Ground-based Light Curve Follow-up Validation Observations of TESS Object of Interest TOI 5938.01

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Abstract

The Transiting Exoplanet Survey Satellite (TESS) has been extensively used to discover new exoplanet candidates. This ground-based follow-up aimed to provide further data and confirm the existence of TESS Object of Interest (TOI) 5938.01. This was done by using AstroImageJ to create and analyze the light curve. Observation data of TOI 5938.01 was obtained from George Mason University and was reduced and plate-solved using AstroImageJ. After generating a light curve using AstroImageJ, it is inconclusive whether or not there is a transit. This study aims to provide a foundation for future work that is necessary to determine if TOI 5938.01 has a transit or not.

1. Introduction

There are over 5,000 exoplanets discovered or validated to orbit other stars to date (Akeson et al. 2013). The Transiting Exoplanet Survey Satellite (TESS, Ricker et al. 2015) launched in 2018 and surveys the sky with the main objective of finding and validating exoplanets. However, out of these exoplanets, a few may be false positives, which is why this follow-up is necessary, in order to validate the existence of TOI 5938.01. A light curve must first be generated, and a transit identified. If a transit is identified, then additional photometry must be conducted in order to determine if there is a Nearby Eclipsing Binary (NEB) that would result in a false positive.
The search for our place in the cosmos has fascinated human beings for thousands of years (1). However, we wish to answer one question above all else. The question we would really like to answer is: Are there Earth-like planets in a habitable zone around other stars? (2) By studying TOI 5938.01, more knowledge about it and exoplanets in general may be revealed, helping us gain a better understanding of the universe. Additionally, there is little to no research done on TOI 5938.01, up to this point. While the data gathered does not provide a conclusive result, this study aims to support future work that may be done on TOI 5958.01 and similar exoplanets.

In this paper, we present follow-up observations of TOI 5938.01. TOI 5938.01 has a Jupiter radius of 0.350, while the star that it orbits, TOI 5938, has a stellar radius of 0.7423160. TOI 5938.01 also has an orbital period of 2.2604310±0.0000131 days. The goal of this paper is to investigate if TOI 5938.01 has a transit, and that it occurs at the expected time, with the expected duration and depth.

In Section 2, we present the observations of TOI 5938.01 from TESS and the George Mason University 0.8m telescope. In Section 3, we present our analysis of the TESS light curve for TOI 5938.01 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 future work.

2. Observations

In Section 2.1 we present the exoplanet properties of TOI 5938.01 and the properties of its host star from the Gaia mission, TESS Input Catalog, and other archival sources. In Section 2.2 we present a summary of the observational data collected with the George Mason University 0.8m telescope."

2.1 Exoplanet Candidate Properties

TOI 5938.01 has an equilibrium temperature (K) of 1106. Its insolation flux (earth flux) is 249.273. The predicted transit depth is 0.2680000±0.0187215, and the predicted transit duration (hours) is 2.098±0.342. The predicted transit midpoint (days) is 2459820.1831530±0.0019658 (3). The host star's stellar effective temperature (K) is 4452.000, and its stellar surface gravity (cm/s^2) is 4.5407400. Its stellar luminosity is -0.7099066, its stellar density (g/cm^3) is 2.405770, and its stellar mass is 0.6980000.

2.2 Observational Data

The data was collected using the George Mason University 0.8m telescope. There were a total of 208 exposures. After reducing and plate-solving, this dropped to 184 exposures. This was because some images were blurry or had distractions in the background like airplanes. The exposure time for each image was 70 seconds, and the filter the observations were made in was R. The date of the observation was 2023-06-15, and the start and end times were 22:20 and 4:30. The right ascension (RA) of TOI 5938.01 was 20h15m38.12s, and the declination (DEC) was +28d39m33.21s (5).

3. Analysis

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

3.1 Analysis Tools

Before creating a light curve for TOI 5938.01, we plate-solved and reduced the data. The tool that was used for plate-solving and data reduction was the CCD Data Processor tool in AstroImageJ. After the data was plate-solved and reduced, we used the Aperture Photometry tool in AstroImageJ, in order to generate a seeing profile of our target. The seeing profile is an azimuthally averaged radial profile of an object that can be plotted by left-clicking near the object in an image. We also ran the Multi-Aperture function, in order to perform differential photometry, and generate the light curve (6). When creating the light curve, we used a default plot configuration from https://astrodennis.com/ (7). Additionally, we used the Multi-plot Main, Data Set 2 Fit Settings, and Multi-plot Y-data panels in order to edit the labels and details of the plot. We also used these panels to mark the ingress and egress times on the plot and adjust the plot to fit in the window.

3.2 Ground-based Light Curve Analysis

After importing the data into AstroImageJ, we reduced and plate-solved it. This was done by stacking the images, then using the CCD Data Processor tool. In the DP Coordinate Converter window, we input the RA and Dec and other information in order to locate the target. The data we collected include flats and darks, along with the sciences. We used the CCD Data Processor tool to dark subtract the flats and create a master flat. We then used the CCD Data Processor tool to data reduce and plate-solve. After reducing the data, we loaded it into AstroImageJ and selected the Aperture Photometry tool. Then after clicking on the target, we generated a seeing profile that allowed us to figure out the aperture sizes. We entered these aperture sizes into the Aperture Photometry settings. Then we temporarily placed a 2.5' circle around the target. Then we used the Multi-Aperture Measurements window to place the apertures, since we plate-solved the data, we checked "Use RA/Dec to locate aperture positions" and unchecked "Halt processing on WCS or centroid error". After clicking on the multiplot function, we imported the default plot configuration into AstroImageJ, for the light curve. When adjusting the plot for the data in the Data Set 2 Fit Settings window, we used astroutils.astronomy.ohio-state.edu/exofast/limbdark.shtml, to obtain the Linear LD u1 and Quad LD u2 values.

4. Results

In this section, we present the results that we obtained using the data collected and tools from AstroImageJ. In Figure 1, the radius that was generated in the seeing profile was the aperture size that was used when creating the light curve. The background's inner and outer radii were the annulus sizes used. Figure 2 is the light curve that was generated using the Multi-Aperture function in AstroImageJ. The red data points represent the normalized relative flux of the target, while the red line is the transit model of the target.

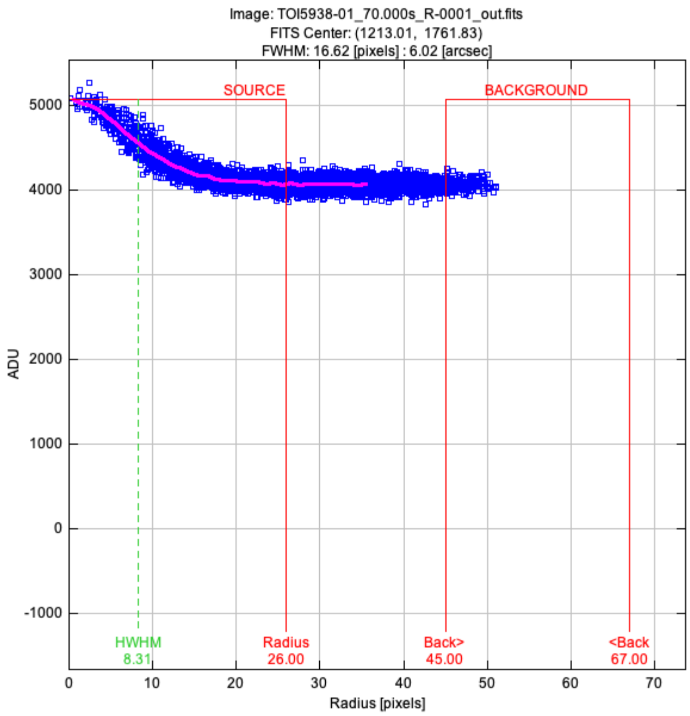

Figure 1. Seeing Profile generated from Aperture Photometry(AstroImageJ)

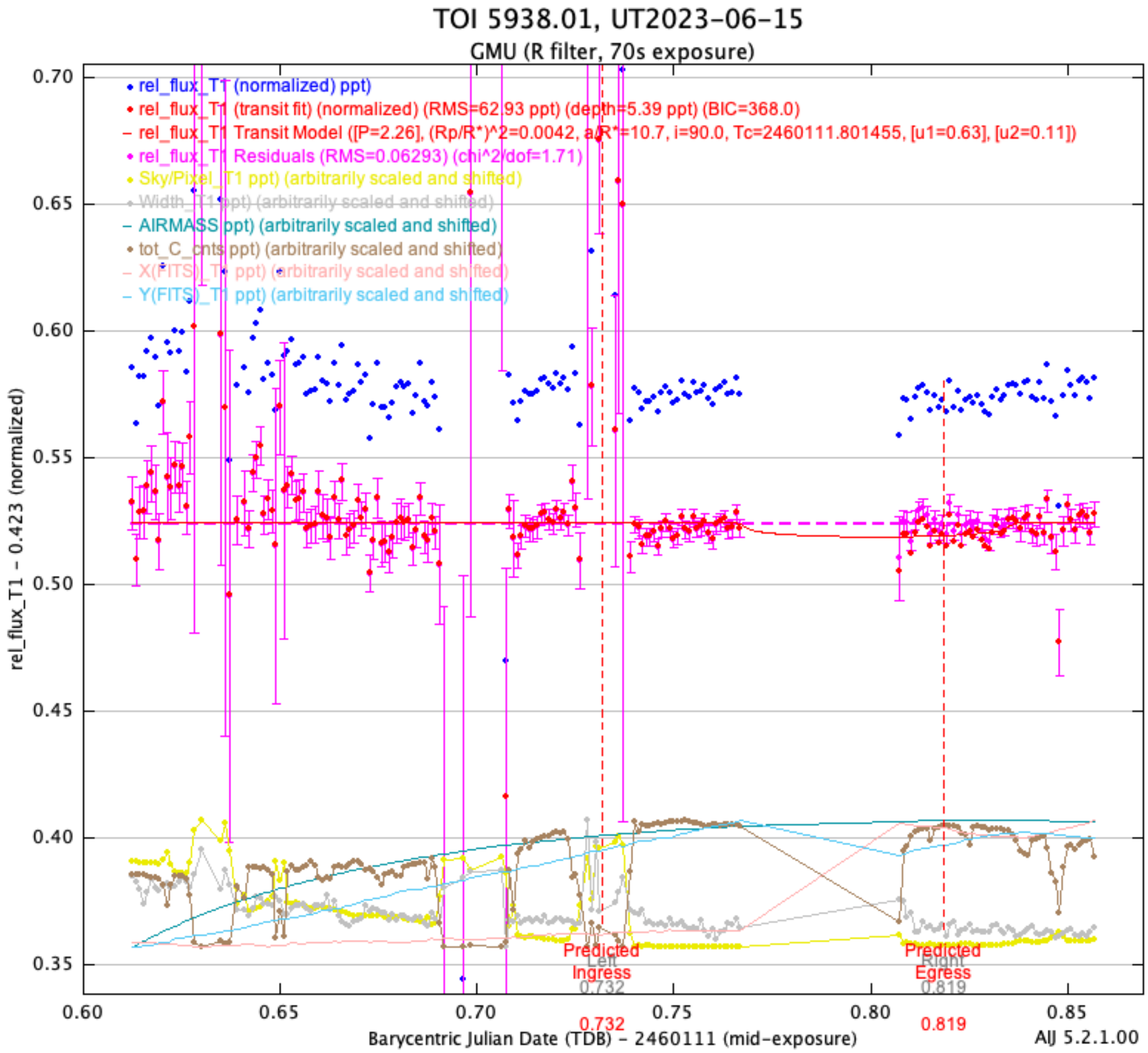

Figure 2. Normalized transit light curve generated from Multi-Aperture function(AstroImageJ)

5. Discussion

When looking at the light curve that we generated, it is unclear whether a transit exists or not. There is a lack of data points during the supposed transit, which may have been a result of clouds and bad weather. Also, the estimated transit depth is 0.2680000±0.0187215, but the transit model shows a transit depth of around 0.01. The data is also very scattered and noisy, making it difficult to make a conclusion. We were also unable to do a NEB search on the target, as after creating a Gaia stars .radec file, around 500 stars were generated, and it was impossible to run the program with the technology we had.

6. Conclusions and Future Work

The conclusion of this study is that it is inconclusive whether a transit occurs or not. Due to bad weather and gaps in the data, it is unclear if a transit occurs, and has the correct depth. This conclusion has left many questions unanswered, and in order to determine if a transit exists, more observations may need to be done on TOI 5938.01. Even if it appears that a transit with the right depth exists in the light curve model, a NEB search will need to be done, in order to fully determine that it is a transit, and not a false positive.

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