

~ 0.4 magnitudes. Therefore, the rotation period must be 4.0804 ± 0.0002 h. The amplitude was measured to be 0.60 ± 0.05 mag. A period of 4.069 ± 0.006 h was reported by Angeli and Barucci (1996). According to the JPL Small-Body Database, this result was based on less than full coverage. Our result agrees with the period found by Angeli and Barucci.

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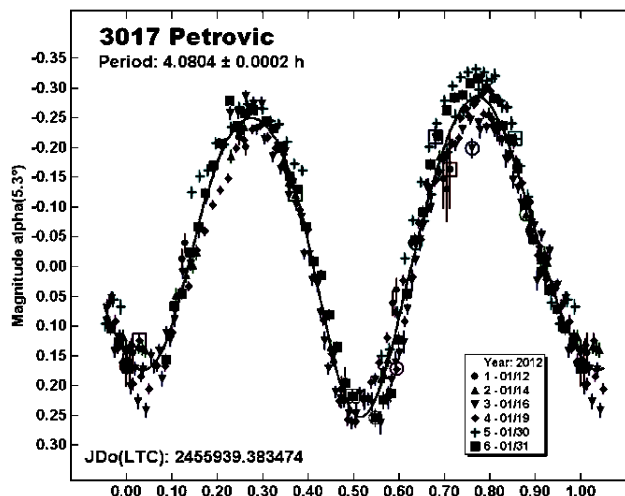
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LIGHTCURVE PHOTOMETRY OF 132 AETHRA

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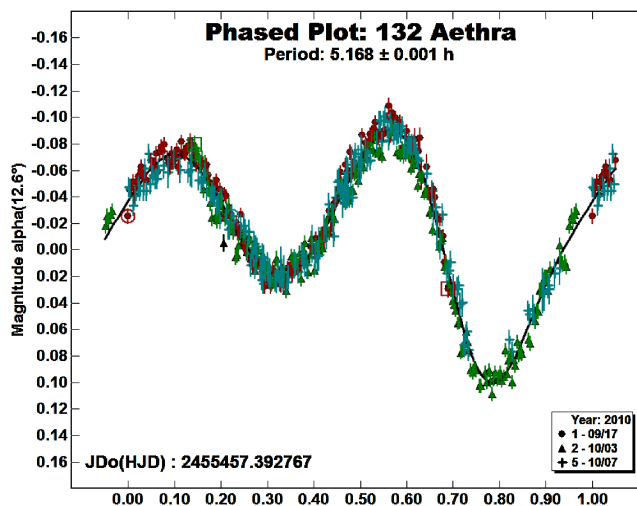
Photometric observations of 132 Aethra were obtained at Celbridge Observatory from 2010 September through October.

Observations of 132 Aethra were made at Celbridge Observatory (MPC Code J65) with a 0.36-m *f*/11 Schmidt-Cassegrain (SCT) and a FLI ProLine 1001E CCD imager. Images were acquired using ACP Observatory Control Software and were unguided, unbinned, and unfiltered. Exposure times were 60 s and the CCD temperature was held at -20° C. The images were calibrated and measured using MPO Canopus, which employs differential aperture photometry to determine the values used for analysis. Period analysis was also carried out using MPO Canopus, which incorporates the Fourier analysis algorithm developed by Harris (*et al.*, 1989).

132 Aethra was chosen as a "proof-of-concept" target. The author had not done asteroid lightcurve analysis before and so, in order to ensure correct processes were followed, an asteroid with a well-known published lightcurve was chosen. A period of 5.168 h is reported on the IAU Minor Planet Center internet site (<http://www.minorplanetcenter.net/iau/lists/LightcurveDat.html>).

Analysis of the data from this study found a period of 5.168 ± 0.001 h. This agrees with the published results and shows that

Celbridge Observatory and the author are capable of carrying out lightcurve photometry.



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PERIOD DETERMINATION OF 617 PATROCLUS

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A photometric study of 617 Patroclus revealed a synodic period of $103.5\text{h} \pm 0.3\text{h}$ and amplitude of 0.06 ± 0.02 mag. The difficulty in obtaining this result was overcome by using an unconventional method of linking the data with differential photometry.

617 Patroclus is a well-studied binary Trojan asteroid. For example, Berthier (2007) found a period of 102.94 ± 0.11 while Mueller (2010) reported a period 103.02 ± 0.40 h. The amplitude of the lightcurves was found to be very low, 0.07 ± 0.01 mag. The two components of the binary system have been determined to be nearly identical in shape and size, $D_1 = 112 \pm 16$ km and $D_2 = 103 \pm 15$ km with a separation of 654 ± 36 km (Berthier, 2007). Other details of the system are described by Mueller *et al.* (2010).

The data obtained for 617 Patroclus was from Kingsgrove and Leura Observatory. Kingsgrove Observatory used a 0.25-m *f*/11 Schmidt-Cassegrain telescope with a self-guiding ST-9XE SBIG CCD camera operating at 1x1 binning. The pixel resolution was 1.45 arc seconds/pixel. Exposures for the unfiltered images were 300 seconds. Leura Observatory used a 0.35-m *f*/7 Schmidt-Cassegrain telescope with an SBIG CCD camera at 2x2 binning, producing a 1.54 arc seconds/pixel resolution. All sessions were taken unfiltered at 300 seconds integration. Details of both observatories can be found in Oey (2011). *MPO Canopus* v.10.4.0.4 software was used for period analysis which incorporates the Fourier algorithm (FALC) developed by Harris (Harris *et al.*, 1989).

The observations from Kingsgrove observatory were initiated at the request of Fernando Mazzone in Argentina as part of a collaboration. Due to poor weather conditions in Argentina, only Oey could continue with observations, eliminating the advantage of a long longitudinal baseline between two observers. The data were reduced with Comp Star Selector (CSS) methodology in *MPO Canopus* v10. This finds up to five values for the target by using

$$M_{\text{target}} = (m_{\text{target}} - m_{\text{comp}}) + M_{\text{comp}} \quad (1)$$

where m_{target} and m_{comp} are, respectively, the instrumental magnitudes of the target and comparison and M_{comp} is the catalog magnitude of the comparison. The final value for the target (M_{target}) is the mean of the intermediate results and the error is the standard deviation of the mean. This had the effect of linking all sessions to a standard scale with reported accuracy of 0.03–0.05 magnitudes.

Care was taken to maximize the SNR in order to achieve a precision of < 0.03 mag, which was required because of the known low amplitude and long period of the lightcurve. Despite a lengthy process in searching through the period spectrum generated by the Fourier analysis in *MPO Canopus*, no convincing period stood out even after extending the search to the known value of > 100 h. It was clear that CSS method in *MPO Canopus* failed in this instance. Fortunately there were a number of consecutive nights of observations during the observing campaign. The data were re-

duced by using differential photometry to tie in groups of two nights per session using common comparison stars. In this way, the sessions would be lined up by arbitrarily adjusting the zero point of each session and overlapping the common data points (Stephens, 2008). This method gave an accuracy equivalent to that obtained with differential photometry and the errors were limited only by the scatter of the data points.

The first group of data points that were linked was the six consecutive nights from Aug 24-29. A period of 103 h was found when searching through the period spectrum. The next three lots of three consecutive nights (Aug 10-12, Aug 20-22, Sep 3-5) were added and adjusted, all the while making sure the chord and lightcurve shape were well-matched. The period search still held at 103 h with an RMS fit of 1.40 (in units of 0.01 mag). Finally, the remaining sessions were included to increase the density of the lightcurve. The search for longer period revealed a possible period of 160 h with RMS = 1.35. Despite the lower RMS value for the longer period, some of the consecutive night's sessions were not consistent with the shape of the lightcurve. Therefore, the longer period was rejected in favor of the one near 103 h. It was interesting to note that once the sessions had been arbitrarily adjusted to fit into the curve derived from the above method, the arbitrary offset was less than 0.05 mag for all sessions, except one, which is within the limit of accuracy for CSS method.

The final period was 103.5 ± 0.3 h and amplitude of 0.06 ± 0.02 mag. This is consistent with the results found from previous studies. The phase angle (α) changed from 6 to 10 degrees. The phase angle bisector (PAB) longitude and latitude were 312 and -24 degrees, respectively.

As noted above, 617 Patroclus is a known synchronous binary. However, for this apparition, no signs of eclipse events typical of synchronous binary were seen in the lightcurve. This might be due to an unfavourable viewing geometry that did not allow eclipses, or it could also be the effect of the low amplitude and long period compounded by having observations from only a single station.

Conclusion

Observations with higher precision linked to a standard photometric system (e.g., using filters and Landolt fields) as well as multiple collaborators spread out over the globe are required to determine with certainty the correct rotational period. The Comp Star Selector method in *MPO Canopus* is an excellent and easy approach to standardize multiple sessions including those from different observers and locations. However the above method can be used as a tool to improve the accuracy of link for challenging targets such as those with long period and low amplitude.

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