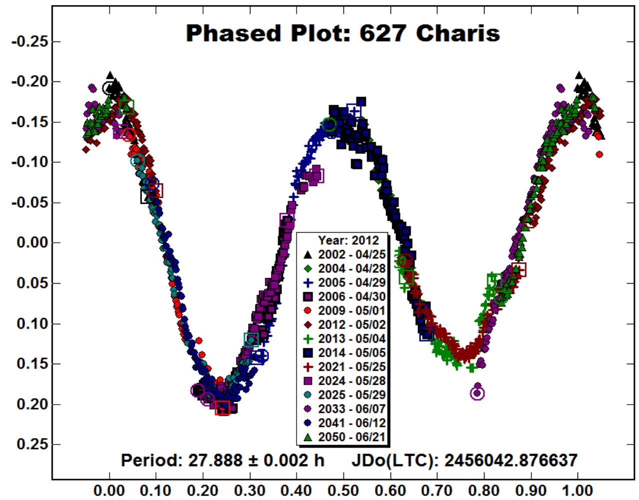

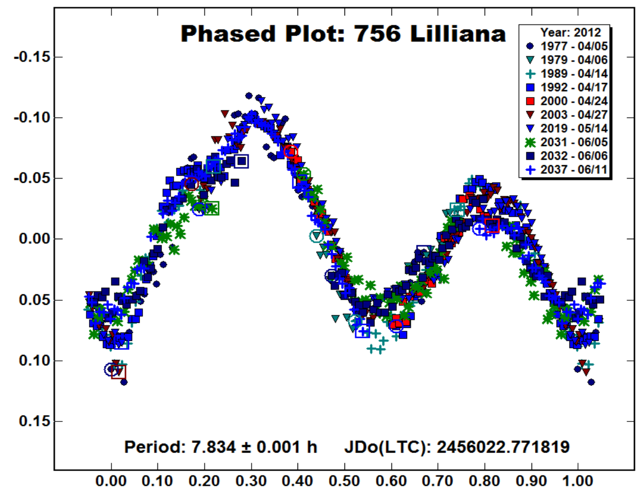

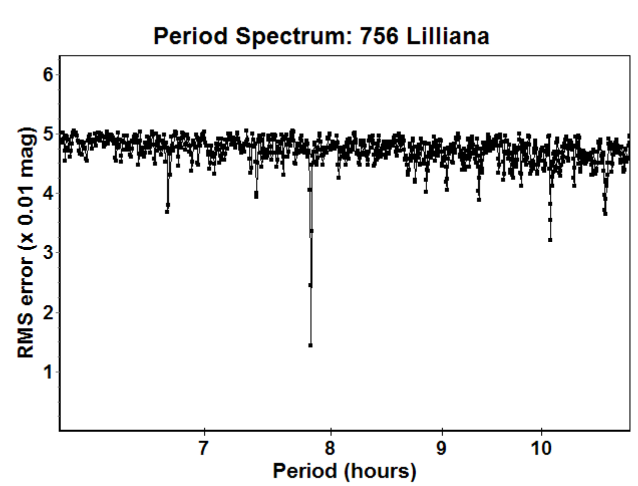

ROTATION PERIOD DETERMINATION FOR 801 HELWERTHIA

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A consortium of observers from Australia, Europe, and North America have obtained lightcurves of the previously unobserved asteroid 801 Helwerthia. The period spectrum between 10 and 50 hours is presented, all minima on which have been carefully investigated. We strongly prefer a rotation period 23.93 ± 0.01 hours, amplitude 0.15 ± 0.03 magnitudes, with almost complete phase coverage, and consider all other alias periods to be highly unlikely.

First author Pilcher chose to observe 801 Helwerthia because the Asteroid Lightcurve Data Base (Warner et al. 2012) showed no previous observations. Observations on the first four nights 2012 March 24 - 31 suggested a period very close to that of the Earth. Full phase coverage would require observations from longitudes widely distributed around the Earth. Andrea Ferrero; the team of Luca Pietro Strabla, Ulisse Quadri, and Roberto Girelli; both from Italy; the team of Rasuli Inasaridze, Yurij Krugly, and Igor Molotov, observing from Kharkiv, Ukraine, and from Abastumani, Georgia Republic; and Julian Oey from Australia; all kindly contributed additional observations. We present the period spectrum between 10 and 50 hours, and explain our observational basis for considering 23.93 ± 0.01 hours, hereafter called the preferred period, to be much more likely than the other alias periods. By examining the period spectrum we immediately rule out all periods except 1/2P (half period), P, 3/2P, 2P (double period), where P is considered 23.93 hours. We present lightcurves based on all observations 2012 Mar. 24 - Apr. 27

phased to all of these trial periods. The rising sections in the 23.93 hour lightcurve between phases 0.3 - 0.5, (Sessions 1985, 1986, 1987, 1988, Apr. 5, 9, 10, and 12, respectively) and 0.7 - 0.85 (Sessions 1982, 1997, 2007, 2008, Apr. 11, 20, 21, 27, respectively) have considerably different slopes. These superimpose between phases 0.5 and 0.8 in the half period representation with sufficient misfit to rule out the half period. In the 3/2 P representation, the small slope session 1987, Apr. 10; and large slope sessions 1982, Apr. 11; and 1997, Apr. 20, respectively, again superimpose with considerable misfit. Still further evidence against the 3/2 period is found from segments separated by 1/3 cycle, 1958, 1969, 1971, 1972, Mar. 24, 29, 30, 31, respectively, appearing nearly identical. This would require a shape model those parts of which produce the identical segments being irregular yet symmetric over a 120 degree rotation, an unlikely occurrence. Consider segments 1958, Mar. 24 and 1971, Mar 30 at phase 0.0 – 0.2; 1969, Mar. 29 at phase 0.3 – 0.5; and 1972, Mar. 31 near phase 0.65 – 0.85. All were obtained over a small time interval and range of phase angles 11.4 - 8.6 degrees, and all look the same. Furthermore segments 1982, Apr. 11; and 1997, Apr. 20; near phase 0.50 – 0.65; look the same as segments 2007, Apr. 21; and 2008, Apr. 27; near phase 0.15 – 0.30. These are again over a small range of phase angles 4.1 - 6.6 degrees.

To consider the likelihood of the double period being the correct one, we consider the following. If a lightcurve is phased to twice the real period, it shows left and right halves which are identical. Conversely if a lightcurve phased to a trial period shows nearly identical left and right halves, this probably indicates the trial period is twice the real period. An alternative interpretation is that the shape of the asteroid is symmetric over a 180 degree rotation. The probability of such symmetry for a real asteroid is extremely small, and smaller still for an irregular lightcurve. In most cases this interpretation may be safely rejected. This argument is most effective when both halves of the lightcurve are from observations closely spaced in time. Otherwise changes in shape of the lightcurve resulting from changes in phase angle and aspect angle between line of sight and polar axis may cause the right and left halves to look different even when the single period is the correct one.

For an object with period very close to that of Earth, as in our preferred period, each participating observatory samples the same segment of the lightcurve on all nights. In this investigation the segment in the 23.93 hour lightcurve between phases 0.0 and 0.3 was sampled at the Organ Mesa Observatory. With an assumed period near one day, sessions 1958, March 24; 1969, March 29; 1971, March 30; and 1972, March 31; within a range of phase angles 11.4 - 8.6 degrees; all superpose on the preferred period lightcurve at phases 0.0 – 0.30. Sessions 1958, March 24; and 1971, March 30, correspond on the double period representation to phases 0.0 – 0.15. Sessions 1969, March 29; and 1972, March 31, between phases 0.5 and 0.65, lie on the alternate half of the double period representation. Segments between phases 0.0 – 0.15 and 0.5 – 0.65, respectively, look the same, and by the criterion of the previous paragraph constitute evidence against the double period. These segments were sampled again on sessions 1993, April 18; and 1996, April 21, respectively, at which time the minimum had become deeper with phase angle decreasing to 3.6, 4.3 degrees, respectively. These two sessions again occupy alternate halves at phases 0.0 – 0.15 and 0.5 – 0.65, respectively, of the double period. Not only do they look identical, the changes from the March data were also the same. This is further evidence against the double period. Observations of sessions 1982, April 11, and 1997, April 20, respectively, from Bigmuskie Observatory; and sessions 2007, April 21, and 2008, April 27, from Bassano Bresciano Observatory are of the lightcurve segment between phases 0.70 and 1.00 on the preferred period representation. On the double period representation sessions 1982, April 11; 2007, April 21; and 2008, April 27; respectively, occupy phases 0.35 – 0.5, and session 1997, April 20 occupies phase 0.85 – 1.0, alternate halves of the double period. Again they look the same. The segment between phases 0.25 and 0.5 on the preferred period representation was sampled from Kingsgrove Observatory as sessions 1985, Apr 5; 1986, April 9; 1987, April 10; and 1988, April 12; respectively. On the double period sessions 1985, Apr. 5; and 1986, Apr. 9 lie between phases 0.15 – 0.20. Somewhat longer sessions 1987, Apr. 10; and 1988, Apr. 12; respectively, lie between phases 0.6 – 0.75 and include a larger part of the lightcurve. Although the data are somewhat sparser, those between phases 0.15 – 0.20 and 0.65 – 0.70, respectively, have no significant differences which could constitute evidence in favor of the double period.

In summary, we show that the double period model has nearly identical left and right halves over about 50% of the whole cycle, and a distinct change in the appearance of 30% of it is the same for both right and left halves. The probability of the double period being the correct one seems almost as small as if the whole double period cycle were sampled and showed nearly identical right and left halves. We have confidence that the 23.93 hour period is the correct one even although phase coverage is slightly incomplete.

We note that a preferred period of 23.939 ± 0.004 hours is obtained from all observations 2012 Mar. 24 - Apr. 27. A single session at phases 0.05 - 0.30 was obtained 2012 May 13 at a much larger phase angle 12.6 degrees. The depth of the minimum sampled in this session was much greater than when sampled earlier, a consequence of the change of phase angle. When combined with all earlier observations the preferred period decreases to 23.920 ± 0.002 hours, which we illustrate with a lightcurve phased to the preferred period which adds the May 13 observations. This is a reminder that the real error in a period determination by the Harris FALC algorithm (Harris et al., 1989) is several times as large as the formal error. We therefore more conservatively present our preferred period as 23.93 ± 0.01 hours, amplitude 0.15 ± 0.03 magnitudes.

The observing cadance by FP at Organ Mesa Observatory is such that a much larger number of data points were acquired there than by AF at Bigmuskie, LS and colleagues at Bassano Bresciano, RI at Abastumani, YK at Kharkiv University, and JO at Kingsgrove Observatories. To make more legible the large number of data points in the segments of the lightcurve included by Organ Mesa observations, they have been binned in sets of three points with a maximum of five minutes between points.

The following table provides details of the individual sessions. Column headings refer to: Obs: Observer code: AF, Andrea Fererro, 0.3m f/8 RC SBIG ST9 CCD; RI, Raguli Inasaridze and colleagues, 0.7m Maksutov, IMG6063E (FLI) CCD in primary focus; YK, Yurij Krugly and colleagues, 0.7m Cassegrain-Newtonian, ML47-10 (FLI) CCD at Newtonian focus; JO, Julian Oey, 0.25 m f/11 S-C, SBIG ST-9XE CCD; FP, Frederick Pilcher, 0.35m f/10 S-C, SBIG STL-1001E CCD; LS, Luca Pietro Strabla, Ulisse Quadri, Roberto Girelli, 0.32 m f/3.1 S-C, Starlight HX-516 CCD; Sess, session number; Date in calendar year 2012; UT of first and last observations of the session; Data Pts, number of data points in session; PA, phase angle.

Obs	Sess	Date	UT	Data Pts	PA
FP	1958	Mar 24	5:17 - 12:20	240	11.4
FP	1969	Mar 29	4:56 - 12:11	307	9.4
FP	1971	Mar 30	4:51 - 12:09	332	9.0
FP	1972	Mar 31	4:52 - 12:07	326	8.6
AF	1982	Apr 11-12	21:15 - 3:35	92	4.1
JO	1985	Apr 5	13:19 - 14:52	22	6.4
JO	1986	Apr 9	11:24 - 13:04	19	4.9
JO	1987	Apr 10	11:00 - 16:32	22	4.5
JO	1988	Apr 12	10:21 - 16:18	25	4.0
FP	1993	Apr 18	3:13 - 11:06	349	3.6
FP	1996	Apr 21	2:54 - 10:52	374	4.3
AF	1997	Apr 20-21	20:40 - 3:25	92	4.2
LS	2007	Apr 21-22	22:39 - 1:04	51	4.5
LS	2008	Apr 27-28	19:40 - 1:51	136	6.6
YK	2010,1	Apr 16-17	18:00 - 0:33	126	3.5
RI	2015,6	Apr 17-18	21:41 - 0:49	36	3.5
RI	2017	Apr 18	17:00 - 18:42	28	3.6
FP	2018	May 13	2:46 - 9:20	300	12.7

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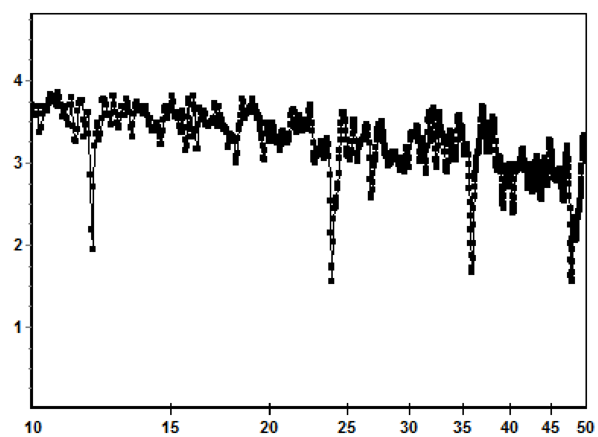

Figure 1. Period spectrum of 801 Helwerthia, hours.

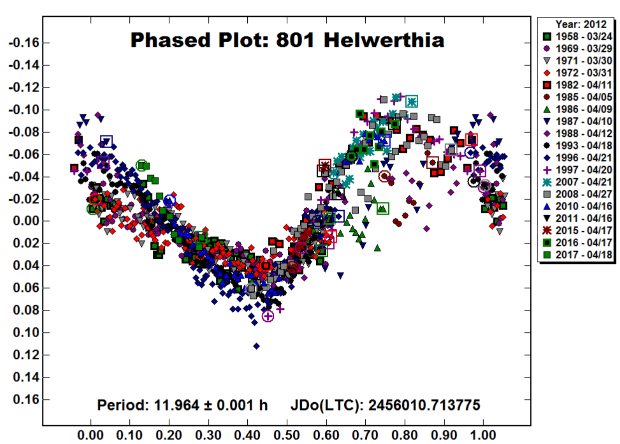

Figure 2. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to 1/2 the preferred period, 11.964 hours.

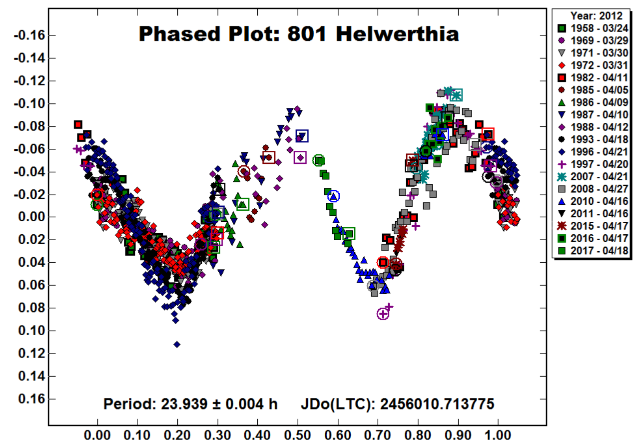

Figure 3. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to the preferred period of 23.939 hours.

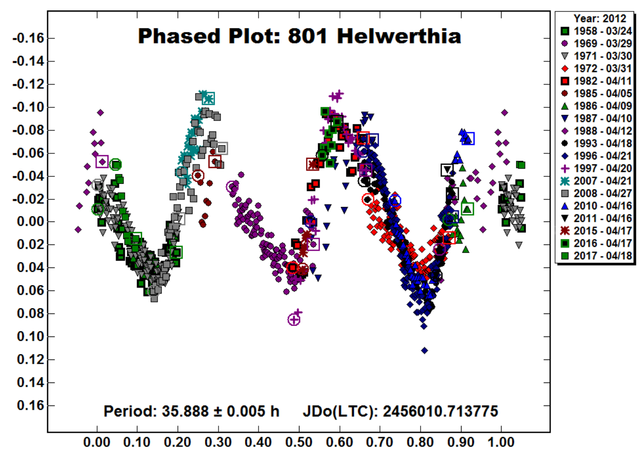

Figure 4. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to 3/2 the preferred period, 35.888 hours.

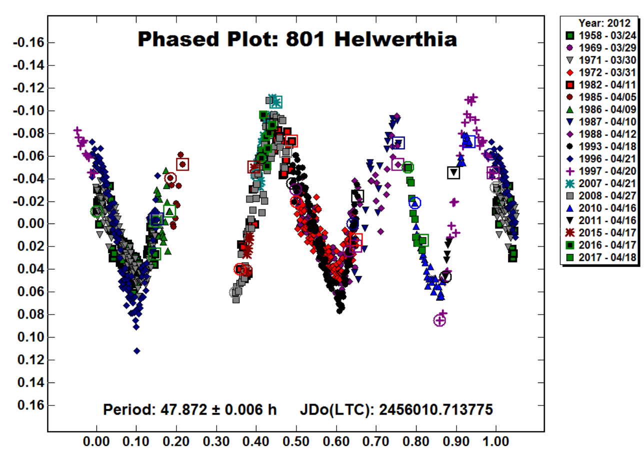

Figure 5. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to the "double period," 47.872 hours, twice the preferred period.

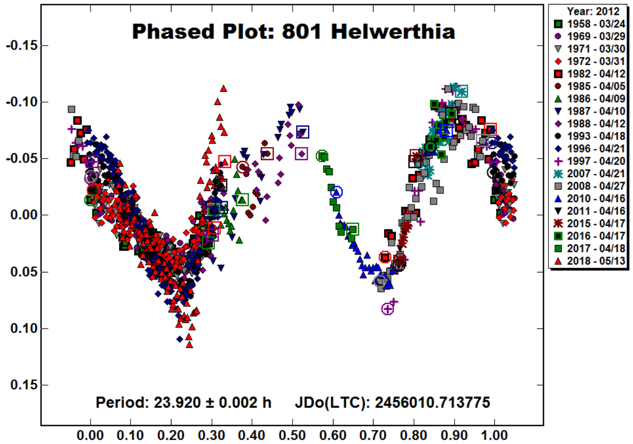

Figure 6. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - May 13 phased to the preferred period of 23.920 hours.

LIGHTCURVE FOR 2074 SHOEMAKER

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Analysis of CCD photometric observations of the Hungaria asteroid 2074 Shoemaker in 2012 showed a low amplitude lightcurve of 0.08 mag. No definitive period could be found, with those of 2.8, 2.5, and 2.4 hours having nearly equal probability. No evidence was found of a satellite, which was suspected based on data from a previous apparition.

The Hungaria asteroid 2074 Shoemaker was observed by Stephens (2004) in late 2003. At the time, a period of 57.02 h and amplitude of 0.45 mag was reported. The images were remeasured and the new data analyzed a few years later (Warner *et al.*, 2009). That analysis indicated a period of 2.5328 h with the possibility of a satellite with a period of, not so coincidentally, of 55.5 h. However, the evidence was far from conclusive. The asteroid was observed again in 2010 (Warner, 2011), where a period of 2.5338 h, amplitude 0.12 mag was found but no indications of tell-tale "mutual events" that could be attributed to a satellite.

In 2012, the authors again observed the asteroid with the hopes of confirming the 2.5 h period and to look for signs of a satellite. The observations at PDO were made using a 0.35-m Schmidt-Cassegrain (SCT) using an SBIG STL-1001E CCD camera. The observations at CS3 used a 0.35-m SCT and STL-1001E as well. All images were unfiltered. The data were put onto an internal standard system using R magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008). Circumstances allowed only short runs for each observing session, about 4 hours or less.

Analysis of the relatively sparse data set, less than 100 observations, found a low amplitude lightcurve, $A \sim 0.08$ mag. It was not possible to find a definitive period. The data best fit a period of 2.820 h. However, almost equally good fits could be found at 2.449 h and 2.523 h, the latter not far removed from the previous results. The phase angle bisector longitudes for the 2005 and 2012 apparitions differed by about 200 degrees, and so not much difference in the lightcurves would be expected. The 2010 apparition, $L_{PAB} = 312°$, was sufficiently different and, as expected if the asteroid was sufficiently elongated, the amplitude was larger. This indicates that the pole longitude might be around 20° (or 200°).

No indications were seen of mutual events from a satellite. Observations at the next apparition (2013 January, V ~ 16.3, Dec –38°, $L_{PAB} \sim 132°$) are encouraged.

Acknowledgements

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