD OF KORONIS FAMILY MEMBER 1840 HUS

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We report rotation lightcurves of 1840 Hus observed during its apparition in 2020. The constraints from our data, combined with a reanalysis of published lightcurves recorded in 2009, yield a secure rotation period of 4.7483 ± 0.0008 h.

Koronis family member 1840 Hus was observed in 2020 as a "target of opportunity" during an ongoing observing program to study rotation properties of the family's brighter objects (Slivan et al., 2008). In the literature we find lightcurves of Hus from only a single previous apparition in 2009, with considerable noise in the data and an uncertain derived rotation period of 4.780 h (Clark, 2010). Subsequent statistical analyses of "sparse data" from photometric surveys suggest a slightly shorter period of 4.749 h (Erasmus et al., 2020) and report a sidereal period and spin vector (Durech et al., 2016).

Observations were made on 14 nights over a 34-night interval in 2020 (Table I) using 0.36-m telescopes at the Wallace Astrophysical Observatory in Westford, MA. Each system imaged a 22 arcmin square field of view at a resolution of 1.3 arcsec per pixel, using an SBIG STL-1001 CCD camera and *R* filter. Image processing and measurement were as described by Slivan et al. (2008), except that for Hus as a fainter object observed with smaller telescopes, we chose synthetic aperture sizes guided by the experience of Howell (1989) for the on-chip relative photometry.

The lightcurves show that Hus completes either four, five, or six rotations in about 23.7 hours; all three candidate periods yield credible doubly-periodic composites. However, these data cannot further distinguish the true period from the aliases because the individual unbroken spans of lightcurve are too short relative to the periods, a consequence of Hus's southern declination in 2020 during northern hemisphere summer, combined with a zone of obstructed telescope view across the meridian at low altitudes.

To resolve the ambiguity, we reanalyzed the published lightcurves from the 2009 apparition, which include spans of nightly coverage that are longer than the candidate periods. Given the noise in these data we used a "noise spectrum" approach, fitting a Fourier series model including through the 2nd harmonic to the lightcurves in order to test a range of trial rotation periods that includes the three candidates. The resulting graph (Fig. 1) shows that 4.748 h is the only period that is consistent with the lightcurves from both 2009 and 2020. Our final result of 4.7483 ± 0.0008 h (Fig. 2) is consistent with the published periods based on "sparse" data.

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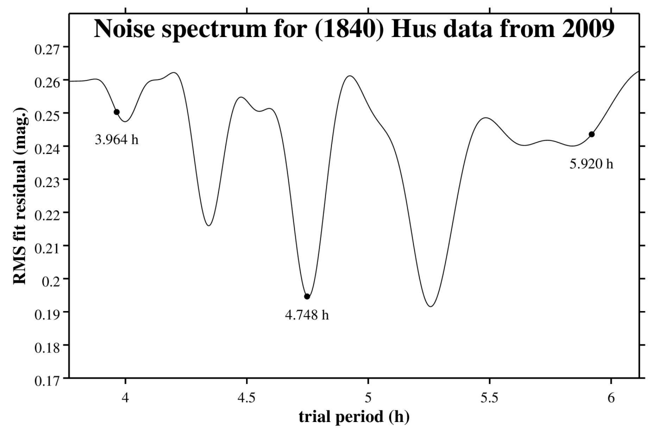

Figure 1. "Noise spectrum" graph for the lightcurves of (1840) Hus recorded during the 2009 apparition by Clark (2010). The candidate periods allowed by the 2020 lightcurves are highlighted; only 4.748 h is consistent with the data from both apparitions.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1840	Hus	2020 07/21-08/23	*9.1,4.0	321	-3	4.7483	0.0008	0.42	0.05

Table I. Observing circumstances and results. Solar phase angle is given for the first and last dates; the asterisk indicates that the phase angle reached a minimum within that interval. L_{PAB} and B_{PAB} are the phase angle bisector longitude and latitude at mid-date range.