Ground Based Light Curve Follow-up Validation Observations of Tess Object of Interest TOI 5886.01

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Abstract

Context. It is important to discover new systems with exoplanets because each new system shows a different aspect of the lifecycle of a solar system. Discovering new solar systems can also act as a way to confirm our understanding of the lifecycle and interactions between planets and stars. The launch of the TESS mission helped to identify thousands of possible exoplanets that need to be manually confirmed.

***Aims*.** The goal of this study was to attempt to define the status of TOI 5886 as an exoplanet or as a false positive or false result.The goal was also to further research into exoplanets in order to make future studies of TOI 5996.01 more successful.

***Methods*.** The George Mason 0.8m space telescope was used to observe TOi 5996.01 on the night of 6/18/24. AstroImageJ was later used to analyze the results and create a light curve and an NEB plot.

***Results*.** Results of the analysis were inconclusive. Although the transit occurred during the predicted time and had a depth close to the predicted value no stars passed the NEB check which indicated that the result could be a false positive.

1. Introduction

Exoplanets describe any planet that does not orbit our sun. Since these planets are very far away it was very difficult to detect them until the first exoplanet was discovered in 1992 (https://exoplanets.nasa.gov/alien-worlds/historic-timeline/#first-exoplanets-discovered). Since That day the discovery of new exoplanets has been made easier and easier by use of the internet and specifically made missions such as the TESS mission. The TESS mission rapidly expanded the number of possible exoplanets observed via the transit method. (Keivan G. Stassun *et al* 2018

AJ 156 102) Exoplanets are detected in this way when they pass in front of another star and reduce its brightness (Guerrero *et al* 2021). Each of these possible directions needs to be manually verified with a ground based follow up observation in order to make sure the reading was not a false positive or a negative result (https://asd.gsfc.nasa.gov/archive/tess/ground_based_followup.html). These confirmations often require several different studies to be conducted on the same proposed exoplanet and many statistical tests need to be performed.

Over 2000 TESS candidates still have yet to be analyzed and fully studied. Additionally new candidates are constantly being found. Some other studies that worked with exoplanet candidates include “Spinning up a Daze: TESS Uncovers a Hot Jupiter Orbiting the Rapid Rotator TOI-778” (Jake T. Clark *et al* 2023 *AJ* 165 207). This study used the data from several telescopes and created light curves in order to indicate both that the planet was a hot jupiter, and that its star rapidly spun. Another study “TOI-3362b: A Proto Hot Jupiter Undergoing High-eccentricity Tidal Migration” (Jaiyin Dong *et al* 2021 *ApJL* 920 L16) uncovered an exoplanet with short- period orbits. This planet also had its temperature changing drastically as it orbited its home star. The exoplanet was also interesting because it has an orbital period of 18.1 days, which is near the limit of the TESS mission’s possibilities.

A follow up on TOI 5886.01 is necessary because there is limited information about TOI 5886.01. A follow up on the candidate could help to provide more resources for future groups attempting to further research on TOI 5886.01. A follow up on TOI 5886.01 can also help to determine if it is likely to be an exoplanet or not.

In this paper, we present follow up observations of TOI 5886.01. The target has an orbital period of 0.97 days and has a radius of 11.5. The star the object orbits is 1.9 times the radius of our own sun and has 1.74 times the mass. The star also is roughly 7500 degrees Kelvin (https://exo.mast.stsci.edu/exomast_planet.html?planet=TOI5886.01). Our goal is to investigate whether or not thetransit occurs on the expected star at the predicted time with the predicted duration and depth.

In section 2, we present our observations from TESS and the George Mason University 0.8m telescope. In section 3, we present our analysis of the TESS light curve for TOI 5886.01 and our ground based light curve analysis. In section 4 we present our light curve results. In section 4, we present our light curve results. In section 5 we discuss our results and in section 6 we present our conclusions and future work

2. Observations

In Section 2.1 we present the TESS Object of Interest 5886.01 and its exoplanet properties for the TESS Input Catalog, the *Gaia* mission, and other archival sources. In section 2.2 we present the TESS sector light curve(s). In section 2.3, we present a summary of the observational data collected with the George Mason University 0.8m telescope.

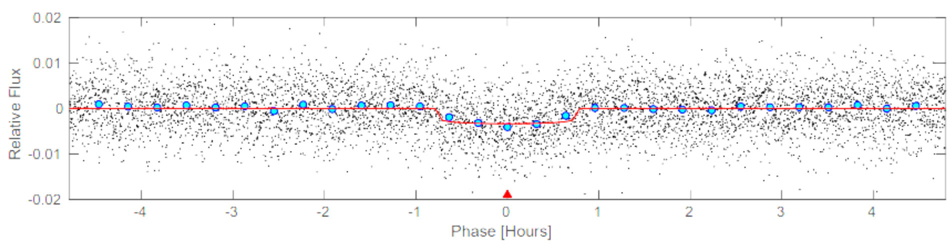
2.1 TESS discovery

TESS Object of interest 5886.01 was observed on 3/08/2024 with a period of 0.965 days. It was observed with a depth of 3.3 parts per thousand. The predicted exoplanet had a radius of 11.5, implying that it is much larger than earth. Likewise, the star in the system had a stellar radius of 1.92 which is also larger than our sun. The target star had a temperature of 7542 ± 254 degrees Kelvin and a stellar density of 0.246. TIC 15682927 is located 832.54 ± 23.66 parsecs away (https://exo.mast.stsci.edu/exomast_planet.html?planet=TOI5886.01). TOI 5886.01 also had a duration of 1.224 ± 0.24 hours. TIC 15682927 exhibited a stellar metallicity of 0.00 which pimples that the star and the surrounding system are still young. Additionally, TOI 5886.01 had a temperature of 3039 degrees Kelvin (https://exofop.ipac.caltech.edu/tess/target.php?id=15682927). This could imply that the proposed exoplanet is an extremely hot jupiter because of both its size and temperature.

2.2 TESS light Curves

The TESS mission captured a light curve measuring the relative flux of TIC 15862927 over a period of slightly less than 2 hours. The dip in the data was symmetrical around the x-axis and the drop in flux was picked up by the TESS mission. The total shift in relative flux was 0.05 as seen in figure 1.

Figure 1 : Relative Flux Shift of TOI 5886.01



2.3 Data collected from ground observation

The GMU ground based 0.8m telescope took 223 total images of the target star.Each photo had an 85 second exposure time.The transit duration of TOI 586.01 was 1 hour 43 minutes. The event occurred from 2024-06/18 to 2024/06/ from 11:32 PM to 2:36 AM.

Additionally, The images were taken with a red filter. The RA of TOI 5886.01 was 20:27:57.32 and the DEC was 37:08:46.88

3. Analysis

In section 3.1 we present our tools used to analyze the TESS sector light curve(s) using AstroImageJ/ExoFASTv1/ExoFASTv2. In section 3.2, we present our analysis of the ground-based light curve using AstroImageJ.

3.1 TESS light curve analysis

AstroImageJ was used to analyze TESS light curve results. Primarily the data set 2 window was used to properly display the correct graph and to place the variance plot properly. The multi-plot main plot window was also used to manipulate the range displayed on the graph. The multi-plot y window allowed for specific curves to be chosen to be shown along with their scale and shift, which de-cluttered to graph significantly (https://docs.google.com/document/d/1MZU2kb9ahNhv7tdghKX7EUUo-ub_7mJr/edit).

3.2 Analysis using AstroImageJ

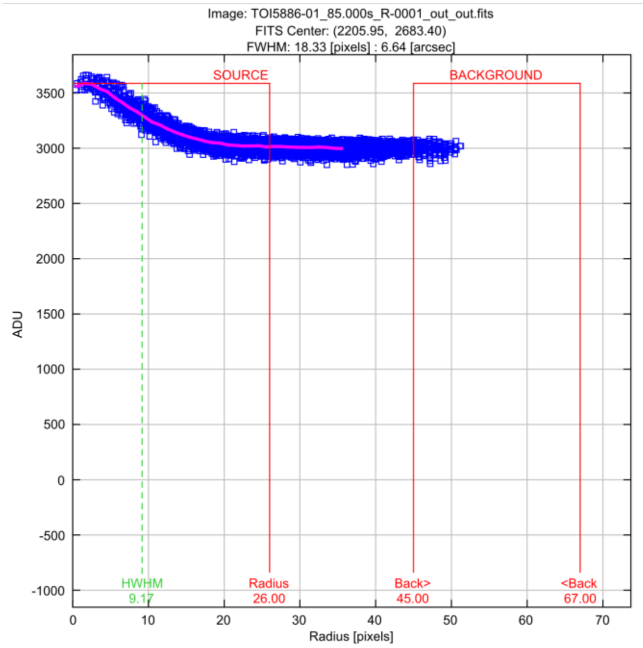
Reduction/ plate solving

Until the images taken by the George Mason University 0.8m telescope are properly reduced and are plate solved they do not provide any useful information. Often errors such as dust on the telescope lens or passing clouds make analysis difficult. In addition to this several images had to be discarded because they were blurry, this was likely caused by movement of the telescope during an exposure period. Once the bad images were discarded AstroImageJ could be used in conjunction with its data processing module to subtract the dark images and divide the flats in order to correct for difficulties during the observing session. These reduced images were then inputted automatically into nova.astrometry.net which was able to detect several stars in the image to provide RA and Dec coordinates for each image. Using these coordinates we were able to locate the target star and begin preparing a light curve.(https://docs.google.com/document/d/1MZU2kb9ahNhv7tdghKX7EUUo-ub_7mJr/edit)

Light curve extraction

AstroImageJ was used to acquire a light curve using aperture photometry. Information provided by George Mason University was used to locate the proper star and generate a seeing profile pictured in figure 2. After a seeing profile was generated a GAIA file corresponding to TOI 5886.01 was overlaid and 15 other comparison stars were chosen. Later the base template information was input into the main light curve menu. After information about the planet and system was inputted into the Multi plot main menu. The data set 2 menu was then pulled up and the “AstroImageJ (AIJ) Tutorial for Transiting Exoplanet Data-Reduction & Analysis” (https://www.astrodennis.com/TFOP_SG1_Guidelines_Latest.pdf) was followed in order to set proper orbital parameters and other information such as effective temperature and metallicity. The rest of the steps present in the GMU tutorial was followed along with the use of the “TFOP SG1 NEB Analysis Macro” menu to create an NEB plot. (https://astrodennis.com/NEB_Table_Instructions.pdf)

Figure 2: Seeing profile of TOI 5886.01 obtained through AstroImageJ



4. Results

In section 4 we present the results of our ground based light curve, our Dmag vs RMS plot, and the overlay of the normalized relative flux graph.

Figure 3 : Ground based Light Curve of TOI 5886.01

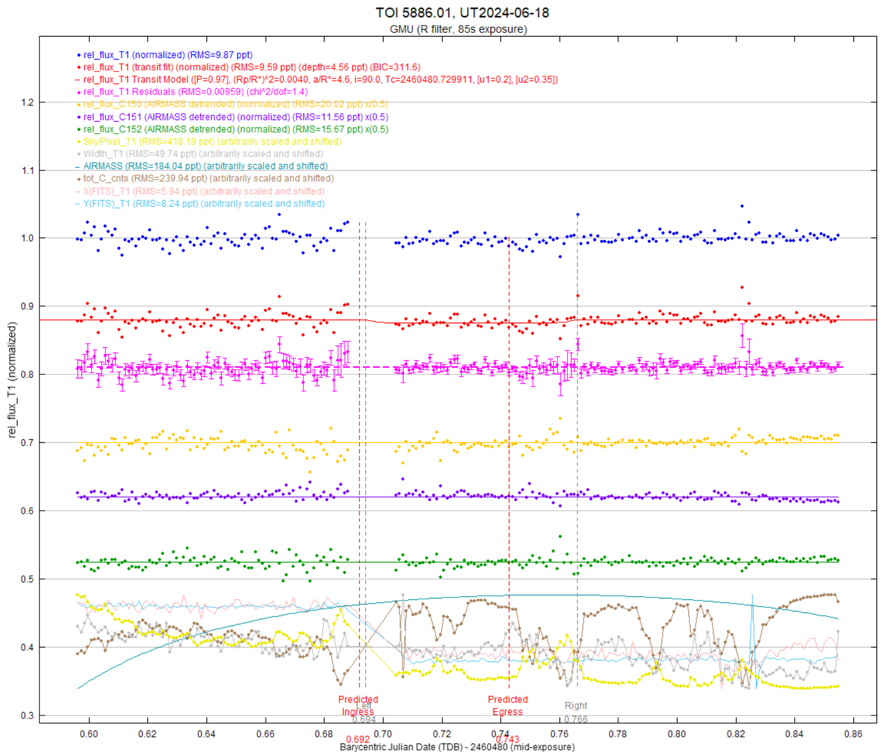


Figure 4: Normalized relative flux of target star

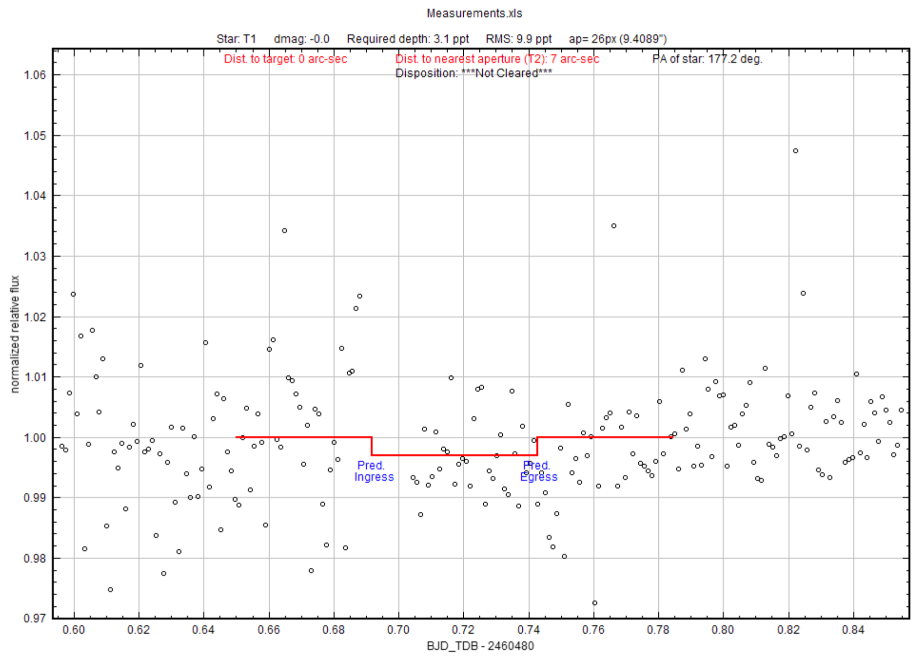
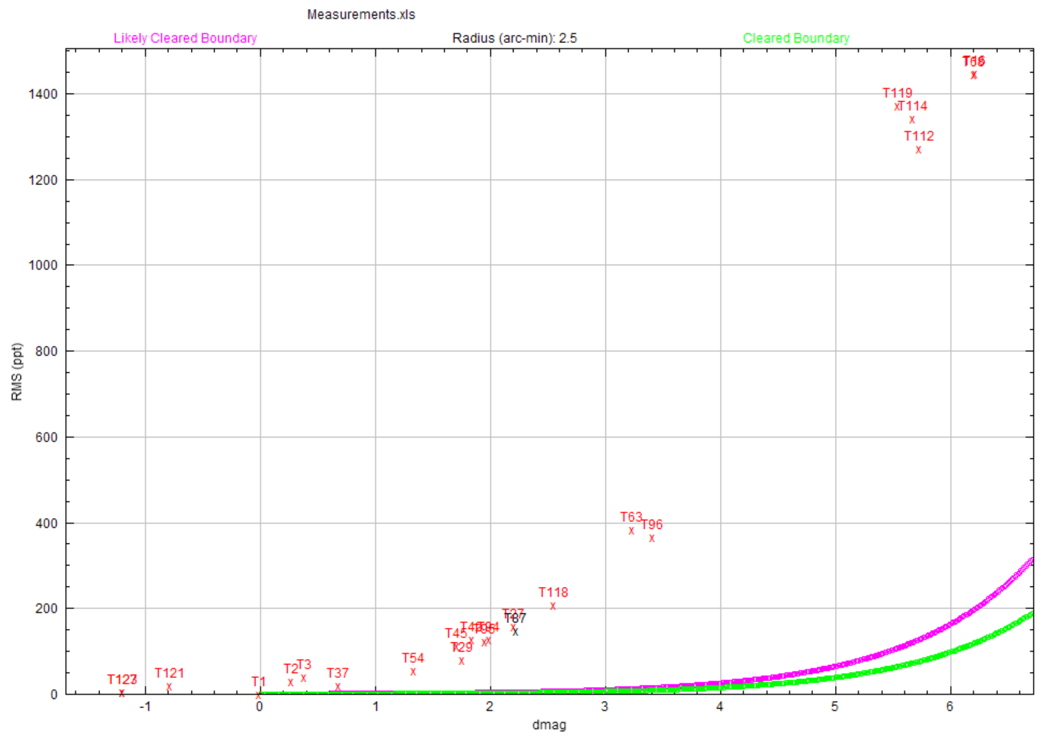


Figure 5 : Dmag vs RMS graph



5. Discussion

In section 5.1 we present our interpretation of our results. In section 5.2 we place our results into context in the greater field of follow-up of candidate exoplanets from the NASA TESS mission.

5.1 Interpretation of the results

The results of the collected data for TOI5886.01 is inconclusive because of a variety of factors. The transit time was similar to the predicted one but was still 20 minutes longer than anticipated although it started close to the predicted time. The target depth of 4.56 ppt was higher than the TESS mission's measured depth of 3.10 ppt. The reason that the depth may have been different is because TESS may have had a harder time detecting the change in brightness considering the large amount of surrounding stars. The scatter of the light curve data reduced during the observation period and remained smaller than the scatter before the transit occurred.

Although this data could suggest that a proper transit and exoplanet was observed no surrounding stars passed an NEB check which means that a false positive result is still likely. Additionally other surrounding stars did not depict similar changes in brightness which indicated that the drop in brightness was not a larger event in the surrounding area or an issue with the GMU telescope.

5.2 Comparison with confirmed TESS exoplanet

TOI 5886.01 has the properties of a hop jupiter because of its high temperature of 3039 degrees Kelvin and a radius of 11.5, which is roughly the size of jupiter. The star that TOI 5886.01 orbits is a star that is 1.9 times the radius of our own sun. The temperature of said star is 7542 ± 254 degrees Kelvin. TOI 3362b is a similar system with a star 1.8 times the size of our sun and an exoplanet that is a hot Jupiter with a radius 1.142 times that of Jupiter. The star of the system also had a low metallicity of 0.017 (Jaiyin Dong *et al* 2021 *ApJL* 920 L16). One of the main differences between the 2 systems is the orbital period of 18.1 days for TOI 3362b and TOI 5886.01 only had an orbital period of 0.97 days. Additionally, TYOI 3362b is undergoing a tidal migration which could allow for a giant such as the exoplanet observed to have a short orbital period.

6. Conclusion and future work

Data from the TESS mission in order to develop a baseline to compare to data generated by the GMU 0.8m telescope. The collected data was processed using AstroImageJ in order to correct for any obstructions present during the viewing session. The resulting light curve that was generated showed a small dip in brightness that was not shown by other nearby stars, along with the transit occurring around the predicted times given by the TESS mission. An NEB analysis shows no passing stars which indicated that the star could be a false positive.

Much more work still needs to be done to fully confirm or deny the existence of TOI 5886.01 as an exoplanet. More in depth statistical analysis could be done in order to conform or deny the possibility of a false positive result. Additionally, alternate forms of exoplanet detection could be used in order to collect more data and create a better profile of TOI 5886.01. If TOI 5886.01 were to be an exoplanet it would give a look into the early life of a star and surrounding planets.

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