Ground-based Light Curve Follow-up Validation Observations of TESS Object of Interest TOI-5868.01

Authors & Affiliations

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ABSTRACT

Our study aimed to examine and characterize data on Object of Interest 5868.01, an exoplanet detected by the Transiting Exoplanet Survey Satellite (TESS). This was done by analyzing the stellar light curve of this object. We remotely obtained ground based data from the Observatory at George Mason University(GMU). We took 280 exposures with the GMU 0.8 m telescope and reduced them using Python collaboratories, then we conducted ground based multi aperture photometry using AstroImageJ to generate a light curve. In addition, we plotted residuals and the fluxes of our target stars and adjusted trends within the data. Although our data was in some measure skewed due to low exposure and periods of imperfections from telescope movement and blurriness, we found that by using less obscured reference stars and the WIDTH_T1 Detrending Parameter, we were able to find data clear enough to work with. Therefore, the results for this study are inconclusive yet suggestive of a transit. Due to the limited scope of our research, we did not perform other detection methods such as Doppler spectroscopy or transit timing variations analysis. Though no confirmed conclusion can be reached at this time, more data should be collected to compare to the current data in order to fully confirm TOI 5868.01 as a transit.

INTRODUCTION

TESS, launched on April 18, 2018, with a mission to catalog the entire sky over two years in order to identify and study thousands of exoplanets orbiting nearby bright stars, helping to expand our understanding of planetary systems beyond our own. They aim to study over 200,000 bright stars to identify transits which are the temporary dimming of a star's brightness caused by a planet passing in front of it.

These events are then analyzed by ground-based observatories to confirm the occurrence of transits and determine the compositions of exoplanets. So far, 543 out of 7203 TESS Project Candidates have been confirmed as planets, unveiling possible sources of Earth-sized planets with habitable conditions and extraterrestrial life.

Though progress has been made, validating hundreds of candidate exoplanets is still a major task. Equivalent studies have underscored the significance of doing follow-up observations from the ground to verify the planetary status of these candidates. For example, Simpson et al. (2022) emphasized the role of stellar activity in generating false positive signals in exoplanet detection, highlighting the need for careful analysis of photometric data to distinguish between planetary companions and stellar variability. Louvis et al. (2011) demonstrated a method for using radial velocity measurements to make the first exoplanet discoveries around Sun-like stars and continues to play a major role in the discovery and characterization of exoplanetary systems. These findings highlight the need for ongoing validation activities to guarantee the validity of exoplanet discoveries.

My research aims to contribute to this ongoing effort by providing a comprehensive analysis of candidate exoplanet 5868.01, offering new insights and methods for its validation. Each new candidate like TOI 5868.01 enhances our understanding of planetary formation and evolution, and pushes the boundaries of our understanding of the universe.

In this paper, we present follow-up surveying on TOI 5868.01 (TIC 236158940). It has a planet radius of 14.794 R_Earth, and orbital period of

2.68 days. It has an expected transit duration of 2.9 hours, and depth of 3441.32 ppm (NASA Exoplanet Archive). Our goal is to verify that the transit occurs at the expected time, for the expected duration and expected depth and verify that it is not a False Positive.

In Section 2 we present our observations from the GMU 0.8m telescope. In Section 3 we present our data reduction process and our multi aperture photometry process. In Section 4 we present the results of our ground based light curve. In Section 5 we present our interpretation of our results. In Section 6 we present our conclusion and recommended future work.

SECTION 2: OBSERVATIONS

In Section 2.1, we present the TESS Object of Interest(TOI) 5868.01 and its exoplanet candidate properties, its host star properties, and a summary of the observational data collected with the George Mason University 0.8m telescope.

2.1 Observational Data:

From the NASA Exoplanet Archive we were able to attain the effective temperature of TOI 5868 which is 6875.79 K while the stellar surface gravity is 3.85 and the solar radius is 2.41. The start and end times collected on July 6, 2024 were from 21:45 pm to 4:30 am, resulting in a total of a 2.68 day period. We observed our target in a R (Red) filter, and found that the RA and Dec coordinates were 20:53:40.689 and +34:21:05.93(in days, minutes, seconds), respectively.

ANALYSIS

In Section 3.1 we present our data reduction process to create reduced exposures. In Section 3.2, we present our analysis of the ground based light curve.

3.1:

The tool we used for this analysis was AstroImageJ(AIJ). We also used the NASA Exoplanet archive, and EXOFOP to access data about TOI-5868.01 and enter information as parameters. We used the python programming language as well as Altinak, a python library, in order to process through the science images and reduce our data. This target had 214 reduced images after a data reduction of 280 raw data images, each science having an exposure time of 65 seconds. In addition to the science exposures, we collected 20 darks and 10 flats. 10 of the darks had the same exposure time as the sciences (65s), and 10 of the darks had the same exposure time as the flats (3s).

3.2:

We then aligned our data, again using AIJ. We created a seeing profile (Figure 1), which gave us the source radius, 33.00, for the aperture photometry and gave us the annulus sizes 57.00 and 86.00.

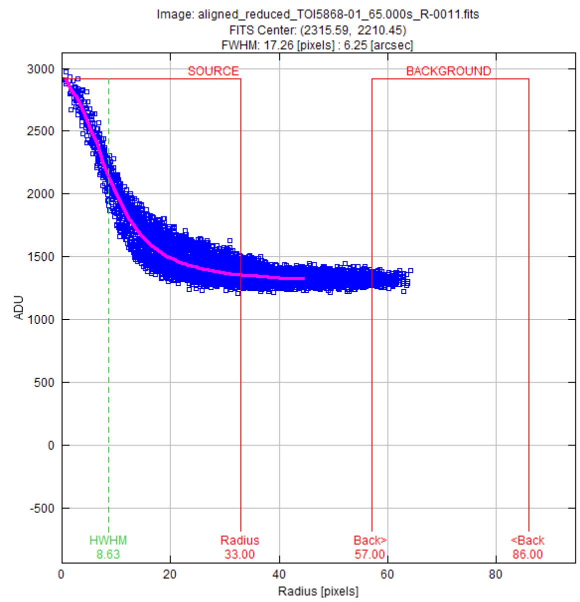

Figure 1: Seeing Profile.

Then, we examined the ground-based light curve using AstroImageJ's multiplot tool. At first, we uploaded the Template plotcfg file to the multi plot main window (https://www.astrodennis.com). The default x-data was modified to BJD_TDB. We chose the auto x range for the plot and put the predicted ingress (0.621) and egress (0.741) timestamps into the V. Marker 1 and V. Marker 2 sections using the Transit Finder Info that we obtained from the GMU Observatory.

In the Data Set 2 Fit Settings window, we entered TOI 5868's period (2.68 days) , its radius (2.405910 solar radii), and its metallicity (0.083 [M/H]). Then, we used TOI 5868's effective temperature and surface gravity values to find Linear LD u1 and Quad LD u2. In addition, we detrended Width_T1 and showed residuals with error. For our light curve we plotted Sky/Pixel_T1, Width_T1, AIRMASS, tot_C_cnts, X(FITS)_T1, Y(FITS)_T1 using the recommended scale, shift, and color from the latest TFOP SG1 Guidelines.

RESULTS

In Section 4.1 we present the results of our light curve analysis.

4.1:

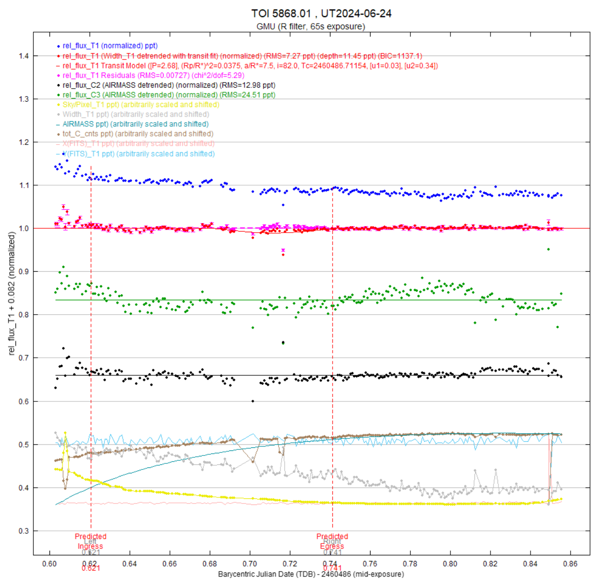

Figure 2: Light Curve Plot of TOI-4064.01

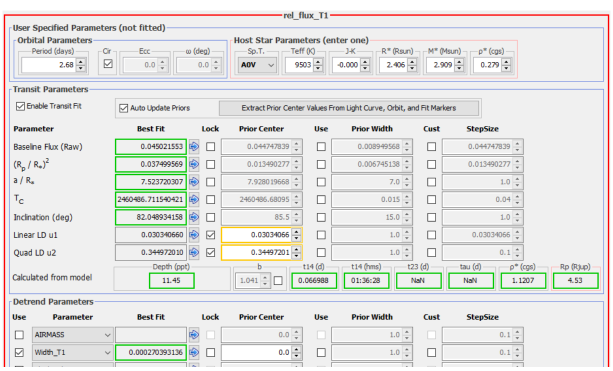

Figure 3: Data Set Fit Settings

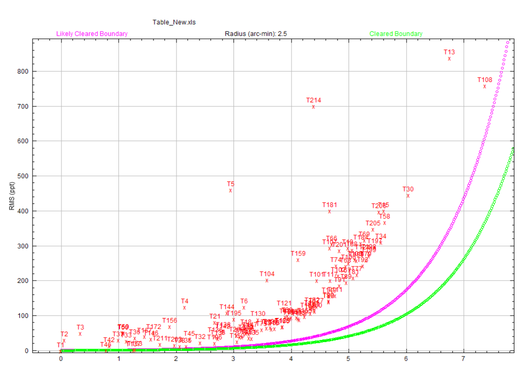

Figure 4: NEB Check (Dmag vs. RMS plot)

DISCUSSION

In Section 5.1 we present our interpretation of our results.

5.1:

From the data we collected, we were unable to neither confirm nor deny the possibility of a transit. Overall, the data we collected points towards there not being a transit. The main factor towards this conclusion, is the major difference between the expected depth, 3441.3ppm (NASA Exoplanet Archive), and the depth we received which was 11.45ppm. Further, the time duration of the transit was expected to be 3 hours and 10 minutes(NASA Exoplanet Archive), however the transit from our data was only 1 hour and 36 minutes as seen in Figure 3.

In terms of the Dmag vs. RMS plot from Figure 4, there are no nearby eclipsing binaries (NEBs) due to the fact that most of the stars lie on the same curve and therefore don't have huge changes in flux throughout the night. There was no significant visible cloudiness or noisiness in our exposures, so it is unlikely that the lack of a transit was due to an error of flaw in our data. It is possible that the star is too far away or too dim for a transit to be detected, with the methodology we utilized.

Despite the potential for the data to indicate something other than a transit, the light curve plot we generated in Figure 2 suggests a possible transit between the ingress and egress timestamps. Although the ingress point appeared slightly earlier than expected, it still hints at a transit event that may have occurred.

CONCLUSION

In Section 6.1 we discuss our conclusions to our analysis of TOI-4064. In Section 6.2 we discuss the future work that can be done.

6.1:

In conclusion, we were unable to come to an exact verdict because of the variability in our analysis. TOI 3792.01 should be given more time, thought, and research. With data collected under better circumstances, we would be able to accomplish our goal of confirming, characterizing, and classifying this target.

6.2:

Although our findings indicate that there are conflicting signs of a transit, it is likely that a false positive occurred since we did not perform a statistical study of false-positive validation.

It's also possible that our exposures were really loud or that the NEB check was done incorrectly, even if it wasn't obvious. Several validations with a more thorough inquiry would be beneficial to determine whether or not there is a transit. The star may be too dim to detect a transit, in which case we may need to use other methods, such as spectroscopy or radial velocity measurements, to locate an exoplanet.

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