Ground-based Light Curve Follow-up Validation Observations of TESS Object of Interest TOI 3718.01

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Abstract

The purpose of this paper is to present light curve follow-up validation observations of the TESS object of interest (TOI) 3718.01. This research aims to characterize and confirm the existence of TOI 3718.01 as an exoplanet or determine its status as inconclusive. Candidates for this experiment were identified using the Transiting Exoplanet Survey Satellite (TESS). Datasets were generated by George Mason University at the Herschel Observatory on December 6, 2023. AstroImageJ, a software package, was utilized to process, reduce, and plate-solve the data. Light curves were then obtained to confirm whether the TESS Satellite detected a transit. This work would confirm the planetary nature of TOI 3718.01, distinguishing it from other astrophysical phenomena that might mimic a planetary transit. This study aims to provide a comprehensive analysis of TOI 3718.01, contributing valuable insights into its potential status as an exoplanet, and enhancing our understanding of planetary systems identified by TESS.

Introduction

Exoplanet research is a crucial part of modern astronomy that expands our fundamental knowledge of the universe, planetary formation, and the evolution of planetary systems. Exoplanets are planets outside the Solar System and exhibit a diverse range of characteristics(1). To date, over 5000 confirmed exoplanets have been discovered orbiting other stars(2). A vital tool in this process is the Transiting Exoplanet Survey Satellite (TESS). Launched on April 18, 2018, TESS surveys exoplanets over a 2-year period, monitoring the northern and then the southern hemisphere. During its missions, TESS produces full-frame images, light curves, and lists of TESS Objects of Interest (TOIs). Light curves are used to measure a dip in brightness from a star, indicating a potential planetary transit where a planet blocks some of the star's light(3). However, transits can also be caused by other obstructions, and nearby eclipsing binaries (NEBs) can result in false positives.

The TOI observed for this study was TOI 3718.01. This object has a right ascension of 04h22m51.28s and a declination of +41d07m31.13s, according to the J2000 reference system. TOI 3718.01 has a radius of 12.171 Earth radii (R_Earth). Weather conditions were partly cloudy with slight winds on the night of observation which may have impaired the telescope’s accuracy. The target star has a visual magnitude of 12.86. The observation session started at 22:35 and ended at 17:50 the following day. Capturing the transit proved challenging due to the wide period of the event. Further observations under better conditions and additional data collection are recommended to reach more definitive conclusions.

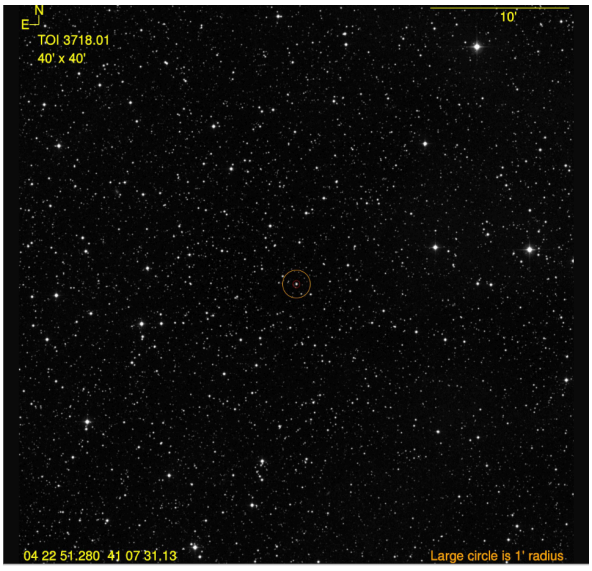
Methods

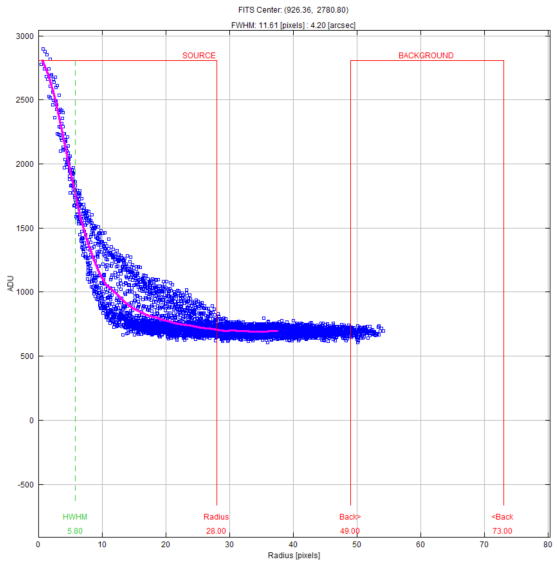
TOI 3718.01 was observed at George Mason University Observatory on December 6, 2023, a Wednesday. A red filter was used to cut through reflections and reduce atmospheric distortion, thus enhancing the quality of the images taken. The sciences were taken with an exposure time of 85 seconds. The estimated transit window began with an ingress time of 22:35 and an egress time of 17:50.

The obtained dataset was processed to remove artificial data counts. The CCD Data Processor tool was employed to perform data reduction, which involved subtracting dark frames and dividing by flat field images based on lens width. Dark frames and flat field images were used to create master darks and master flats.Images were corrected for condensation spots, thermal interference, and dust particles. Any images that were out of focus or obstructed by clouds were labeled as bad and set aside. As a result, nearly a third of the data was discarded.

After this reduction process, the object was plate-solved to determine its precise celestial coordinates. This setup improved the accuracy of the photometry by ensuring reliable measurements even if the star moved out of the aperture. The Aperture Photometry tool was utilized to develop a seeing profile. The tool was adjusted to a radius of 8 to accommodate for the small size of the TOI. The processed data was then visualized to generate the light curve. This was done by comparing the TOI to 30 nearby stars through multi aperture photometry. The reference stars used were C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, and C14. The curve was optimized to limit the RMS and develop the best fitting curve for the data.

Figure 1: TOI 3718.01 (left) and Seeing Profile (right)





Results

Figure 2

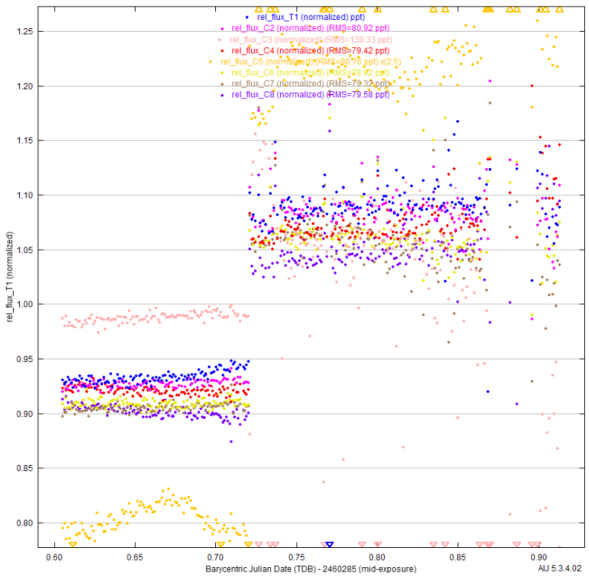
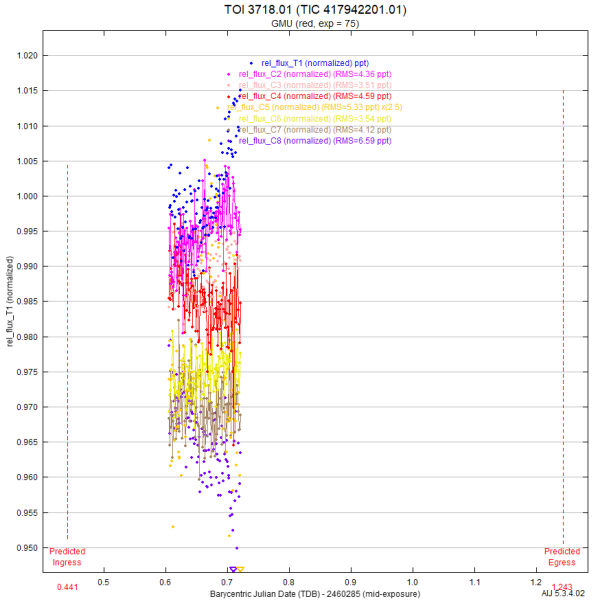


Figure 3



Discussion

The results obtained were inconclusive as we failed to capture a full transit. As the data is fully within the ingress/egress period as shown in Figure 3, but there is no dip in the star's brightness where a planetary body could block a consistent amount of light. In Figure 2, it is clear the light curve has 2 distinct flat sections, one at a lower flux and one at a higher flux. The first flat section likely represents the part of the light curve where some part of the star's light was blocked. The second second flat section is likely the post-transit baseline. Based on this analysis, it is possible that we captured the egress phase of the transit. This is the phase where the planetary body exits the transit, and the star returns to its normal brightness.

As the full transit was not detected, it is not possible to make definite conclusions. Thus, we cannot analyze the full depth or duration of the transit, and therefore cannot analyze the exoplanet. This could have been caused by the poor weather conditions on the observation night. If observation could not begin due to poor weather, it is possible that the ingress period was missed entirely. It also could have been caused by issues during the data reduction process, such as poor calibration, inconsistent background subtraction, or errors in aperture photometry. Due to experimental limitations and possible errors during data processing, it is unreliable to produce full results. In spite of these limitations, the hint of an egress makes TOI 3718.01 a strong candidate for further research.

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