

A NEW LIGHTCURVE AND SPIN-SHAPE MODEL FOR 46 HESTIA

Lorenzo Franco
Balzarotto Observatory (A81)
Rome, ITALY
lor_franco@libero.it

Frederick Pilcher
4438 Organ Mesa Loop
Organ Mesa Observatory (G50)
Las Cruces, NM 88011 USA

(Received: 2019 Jan 4)

At its opposition in late 2018, minor planet 46 Hestia has a synodic rotation period of 21.039 ± 0.001 h and amplitude 0.11 ± 0.01 mag. A lightcurve inversion model based on four dense data sets in the years 1978-2018 plus sparse observations provides a sidereal period of 21.04010 ± 0.000035 h with two mirrored pole solutions at longitude 291 deg, latitude +13 deg; or longitude 110 deg, latitude 7 deg; all ± 5 degrees, respectively. A shape model is also provided.

Minor planet 46 Hestia has a semi-major axis of 2.5252 AU and revolution period of 4.013 years. Each sequence of three oppositions repeats after four years under early identical circumstances with only a very slow westward circulation. Three previously published dense lightcurves all state rotation periods within 0.005 h of 21.040 h and amplitudes near 0.11 mag, as does the current study. All four studies are shown in the table I with the respective year and month of mid date of observing campaign and longitude of phase angle bisector (LPAB).

Author	Mid date	LPAB
Scaltriti et al. (1981)	1978-11-14	58
Pilcher (2012)	2012-03-06	154
Pilcher (2017)	2017-05-23	235
This study	2018-10-14	34

Table I. Observational circumstances for 46 Hestia over four apparitions

A new photometric data set was obtained with 12 sessions 2018 Sept. 9 – Nov. 18 by second author Pilcher at Organ Mesa Observatory with a 0.35-m f/10 Meade LX200 GPS Schmidt-Cassegrain (SCT) telescope and SBIG STL-1001E CCD, unguided with an R filter. These data provide a good fit to a lightcurve phased to period of 21.039 ± 0.001 h, and amplitude of 0.11 ± 0.01 mag.

Lightcurve inversion was performed using MPO LCInvert v.11.7.5.1 (BDW Publishing, 2016). For inversion process we have also used sparse data from (689) USNO Flagstaff station in addition to the dense data. Figures 2 and 3 show respectively PAB longitude/latitude distribution for dense / sparse data and the

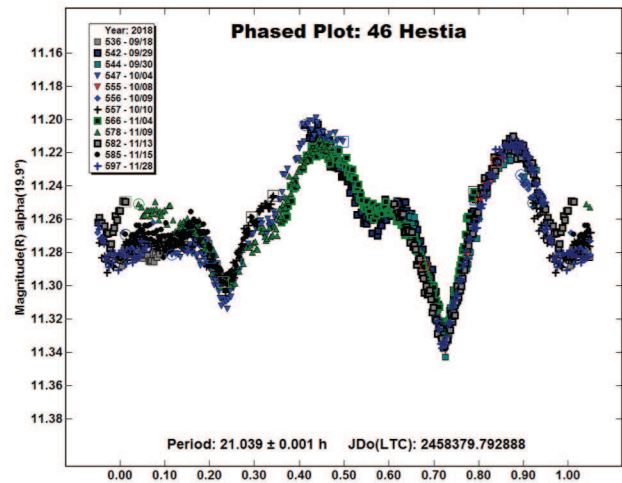


Fig. 1: The lightcurve acquired at the 2018 apparition.

PAB Longitude Distribution: 46 Hestia

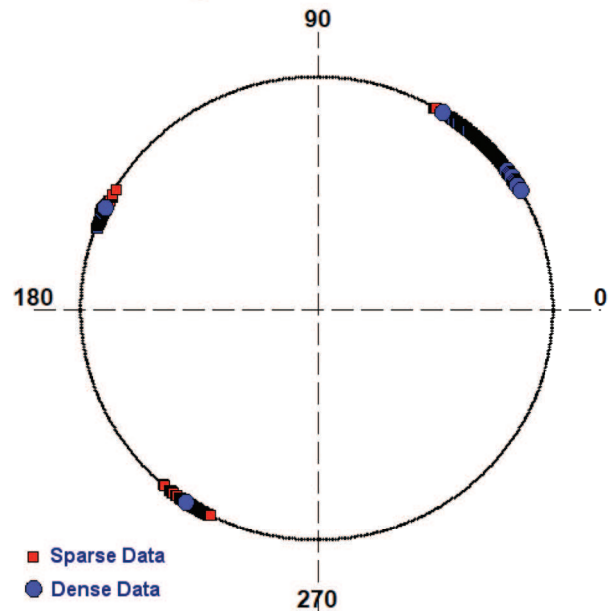


Fig. 2: PAB longitude distribution of the data used for the lightcurve inversion model.

sparse photometric data distribution with the corresponding phase curve.

The photometric data of the 1978 apparition were no longer available and therefore were reconstructed by the digitization of the published lightcurve.

The sidereal period search was started around the average of the synodic periods found in the previous studies. We found two sidereal periods with a lower chi square value near 21.040 and

Number	Name	2018 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
46	Hestia	09/09-11/18	3950	19.8, 4.2, 15.6	33.6	-1.5	21.039	0.001	0.11	0.01

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first date, minimum value reached, and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

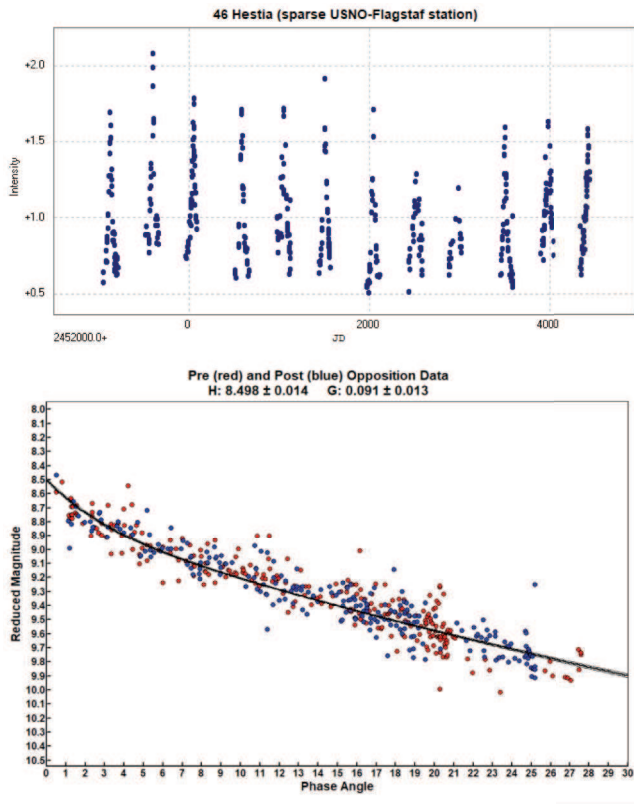


Fig. 3: Sparse photometric data point distribution from USNO Flagstaff station with the phase curve (reduced magnitudes vs phase angle).

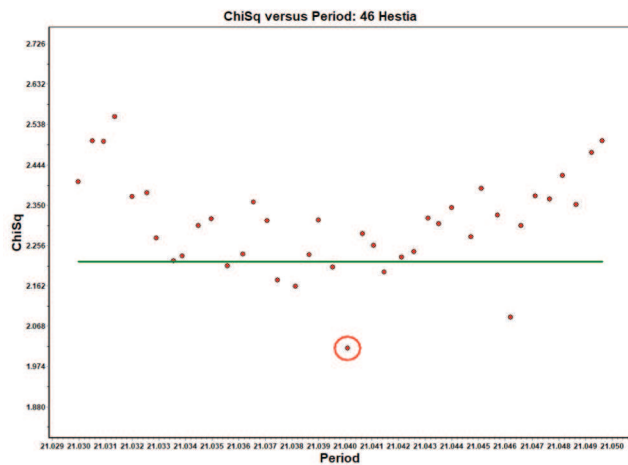


Fig. 4: The period search for 46 Hestia shows two lower chi square values. For the inversion process the one with the lowest chi square value was used.

21.046 hours (Figure 4). The second of which leads to solutions with a higher chi square values, so the first period was used for the subsequent steps.

The pole search was started using the “medium” option with the previously found sidereal period set to “float”. The “dark facet” weighting factor was set to 0.8 and the number of iterations was set to 50. From this step we found two rough mirrored lower chi square solutions (Figure 5) separated by 180° in longitude at $(300^\circ, 15^\circ)$ and $(120^\circ, 15^\circ)$. The subsequent “fine” search, centered on these rough positions, allowed us to refine the position of the pole (Figure 6). The analysis shows two clustered solutions

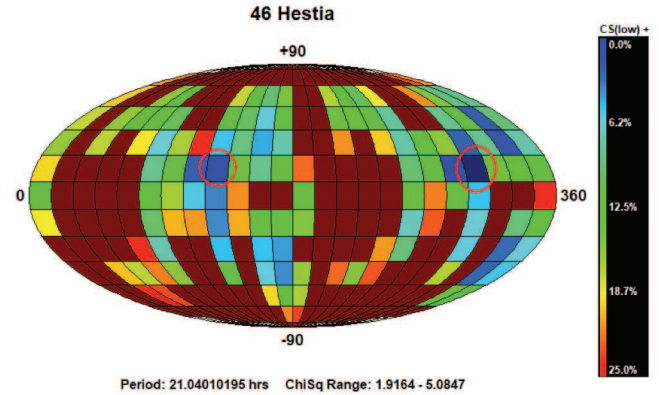


Fig. 5: Pole search distribution. The dark blue indicates the better solutions, while maroon the worst ones.

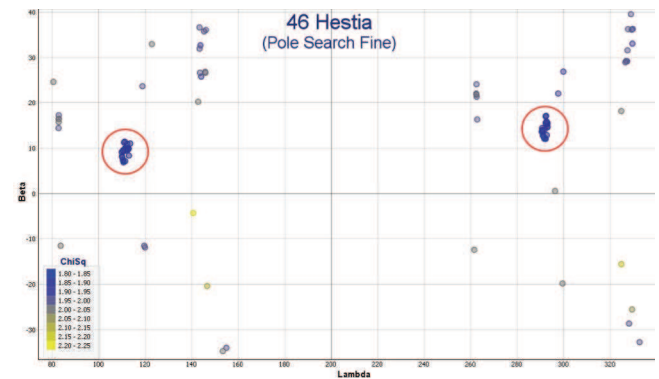


Fig. 6: The “fine” pole search shows two clustered solutions centered at the ecliptic longitude/latitude $(292^\circ, 14^\circ)$ and $(112^\circ, 9^\circ)$ with chi square values below 5% than the others.

within 5 degrees in longitude-latitude pairs with chi square values below 5% than the other solutions. The two best solutions (lowest chi square values) are reported in Table III. The sidereal period has been obtained averaging the two solutions found in the pole search process. Typical errors in the pole solution are ± 5 degrees and the uncertainty in sidereal period has been evaluated as a rotational error of 10° over the total time span of the dense data set. Figure 7 shows the shape model (first solution) while Figure 8 shows the fit between the model (black line) and observed lightcurves (red points).

λ °	β °	Sidereal Period (hours)	RMS
291	13	21.040101 ± 0.000035	0.0137
110	7		0.0138

Table III. The two spin axis solutions for 46 Hestia. The sidereal period was the average of the two solutions found in the pole search process.

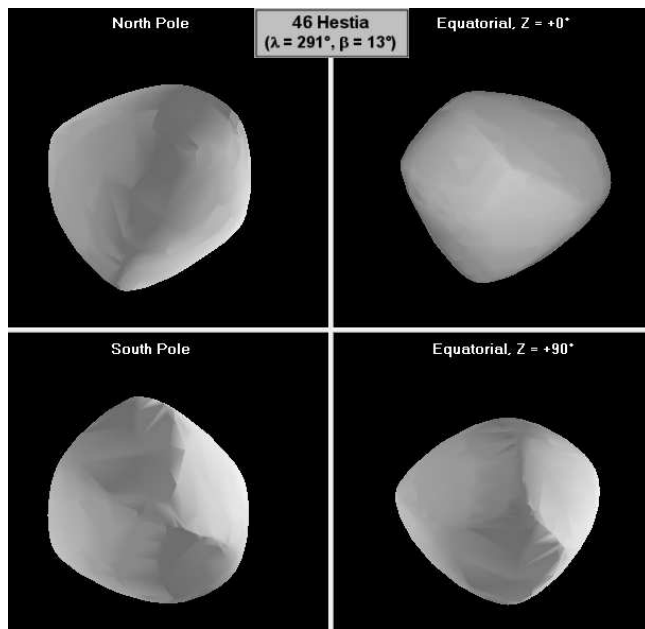


Fig. 7: The shape model for 46 Hestia ($\lambda = 291^\circ$, $\beta = 13^\circ$).

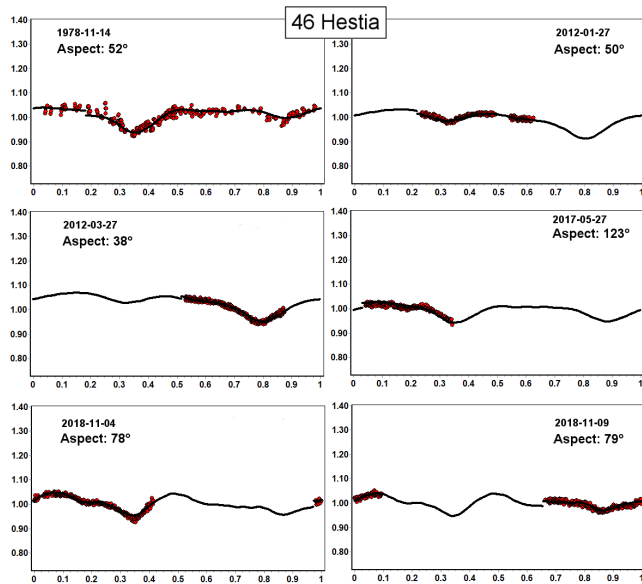


Fig. 8: Model fit (black line) versus observed lightcurves (red points) for ($\lambda = 291^\circ$, $\beta = 13^\circ$) solution.

References

- BDW Publishing (2016).
<http://www.minorplanetobserver.com/MPOSoftware/MPOLCInvert.htm>
- Harris, A.W., Young, J. W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.
- Pilcher, F. (2012). "Rotation period determinations for 46 Hestia, 223 Rosa, 225 Henrietta, 266 Aline, 750 Oskar, and 765 Mattiaca." *Minor Planet Bull.* **39**, 171-173.
- Pilcher, F. (2017). "Rotation period determinations for 46 Hestia, 118 Peitho, 333 Badenia, 356 Liguria, and 431 Nephela." *Minor Planet Bull.* **44**, 294-297.
- Scaltriti, F., Zappala, V., Harris, A. W. (1981). "Photoelectric lightcurves and rotation periods of the asteroids 46 Hestia and 115 Thyra." *Icarus* **46**, 275-280.