

LIGHTCURVES FROM THREE MUTUAL EVENTS OF TROJAN BINARY 617 PATROCLUS IN OCTOBER 2024

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We present three raw lightcurves of Trojan binary 617 Patroclus on 2024 October 2, 6, and 21 during mutual events of the binary system.

The Lucy Mission is a NASA Discovery-class mission set to probe the Trojan asteroids around the L4 and L5 points of Jupiter (Levinson et al., 2021a). Named after a primitive *Australopithecus* human fossil, Lucy symbolizes the call to understanding the evolution of the Solar System. Lucy was launched on 2021 October 16 and will do a series of flybys near the following eight Trojan asteroids until 2033: 52246 Donaldjohanson, 3548 Eurybates + Queta, 15094 Polymele, 11351 Leucus, 21900 Orus, and 617 Patroclus + Menoetius. The mission will examine the geology of the surface, bulk properties (such as bulk density), and any potential satellites and/or rings associated with each asteroid (Levinson et al., 2021b).

Patroclus, officially titled 617 Patroclus, is a C-type binary Trojan asteroid (Smith et al., 1981). Previous observations have determined that Patroclus has a semimajor axis of 5.207 AU and an orbital period of 11.89 years (JPL, 2024). Its rotation period is notably long at 103.02 ± 0.40 hours (Mueller et al., 2010). 617 Patroclus is a binary system consisting of Patroclus and its companion Menoetius, which is similar in size and separated from the main body by a distance of 692.5 km. These asteroids are tidally locked such that their orbital period around each other is also 102.8 hours (Brozović et al., 2024). The binary nature of the system allows for mutual events such as transits and occultations to occur. These events can provide more information on Patroclus's characteristics, including its shape and surface features, which currently lack thorough documentation. Observing these characteristics will provide insight into the gravity field surrounding Patroclus, impacting how research endeavors including NASA's Lucy mission will approach flyby observations.

Images were taken using two different telescopes. All images were taken at Siding Spring Observatory (MPC Q62) in New South Wales, Australia. The images from October 2 were taken using a 0.50-m f/6.8 reflector telescope with a FLI-PL6303E CCD camera with an array of 3072×2048 pixels (iTelescope, 2024a). The images from October 6 and 21 were taken using a 0.43-m f/6.8 Corrected Dall-Kirkham telescope with a Moravian G4 16000 CCD camera with an array of 4096×4096 pixels (iTelescope, 2024b). All images were taken through an Astrodon E-Series Luminance filter with an exposure time of 300 seconds.

On 2024 October 2, a series of software and equipment issues severely impacted the images taken. After the first nine images, a software glitch caused the following 21 images to be mislabeled and

prevented us from accessing them (access was restored days later). Additionally, starting with the 24th image, all subsequent images in the first sequence were very out of focus. Sometime later, another software glitch caused all of the images taken to be labeled under another iTelescope username, once again preventing access to acquire them (restored later). After the requisite meridian flip, the images were in focus until the 11th frame, where the telescope once again lost focus for the last 30-odd images of the night. After this, the iTelescope website repeatedly revoked access to the telescope and then restarted itself until the observatory closed at 17:57 UTC, preventing further imaging.

On 2024 October 6, the weather conditions were clear and there were no obstructions, and 36 images were taken. 617 Patroclus set below the horizon at approximately 18:30 UTC, so no more images were taken after this time.

2024 October 21 was the final night for observations by this campaign. The weather conditions were also clear with no main obstructions. 617 Patroclus dipped below the telescope's viewing range as the event was beginning, so the 13 images were taken before it began.

iTelescope automatically calibrates the images produced with a standard bias, dark, and flat field calibration procedure. Aperture photometry was conducted using the R magnitudes of several stars in the ATLAS catalog (Tonry et al., 2018), the MPOSC3 catalogue (Warner, 2018), or the APASS catalog (Henden et al., 2009) in *MPO Canopus* (Warner, 2018). Some of the images collected were out of focus, so observing data were split into various groups based on whether the images were in focus or before/after a meridian flip, with aperture sizes adjusted accordingly. In *MPO Canopus*, we chose five known non-variable comparison stars to determine the brightness of the asteroid. *MPO Canopus* automatically cycled through each image and determined the magnitude of 617 Patroclus based on the magnitudes of the comparison stars. This process was repeated several times on the various sets of in-focus and out-of-focus images in order to achieve the lightcurves below. For the October 2 session with some out-of-focus images, the same comparison stars were used throughout the photometry analysis for all images.

Fig. 1 is a raw lightcurve created using observations from October 2. These took place over the course of approximately 9.5 hours starting at 10:30 UTC and ending at 19:55 UTC when the observatory closed for the night. Some of the images from the end of the night were discarded due to being highly out of focus and because they were taken after the partial occultation/eclipse had ended. Each session of data indicated on Fig. 1 corresponds to the first images that were in focus (session 12), then a sequence of images that were out of focus (session 13), then a sequence of images that were in focus (session 14), then in-focus images after a meridian flip (session 15), and finally images that were out of focus (session 16).

The three vertical lines present in Fig. 1 correspond to the beginning, peak, and end times of the superior event as predicted by Brozović et al. (2024) and listed in Table I. Interestingly, these lines do not align with the beginning, peak, and end of the event according to the images taken. We are confident in our time calculations and placement of these lines, so it is unclear why this discrepancy exists. It could potentially be the result of an unknown aspect of the binary asteroid system, but more observations are needed to confirm this.

TABLE OF EVENTS:

Event Date	Event Start	Event Peak	Event End	Event Type (Superior/Inferior)
2024 10 02	09:14	21:51	00:51	Superior
2024 10 06	16:12	18:48	21:20	Superior
2024 10 21	16:14	19:20	21:58	Inferior

Table I. Event times (in UTC) for the observations in this paper (Brozović et al., 2024).

Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
617	Patroclus	2024 10/02	4.1	5	-16.2					
617	Patroclus	2024 10/06	4.3	4.9	-16					
617	Patroclus	2024 10/21	6.4	4.7	-15.3					

Table II. Observing circumstances and results. 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).

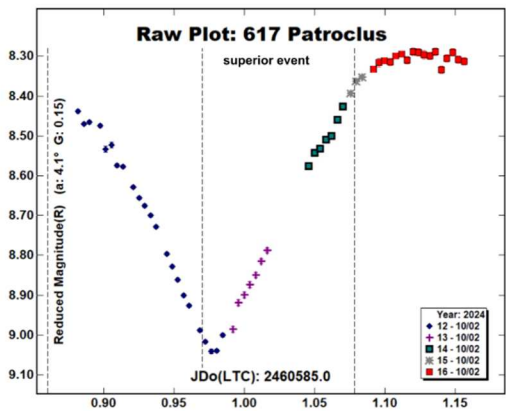


Fig. 1. Raw lightcurve of 617 Patroclus on 2024 Oct. 2 for superior event.

Observations resulting in the lightcurve shown in Fig. 2 were done on 2024 October 6. Data were collected over a period of 2.5 hours, from 15:00 to 17:30 UTC. Though the event was projected to peak at 18:48 UTC (Table I), we were unable to observe 617 Patroclus past 17:30 UTC due to it being out of the telescope’s viewing range.

The raw lightcurve from the event on October 6 aligns with the timeline provided by Brozović et al. (2024). The vertical line in the plot represents the predicted start time for the event. To the left of this vertical line, the brightness does not appear to fluctuate immensely. However, the brightness drops significantly after the predicted start time for the event, further reinforcing the accuracy of the event timing given by Brozović et al. This was a superior event, and the lightcurve captured from our observations demonstrates a combination of an occultation and eclipse.

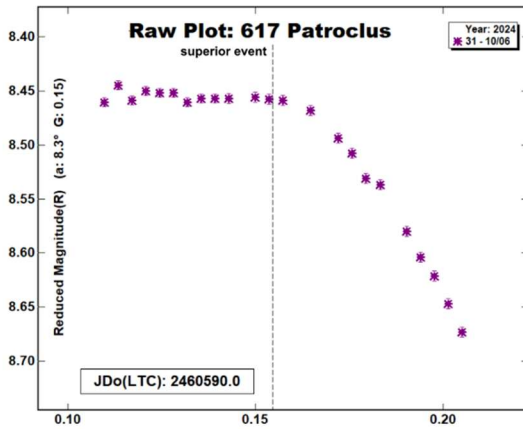


Fig. 2. Raw lightcurve of 617 Patroclus on 2024 Oct. 6 for superior event.

The lightcurve shown in Fig. 3 is from observations taken on 2024 October 21. Brozović et al. (2024) predicted the combined inferior eclipse and occultation event to start at 16:14 UTC (Table I). The vertical line represents when the event was supposed to start. The line is on the far right due to the event starting just before Patroclus went below the telescope’s observing capabilities.

All data will be loaded into the Asteroid Lightcurve Photometry Database (ALCDEF; Warner et al., 2009) following publication.

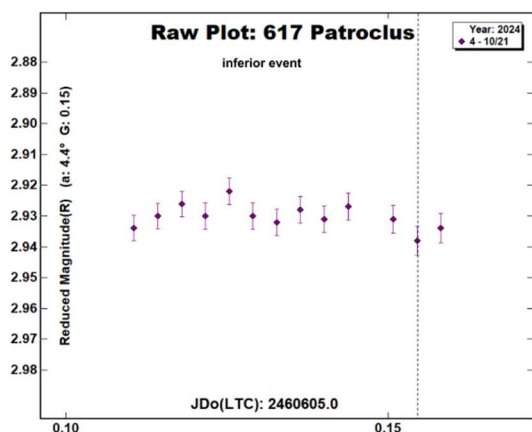


Fig. 3. Raw lightcurve of 617 Patroclus on 2024 Oct. 21 for inferior event.

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