Ground-based light curve validation observations of TESS object of interest TOI 5356.01

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August 4, 2024

Abstract

The goal of this study is to confirm the existence of TESS Object of Interest(TOI) 5356.01, an exoplanet detected by the Transiting Exoplanet Survey Satellite(TESS). We remotely obtained ground-based data on TOI 5356.01 from the observatory at George Mason University. We analyzed the light curve of TOI 5356.01 through AstroImageJ by reducing the transit data of TOI 5356.01.

1 Introduction

An exoplanet is a planet that orbits a star other than the Sun. While exoplanets are made up of elements similar to those found in planets within our solar system, many have very different compositions. Exoplanets can be detected through various methods, such as direct imaging and the observation of planetary transits. Direct imaging involves capturing images of exoplanets by blocking out the overwhelming light from their host stars, allowing us to see the planets directly through observation tools such as telescopes. However, most exoplanets are discovered by an indirect method: the observation of planetary transits. A planetary transit occurs when an exoplanet passes in front of its host star, leading to a temporary dip in the star's brightness. By measuring these periodic decreases in brightness, we can identify the presence of an exoplanet and gather data about its size, orbit, mass, composition, and atmosphere [1].

One of the key missions dedicated to discovering exoplanets through the transit method is the Transiting Exoplanet Survey Satellite (TESS), an Explorer mission launched by the National Aeronautics and Space Administration (NASA) in April 2018. This mission has discovered thousands of exoplanets, including gas giants such as Hot Jupiters, Earth-sized planets, and super-Earths. TESS uses an array of wide-field cameras to monitor over 200,000 stars, looking for the telltale dips caused by transiting exoplanets. While TESS provides thousands of exoplanet candidates, additional follow-up analyses, such as this paper, are performed on TESS exoplanet candidates to confirm the existence of the planets and rule out false positives. To date, only 543 candidates out of 7,203 TESS project candidates are confirmed planets. This paper focuses on the validation of TOI 5356.01 by utilizing observational data from the George Mason University Observatory. [2].

2 Observations

We observed TOI 5356.01 on January 7th, 2023, from 18:05 EST to 3:00 EST using a George Mason University 0.8m telescope with an R filter and an 85-second exposure time. The ingress time started on January 7th, 2023, at 18:34 EST to 22:22 EST, indicating the duration of transit, as seen from ground observation, was 3 hours and 48 minutes [3].

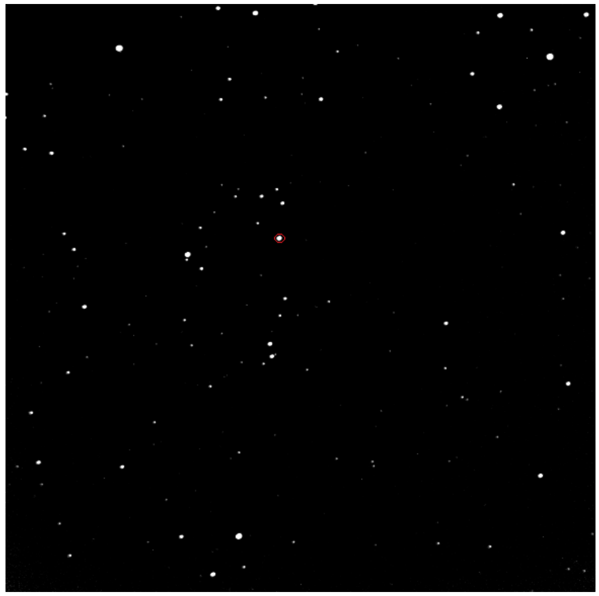

Figure 1: Image of TOI 5356

TOI 5356.01 has an equilibrium temperature of 1812 K and receives stellar irradiation 1793.16 times that of Earth. The candidate exoplanet's orbital period is 3.1948695±0.0005079 days, and its radius is approximately 13.3231 Earth radius. TOI 5356 (shown in Figure 1) is the star that TOI 5356.01 orbits. TOI 5356 exhibits a temperature of 6577.37, a metallicity of -0.025±0.049 M/H, and is 933.117 parsecs or 3043.420 light years away from Earth. TOI 5356 is located at Right Ascension (RA): 04h03m51.52s, Declination (DEC): +31d46m33.47s, and a transit duration of 3.786±0.312 hours with TOI 5356.01 [3].

3 Method

AstroImageJ is used to reduce and plate-solve the raw data collected from the George Mason University Observatory. The data reduction process is important because it eliminates false, artificial, and spurious influences on the images. Four types of images are captured during data collecting: bias, dark, flat, and science. Normally, bias, dark, and flats need to be cleaned up. However, in this case, we only need to target and clean up dark and flats because a bias image can only be taken with a shutter closed and at an exposure time of nearly 0s. The exposure time of TOI 5356.01 is 85s. Thus there is no need to clean up bias images. A dark is an image with noises generated through thermal processes that are taken with a shutter closed and at exposure that is much longer than bias images. Flat images, taken with the shutter open and enough exposure to have roughly 20,000 counts per pixel, are used to remove artificial distortions caused by imperfect or defective pixels. Science images are the target images to be analyzed, with raw science being unprocessed and reduced science being data-reduced.

After reducing the data, we used AstroImageJ to stack the images of TOI 5356 by performing Aperture Photometry. This process sums up the observed flux within a specified radius from the object's center and then subtracts the total contribution of the sky background within the same region. This leaves only the flux from the object, which is used to calculate an instrumental magnitude.

4 Results

We present our ground-based light curve shown in Figure 2, Dmag vs. RMS plot as shown in Figure 3 and the overlay of the normalized relative flux depth over time for the target star as shown in Figure 4.

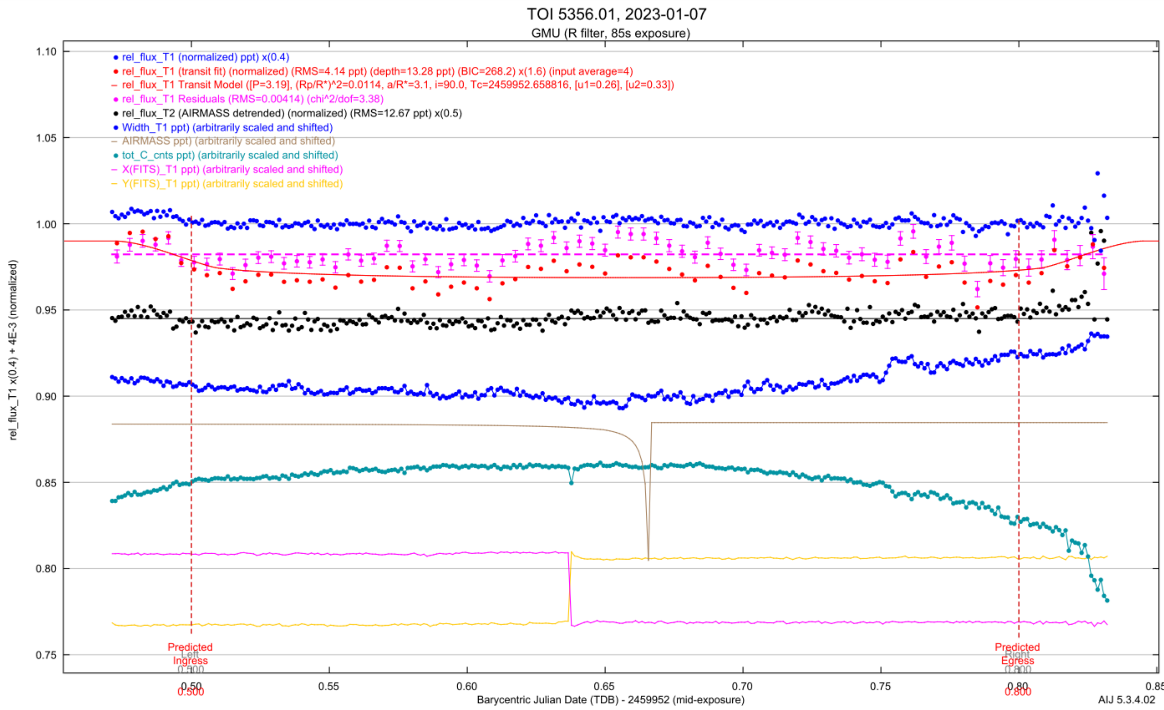

Figure 2: Ground-based light curve of TOI 5356.01, which shows noisy data during the transiting time and shallow transiting depth on the light curve

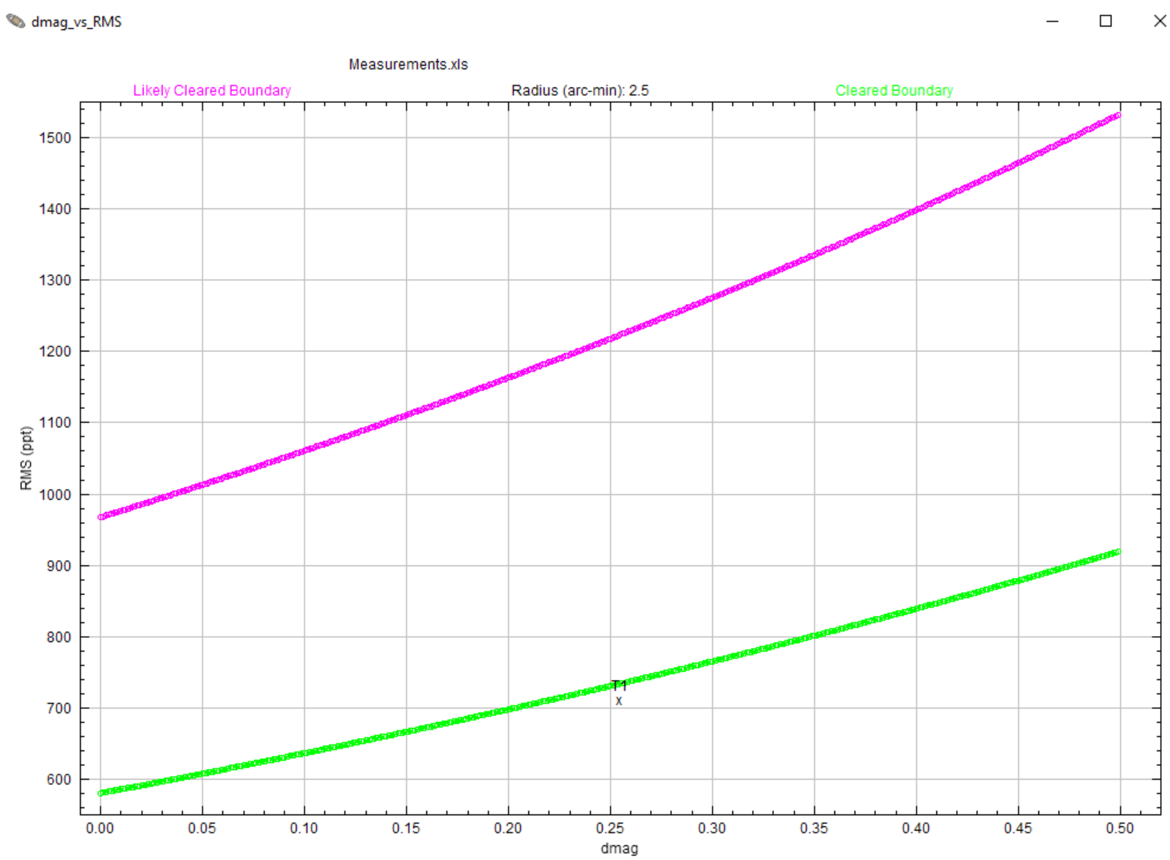

Figure 3: dmag vs RMS

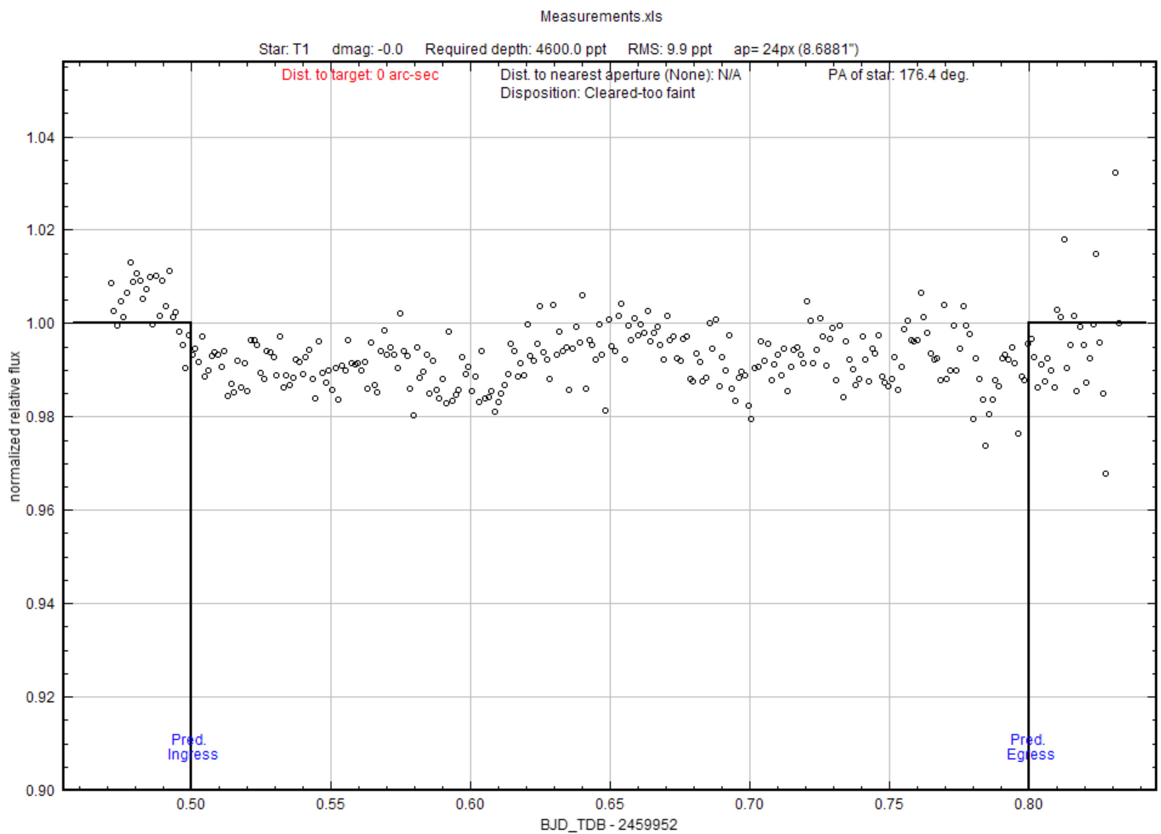

Figure 4: Overlay of Required NEB Depth

5 Analysis

We created the light curve graph with normalized, fitted transit model residuals for TOI 5356. The light curve shows a clear pattern (Figure 2) as there are periodic dips with consistent shape and depth in the rel flux T1 transit fit which indicate potential transits. We found a reduced chi-squared value of 3.38 for the data set of TOI 5356.01 (Figure 2). We calculated the transit depth of TOI 5356.01 to be 0.1067. Furthermore, the overlay of the required NEB depth (Figure 4) shows clear periodic dips. The clear periodic dips in both the light curve and the overlay of the required NEB depth suggest the existence of a transiting exoplanet. These periodic dips indicate that the brightness of the star consistently decreases at regular intervals which possibly corresponds to the orbit of the exoplanet passing in front of the star during our observation. This periodic pattern is a strong indicator that the observed dips are not due to random noise or other stellar activity but are instead caused by a planet transiting the star, blocking a portion of its light each time it passes. The consistency in the depth and timing of these dips supports the conclusion that the candidate is a valid exoplanet. Lastly, We also performed a nearby eclipsing binary (NEB) check to see if a false positive existed. We graphed dmag against RMS (Figure 3), which shows a distinct difference and a clear increasing pattern, indicating that transit events that are distinct from the noise happened and are not caused by a nearby eclipsing binary. The clear separation between the dmag and RMS values for the transit events confirms that the observed transits are likely due to an exoplanet rather than a false positive.

6 Conclusions and Future Work

In this study, we analyzed the light curve data for the exoplanet candidate TOI 5356.01 using AstroImageJ. Our light curve graph shows periodic dips with a consistent shape and depth. The overlay of the required NEB depth also displayed clear periodic dips, further proving the presence of a transiting exoplanet. Furthermore, the NEB check showed a clear increasing pattern in the dmag vs. RMS graph, indicating that the observed transit events are distinct from noise and unlikely to be caused by a nearby eclipsing binary. These findings collectively suggest that TOI 5356.01 is a valid exoplanet candidate.

More future work can be conducted to validate TOI 5356.01 as an exoplanet. For example, use or collect another data set to reproof the existence. Furthermore, only 543 candidates out of 7,203 TESS project candidates are confirmed planets. More work can be done to confirm the existence of other exoplanets.

7 Acknowledgements

We would like to thank Dr. Peter Plavchan (Associate Professor of Physics and Astronomy at George Mason University and the Executive Director of George Mason Observatories) for providing us with the necessary teaching and resources and Owen A. (Teaching Assist) for his patient guidance through this project.

References

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