

A REEXAMINATION OF THE ROTATION PERIOD OF 1541 ESTONIA

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A previously published period ambiguity for 1541 Estonia of 6.444 or 12.890 hours has been reexamined. We prefer a 12.889 ± 0.001 -hour period with amplitude 0.16 ± 0.01 magnitudes.

The two authors of this paper made independent photometric investigations of the rotational properties of 1541 Estonia in the interval 2022/02 to 2022/04. Dose (2022) found a period of 6.444 hours and Pilcher (2022) found a period twice as great, 12.890 hours. After learning of our respective results, we have merged our data in an attempt to resolve the ambiguity. Our equipment and observational procedures have been previously described in our papers referenced above. To reduce the number of data points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with maximum time difference 5 minutes. Earlier published rotation periods are by Behrend (2015web), 10.1 hours; and by Polakis (2021), 12.84 hours.

Sessions 1732-1757, 2022 Feb. 25 to Apr. 3, are by Pilcher, originally obtained in CMC15 R band, where $R=r'-0.22$. Sessions 1818-1823, 2022 Feb. 9 - Apr. 4, are by Dose, originally obtained with the exoplanet/blue-blocker filter and transformed to the Sloan r' band. During the merger of the two data sets the zero points of one set had to be adjusted by about 0.17 magnitudes to obtain best fit to the other set. Lightcurve construction and period solution was done with *MPO Canopus* software.

MPO Canopus software uses the FALC algorithm written by Alan Harris to find the rotation period that best fits the data within the range specified by the user. This algorithm finds the coefficients of each order of the Fourier series up to a user specified maximum number, 10 in the calculations performed here, for a specified range of periods, and computes for each period within that range the rms residual, in units of 0.01 magnitudes, of all the individual data points from the graph specified by the Fourier components. It then plots the lightcurve for that period within the specified range for which the rms is a minimum and writes the both the period and rms residual of the individual data points. The saved lightcurves do not state the rms residual, but the first author has written them onto each lightcurve.

For all twelve sessions, range of phase angles 12.9° to a minimum of 1.6° to 10.6° , lightcurves were drawn to 6.445 hours (Fig. 1) with a mean residual of 1.3932×0.01 magnitudes and to 12.889

hours (Fig. 2) with a mean residual of 1.1622×0.01 magnitudes. The data scatter by eyeball scanning is notably smaller for the 12.889-hour lightcurve. The split halves plot for the 12.889-hour lightcurve (Fig. 3) also shows a small systematic difference between the two halves for some segments of the lightcurve. By all three criteria a period of 12.889 hours is preferred to one of 6.445 hours. The minimum near phase 0.5 of the 12.889-hour lightcurve is deeper for the larger phase angles than for the smaller ones. This is a commonly occurring effect found in lightcurves sampled over a large range of phase angles for many asteroids. The change of depth with phase angle is not seen in the minimum near phase zero. If the period really were 6.445 hours, the depths of the minima should change in step. The different behaviors of the two minima constitute a fourth criterion for which the longer period 12.889 hours is preferred.

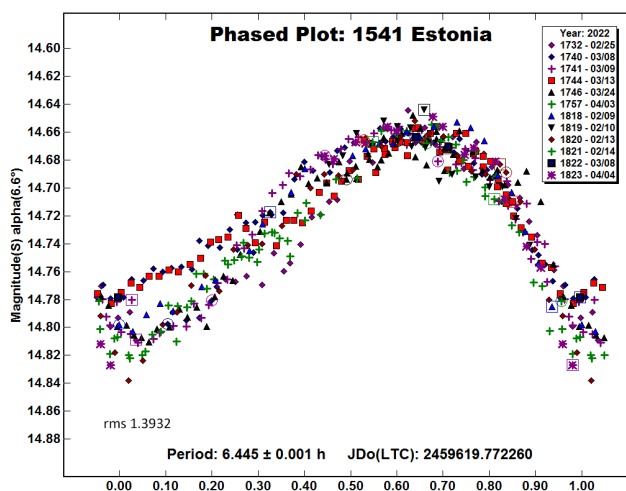


Figure 1. Lightcurve of 1541 Estonia, 2022/02/09 to 2022/04/04 phased to 6.445 hours.

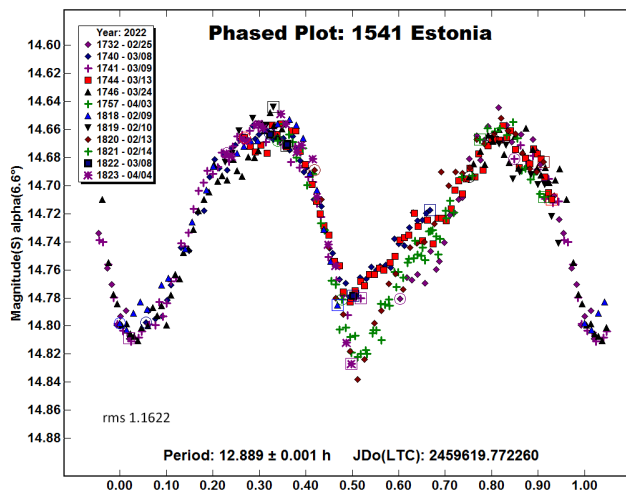


Figure 2. Lightcurve of 1541 Estonia, 2022/02/09 to 2022/04/04 phased to 12.889 hours.

Number	Name	yyyy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E	Amp	A.E.
1541	Estonia	2022/02/09-2022/04/04	*12.9, 10.6	170	1	12.889	0.001	0.16	0.01

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

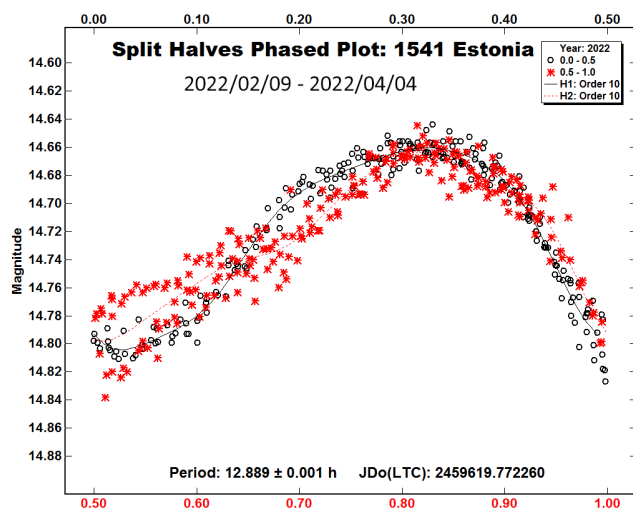


Figure 3. Split halves lightcurve of 1541 Estonia for the interval 2022/02/09 to 2022/04/04.

A long interval of observations, nearly two months for the study in this paper, covers a larger number of rotational cycles and provides a more accurate period. There is a trade-off, in that the shape of the lightcurve changes with phase angle and reduces any shape differences in any bimodal lightcurve. A subset of five sessions from 03/08 at phase angle 1.6° through 03/24 at phase angle 6.0° does not include a large enough change of phase angle for this effect to be apparent. A lightcurve drawn to a period of 6.449 hours (Fig. 4) shows a rms residual of 1.2382×0.01 magnitudes and a bifurcation of data points near the single minimum. A lightcurve drawn to a period of 12.894 hours (Fig. 5) shows a clearly asymmetric lightcurve with rms residual only 0.7010×0.1 magnitudes. The split halves lightcurve for the interval March 08 to March 24 (Fig. 6) also shows a distinct separation of many corresponding segments of the two halves. The evidence at a small range of phase angles favoring the longer period is now very strong.

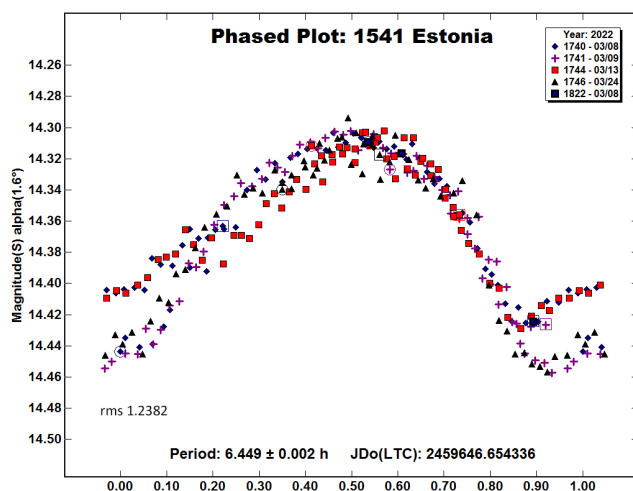


Figure 4. Lightcurve of 1541 Estonia, 2022/03/08 to 2022/03/24 phased to 6.449 hours.

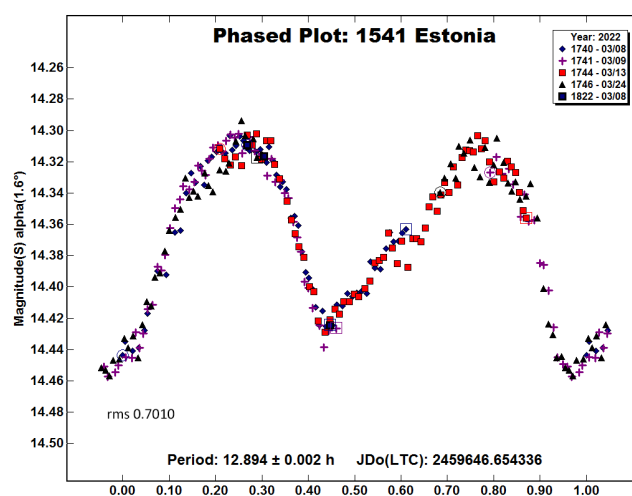


Figure 5. Lightcurve of 1541 Estonia, 2022/03/08 to 2022/03/24 phased to 12.894 hours.

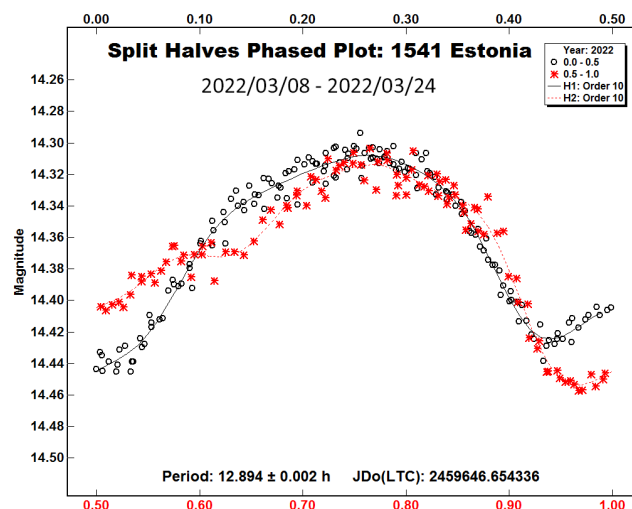


Figure 6. Split halves lightcurve of 1541 Estonia for the interval 2022/03/08 to 2022/03/24.

We conclude that the synodic rotation period of 1541 Estonia is 12.889 ± 0.001 hours and the amplitude is 0.16 ± 0.01 magnitudes. The new observations are consistent with Polakis (2021) and rule out the 10.1-hour period reported by Behrend (2015web).

References

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