Ground-based light curve follow-up validation observations of TESS Object of Interest TOI 5585.01

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ABSTRACT

The Transiting Exoplanet Survey Satellite (TESS) detects transiting exoplanets by monitoring changes in brightness of various stars (National Aeronautics and Space Administration, [NASA], 2021). Such changes in brightness may indicate the star hosts a transiting exoplanet, since the candidate exoplanet temporarily eclipses the host star. In this paper, we aim to verify the candidate planet Tess Object of Interest (TOI) 5585.01 as a transiting exoplanet using the transit method. Moreover, the transit method measures the brightness of a host star during a candidate exoplanet's transit. Using various softwares such as AstroImageJ, we reduced data derived from exposures taken using the George Mason University 0.8m telescope. AstroImageJ additionally allowed us to perform image alignment, multiple aperture photometry, and light curve generation in order to interpret varying levels of brightness coming from the host star. From our analysis, our data suggested that further work needed to be conducted to validate the candidate planet TOI 5585.01 as a transiting exoplanet because of an insufficiency of data during the candidate planet's predicted ingress and egress times.

1. INTRODUCTION

Recently, astronomers have increasingly been conducting studies and discoveries of exoplanets, which are any planets outside the solar system, that add to society's understanding of the galaxy tremendously (Burrows & Marcy, 2014). Through studies of exoplanets, astronomers can ascertain the possibility of life outside of Earth using methods such as measuring discernible levels of biosignature gas, which are created by living organisms (Seager, 2014). The TESS Mission has found thousands of celestial bodies that may be exoplanets yet to be verified, also known as candidate exoplanets. Since exoplanets typically orbit a host star, celestial bodies found through the TESS Mission can be validated as a confirmed exoplanet if it revolves around a host star. Therefore, by using transit photometry to compare the brightness of a star hosting a candidate exoplanet during predicted ingress and egress times to the median brightness of the star, the method can be used to determine when the candidate exoplanet eclipses the host star and confirm the celestial body as an exoplanet.

With the plenty of candidate exoplanets discovered through the TESS Mission, many astronomers seek to prove or disprove the validity of these candidates as exoplanets. Frequently, such astronomers also choose to use transit photometry to determine varying levels of brightness from host stars.

Within astronomy and astrophysics, the need for follow-up observations to further validate candidate planets exists as a necessity. Though the candidate exoplanet TOI 5585.01 that we observe throughout this paper has yet to be confirmed as a true exoplanet, advancements in science and technology influence future developments and findings by creating more precise equipments and software used in the process of verifying candidate exoplanets.

In this paper, we present follow-up observations of TOI 5585.01. TOI 5585.01 has a radius of 8.05828 R⊕, or 8.05828 times the value of Earth's radius. Additionally, TOI 5585.01 has an orbital period of 1.8434549 ±0.0009500 days around TOI 5585, its stellar host. Our goal is to determine if the transit occurs at the expected time, duration, and depth.

In Section 2, we present our observations from Tess and the exposures taken using an 0.8m telescope from George Mason University's Department of Physics and Astronomy. In Section 3, we present our analysis of the TESS light curve produced for TOI 5585.01 and our ground-based light curve analysis. 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 final work.

2. OBSERVATIONS

In Section 2.1, we present TOI 5585.01 as well as its exoplanet candidate and host star properties from the TESS Input Catalog. In Section 2.2, we present a summary of the observational data collected with the George Mason University 0.8m telescope.

2.1

Updated by the TESS project on August 22, 2024 in the Caltech ExoFop database for TESS Input Catalog IDs (TICs), TOI 5585.01 is listed as TIC 188389305. The Right Ascension (RA) of TIC 188389305 is 08h37m56.01s while the Declination (DEC) is +37d44m07.13s. TIC 188389305 has a depth of 4.74416 ± 0.213132 milli-magnitudes (mmag) and a duration of 1.444 ± 0.658 hours.

Additionally, TIC 188389305 also has a planet insolation of 1139.02 Earth fluxes and a stellar distance of approximately 771.853 parsecs. It also has a stellar effective temperature (T_{eff}), surface gravity (log g), and metallicity of approximately 6457.2 Kelvins, 4.44 cm/s^2, -0.581, respectively.

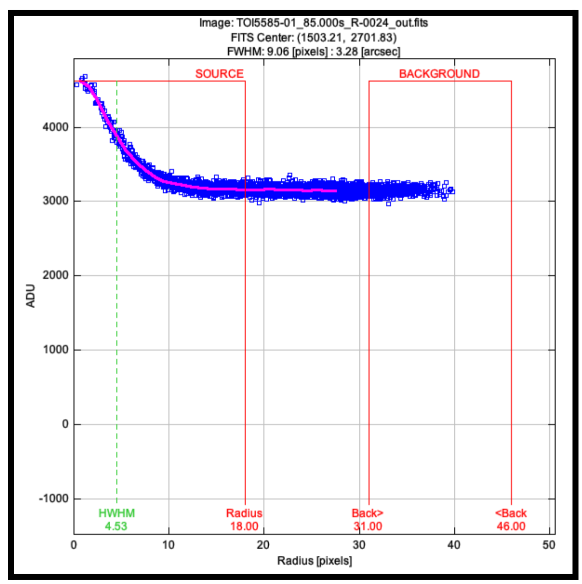

Figure 1: Seeing profile for TOI 5585.01.

2.2

While collecting data with the 0.8m telescope, we gathered 180 exposures total, and from the total, 150 exposures were science images with an exposure time of 85 seconds. Our observation period lasted from 22:33 to 23:59 on 3/14/2024 while using the R filter. Using AstroImageJ, we created a seeing profile **(Figure 1)** to determine the radius of object aperture size as well as the inner and outer radii of the background annulus. These values were used for Multi-Aperture Photometry.

3. Analysis

In Section 3.1, we present our tools used to analyze the TESS sector light curves such as AstroImageJ. In Section 3.2, we present our analysis of the ground-based light curve using AstroImageJ.

Figure 2: Full field-of-view image of TOI 5585 with selections of target and comparison stars, or apertures.

3.1

After collecting exposures of the candidate exoplanet, we analyzed the dataset for any unclear or out-of-frame exposures and then removed them from the dataset. Using the CCD Data Processor, we performed data reduction to create a median dark and median flat image while also performing dark subtraction and flat division. Next, we plate-solved the science images to prepare them for multi-aperture photometry. Finally, we created a measurement table and used it to create the light curve by selecting multiple stars for multi-aperture photometry **(Figure 2)**.

3.2

During our analysis of the ground-based light curve, to determine whether the candidate exoplanet was in transit, we compared the flux of the host star to reference stars within each exposure. We observed the flux of the host star between the ingress and egress values and compared it to the flux outside of the ingress and egress values to determine if there was a change in the star's brightness because of the transiting exoplanet. Then, we compared the curve of the host star to the curve of nearby reference stars within the exposure to determine if there was any variance between the host star's and the reference stars's flux.

4. RESULTS

In Section 4.1, we present our finding and our light curve for TOI 5585.01 which includes all measurements we collected. The light curve below presents the graph of the flux of various target and comparison stars as a function of time with various detrending parameters. The Delta Magnitude (Dmag) vs. RMS plot can be used to determine Eclipsing or Non-Eclipsing Binaries.

4.1

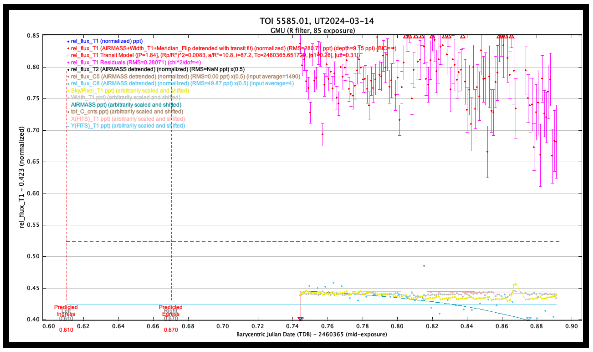

Figure 3: Tess light curve for TOI 5585.01

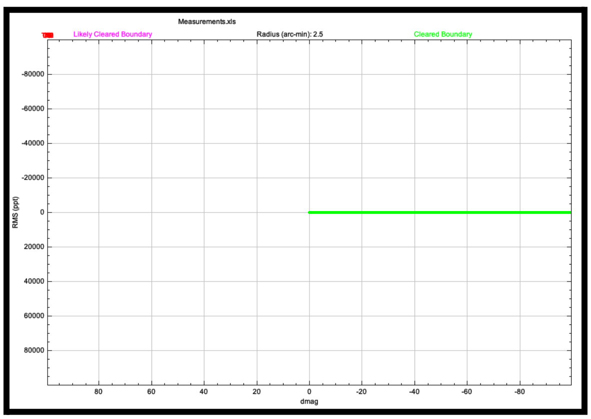

Figure 4: Delta Magnitude (Dmag) vs. RMS plot of the stars

5. DISCUSSION

In Section 5.1, we present our interpretation of our results. In Section 5.2, we describe how our results fall into the context of the greater field of follow-up of candidate exoplanets from the NASA TESS mission.

5.1

The light curve above **(Figure 3)** plots the flux of various target and comparison stars as a function of time through TOI 5585.01's transit epoch. The vertical red dotted lines represent the transit's predicted ingress and egress times. The pink data points towards the top right of the light curve represent the residual of the flux of reference star T1 through time. The black data points represent the flux of reference star T2 through time. The brown data points represent the flux of reference star C5 through time, and the light blue data points represent the flux of reference star C8 through time. The bottom of the light curve contains plots for Width_T1, Sky/Pixel_T1, AIRMASS, X(FITS)_T1, and Y(FITS)_T1. Through examination of the light curve we produced, we saw there were no data points between the predicted ingress and egress values. We determined this was likely due to invalid data collection during transit predicted ingress and egress times. Therefore, we could not compare the flux of TOI 5585 during transit to other reference stars.

The Dmag vs. RMS plot **(Figure 4)** presents a constant relation between Dmag and RMS, specifically as Dmag decreased, RMS remained zero. A Dmag vs. RMS plot can specifically be analyzed to determine a transiting exoplanet if a star does not fall within the exponential path of the curve. Similar to the light curve, through examination of the Dmag vs. RMS, we did not observe an exponential pattern, nor any stars that did not fall within the exponential path of the curve. Therefore, we did not have enough data to accept or reject the validity of a transiting exoplanet for TOI 5585.

5.2

Because TOI 5585.01 is quite large and hot with a radius of 0.718913 Jupiter radii and a stellar effective temperature of 5465 Kelvin, TOI 5585.01 may be considered a Hot Jupiter. Additionally, it has a rather short period of 1.8434549 days.

Celestial bodies similar to TOI 5585.01 can be classified as Hot Jupiters for their close proximity to their host star as a result of their size (Becker). A Hot Jupiter's size can set off a chain reaction of influences: a Hot Jupiter will orbit its host star closely because of its size.

Because the Hot Jupiter is in such close proximity with its house star, the time it will take to complete one orbital period will decrease. Finally, as another result of the Hot Jupiter's close proximity to its host star, the Hot Jupiter will have a high stellar effective temperature.

6. FUTURE WORK

In Section 6.1, we discuss the results we found from our data analysis. In Section 6.2, we discuss possible future work to be done for our data analysis in order to improve the accuracy and quality of our results.

6.1

From our data analysis, we saw that the light curve did not plot the fluxes of the stars during TOI 5585.01 predicted transit ingress and egress times. We concluded that this was likely due to an incomplete dataset or obstructive weather conditions. As referenced in Section 3.1, the dataset was analyzed for any unclear or out-of-frame pictures which included exposures taken earlier than the exposures that were processed to produce the light curve. The earlier exposures were removed because of considerable observed shifting or jolting of the target between each frame. As a result, this likely may be a factor as to the absence of data points during the transit's predicted ingress and egress times.

6.2

To validate TOI 5585.01 as a transiting exoplanet, we recommend for future data collection of TOI 5585.01 and its field in order to conduct proper analysis to determine if there is a considerable difference in flux during TOI 5585.01's transit predicted ingress and egress times. Additionally, we recommend detailed statistical testing for false-positive validation analysis, as light curve analysis does not fully validate the existence of a candidate exoplanet.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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