Ground-based Light Curve Follow-up Validation Observations of TESS Object of Interest TOI-6185.01

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Abstract

NASA's Transiting Exoplanet Survey Satellite (TESS) identifies Objects of Interest (TOIs) as possible exoplanets scanned by the satellite using the transit photometry method. This paper presents the ground-based light curve follow-up observations for the TESS object of interest, TOI-6185.01. This research aims to distinguish potential TOIs as either exoplanets or false positives. In this paper, we detail our observations, analysis, and results. Data was collected by the George Mason University 0.8m telescope and light curves were generated to confirm and validate the exoplanet candidate's transit events detected by TESS. Unfortunately, our results pointed to our data being inconclusive.

Introduction

The first exoplanet was discovered in 1992, which started a new important subfield of research within astronomy. NASA's Transiting Exoplanet Survey Satellite (TESS), launched in 2018, has significantly advanced the study of exoplanets. In order to scan for satellites, the satellite employs the transit photometry method. A planet transit occurs when a planet passes between a star and its viewer. As the transit happens, the light levels measured from the star dim minutely. This phenomenon is key to confirming the identity of a potential exoplanet (Collins et al., 2017).

Across its few years of activity, TESS has conducted a comprehensive survey of the sky, detecting thousands of possible exoplanets—currently, numerous published papers detail ground-based observations of their respective TOIs. For example, a very recent study in 2024 verified three exoplanets, all mini-Neptunes, orbiting TOI-663. Furthermore, they were able to estimate the radii of the mini-Neptunes, discovering that the size of the planet suggested volatiles such as water to be present (Cointepas et al., 2024).

This paper presents the follow-up observations of TOI-6185.01. Our primary objective is to determine if the object's transit lines up with the expected parameters. Currently, a few characteristics are known: TOI-6185.01 has an orbital period of 6.372 days, a radius of 12.172 earth radii, and a transit time of 1.322 hours. The above information is important to our analysis at the end of the paper.

Observations

TESS Observational Data

TESS Input Catalog ID for our object of interest TOI-6185.01 is TIC 346077232.01. The RA and DEC coordinates of TOI-6185.01 are 23:47:34.59 and +56:04:14.54 respectively. As measured by TESS, the candidate exoplanet's transit midpoint is approximately 10147.8077 BJD, the orbital period is approximately 6.37 days, the transit depth is 5.7 ppt, its radius is approximately 1.499 $R_\odot$, the duration is 1:19 minutes, and its average temperature is approximately 771 K.

Furthermore, as measured by TESS, the stellar effective temperature is approximately 6390 K, the stellar log(g) is approximately 4.1934700 $\log_{10}(cm/s^2)$, the stellar radius is approximately 1.499 $R_\odot$, and the distance between Earth and the host star is [insert].

GMU Telescope Observational Data

In order to conduct our research, we used the George Mason University 0.8m in Virginia, which has a geographic location of -77:18:19.24 longitude, +38:49:41.5 latitude, and an altitude of 148.72.

We observed 99 Science exposures, each with an 85s exposure time, starting from 01:38 UTC to 08:53 UTC on, 2023-07-21. The telescope uses an R filter.

Analysis

Tools

AstroImageJ is a software that we use to display images captured from telescopes, data reduce, perform multi-aperture photometry, and generate light curves. We used it to analyze the candidate exoplanet associated with TOI-6185.01.

Analysis Using AstroImageJ

We used AstroImageJ to generate a light curve of our target, TOI-6185.01.

Firstly, we downloaded 242 images captured by the GMU telescope on July 21st, 2023. We distinguished between science, flat, flat dark, and science dark images to prepare for data reduction of the sciences and sorted them into their respective folders.

Secondly, we performed data reduction and plate via code from GitHub user oalfaro2. The code performed data reduction, eliminating unnecessary information, and making it significantly easier to interpret the images. It then plate-solved the science, meaning it centered each image around the RA and Dec coordinates to generate our light curve.

Then, we generated a measurement table for TOI-6185.01, containing the reference stars with time, changing fluxes of our target star, and the Gaia stars. A photometry radius of 28 was obtained. Multi-aperture photometry was performed with 14 Gaia stars as reference.

After multi-aperture photometry was successfully performed, a measurement table was created which was then used to plot our light curve.

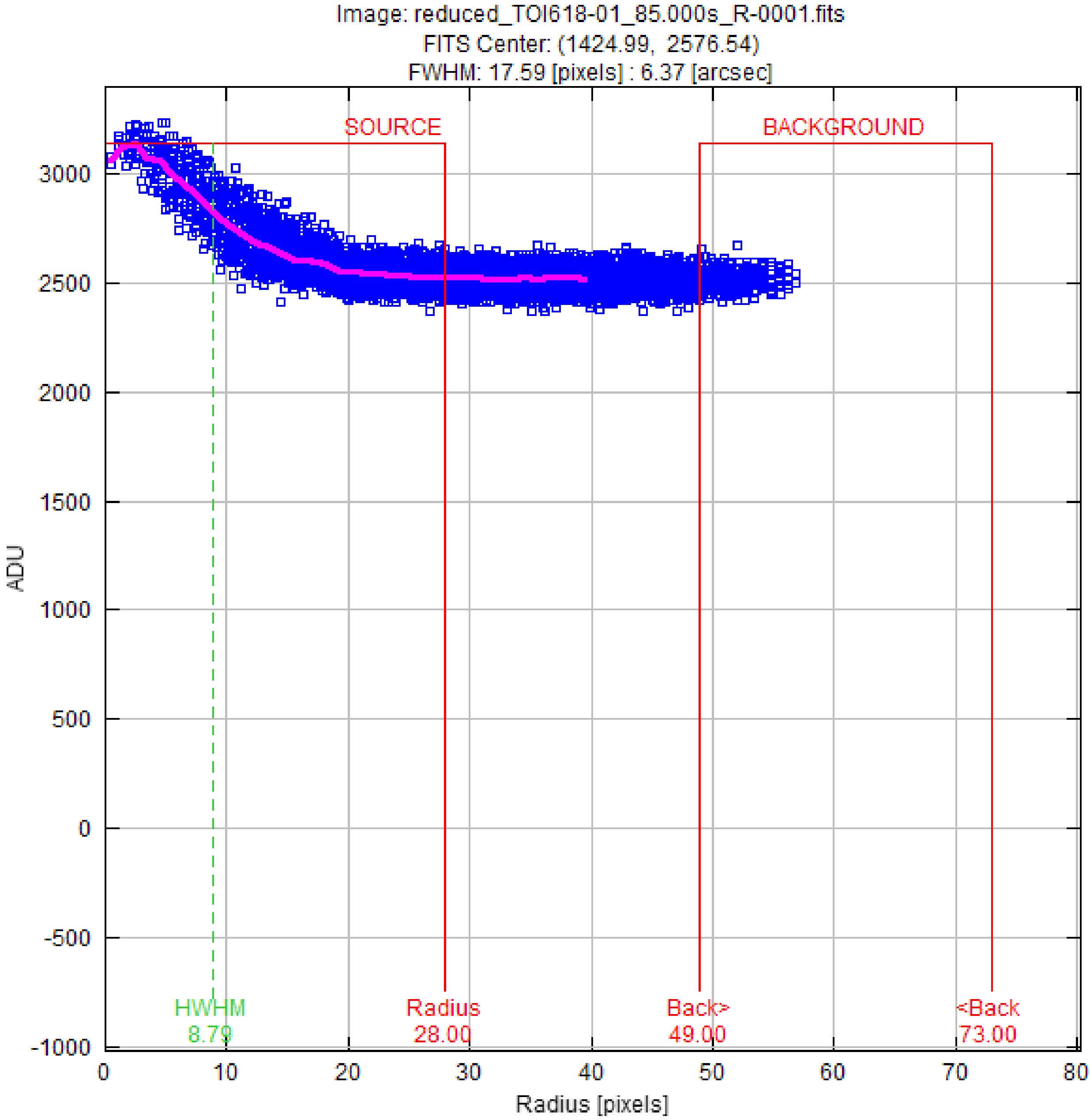

Figure 1: Viewing profile of TOI-6185.01 on AstroImageJ

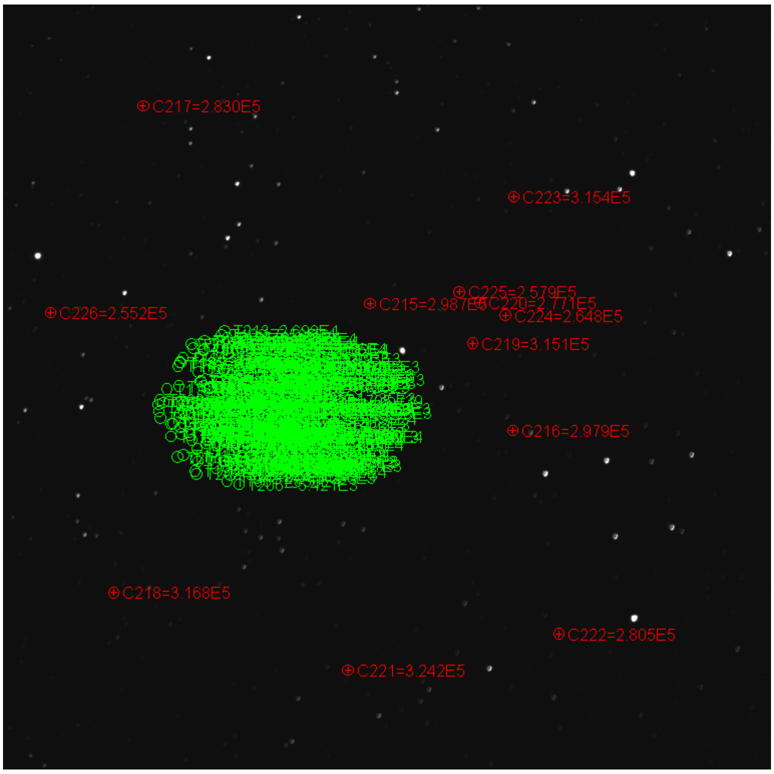

Figure 2: AstroImageJ displaying TOI-6185.01 and all reference stars, as well as stars from the Gaia database

Next, we started AstroImageJ to plot the light curve for TOI-6185.01. We input data collected by TESS, including values such as the period of our exoplanet, the host star radius, metallicity, effective temperature, and ingress and egress times. Afterward, we configured the light curve by creating the title and choosing the required plots to show. We then configure the light curve by, for instance, appropriating the title and selecting all necessary plots to show. Then, we manually review each reference star and remove the ones causing significant variation. Lastly, we performed an NEB analysis. NEB stands for nearby eclipsing binary, and the analysis checks for eclipsing binary stars as TOI-6185.01 could be an eclipsing binary.

Finally, we plot the light curve for TOI-6185.01 looking for noticeable dips in the light curve that would indicate an exoplanet transit.

Results

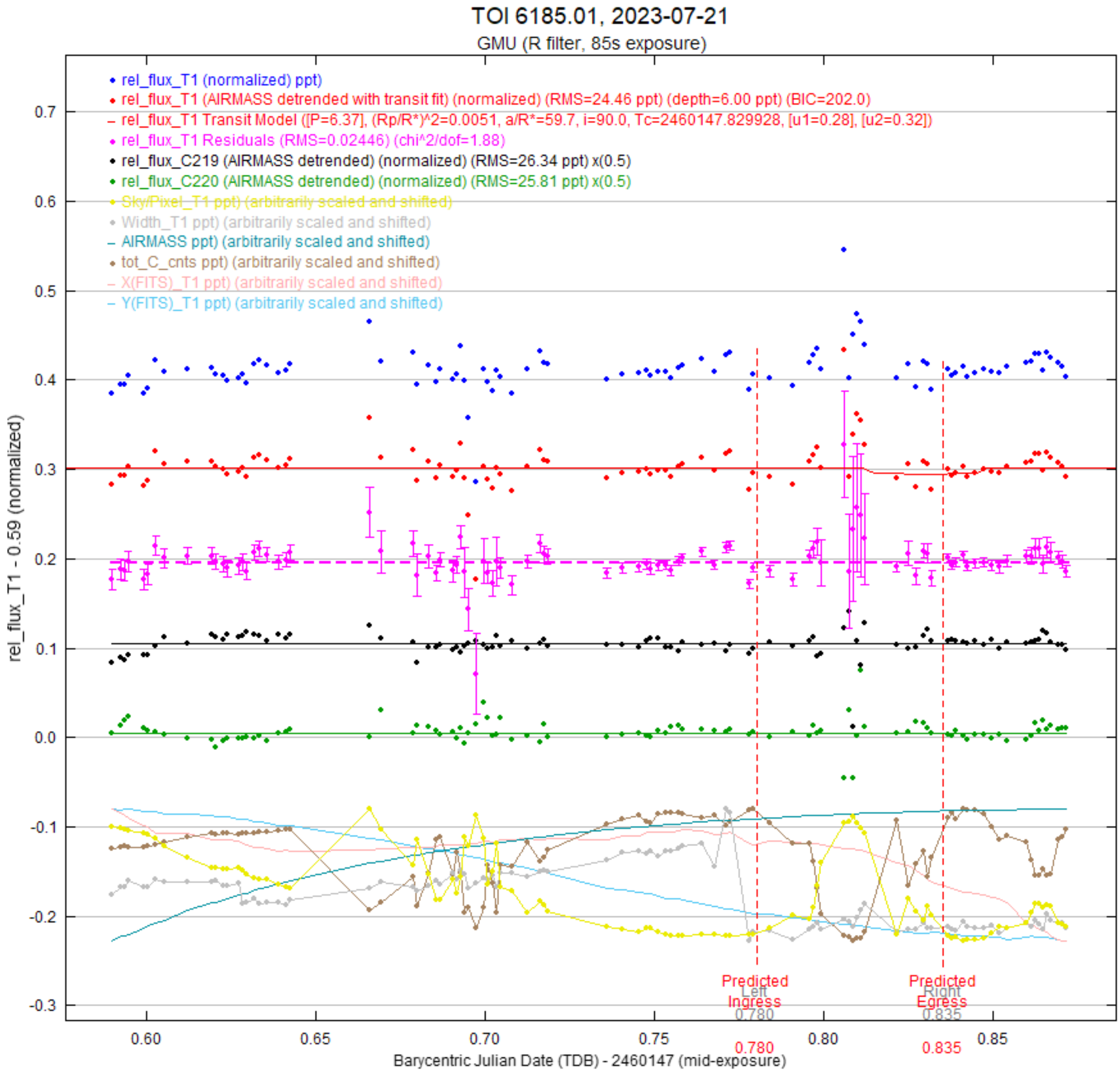

Figure 3: Generated light curve for TOI-6185.01.

In our light curve plot, our residuals appear to expand at the anticipated transit. This may be due to the weather since our parameters, the rel_flux_T1 (normalized), rel_flux_T1 (AIRMASS detrended with transit fit) (normalized), rel_flux_T1 Transit Model, rel_flux_C219 (AIRMASS detrended with transit fit), rel_flux_C219 (AIRMASS detrended with transit fit),) Sky/Pixel_T1, Width_T1, AIRMASS, tot_C_cnts, X(FITS)_T1, and Y(FITS)_T1 go through an extensive change as observed in the plot. This means that our data is altered because our predicted error increases at the transit. Our data for our images that were not reduced (rel_flux_T1 (normalized) depicted in blue on the plot) were observed to be similar to that of the detrended data (rel_flux_T1 (AIRMASS detrended with transit fit) (normalized) depicted in red on the plot) which displays that or raw data aligns with the edited data.

Our ppt value for our parameter, rel_flux_T1 (AIR MASS detrended with transit fit) (normalized) data is relatively high at 24. A result of 24 ppt indicates that our observed data points' normal deviation from the fitted model is 24 parts per thousand, which is not preferred as we typically desire a value less than five. Our ppt of the two closest reference star values, rel_flux_C219 (AIRMASS detrended with transit fit) and rel_flux_C219 (AIRMASS detrended with transit fit) were close to 24 yet not below the value which proves to be acceptable comparisons.

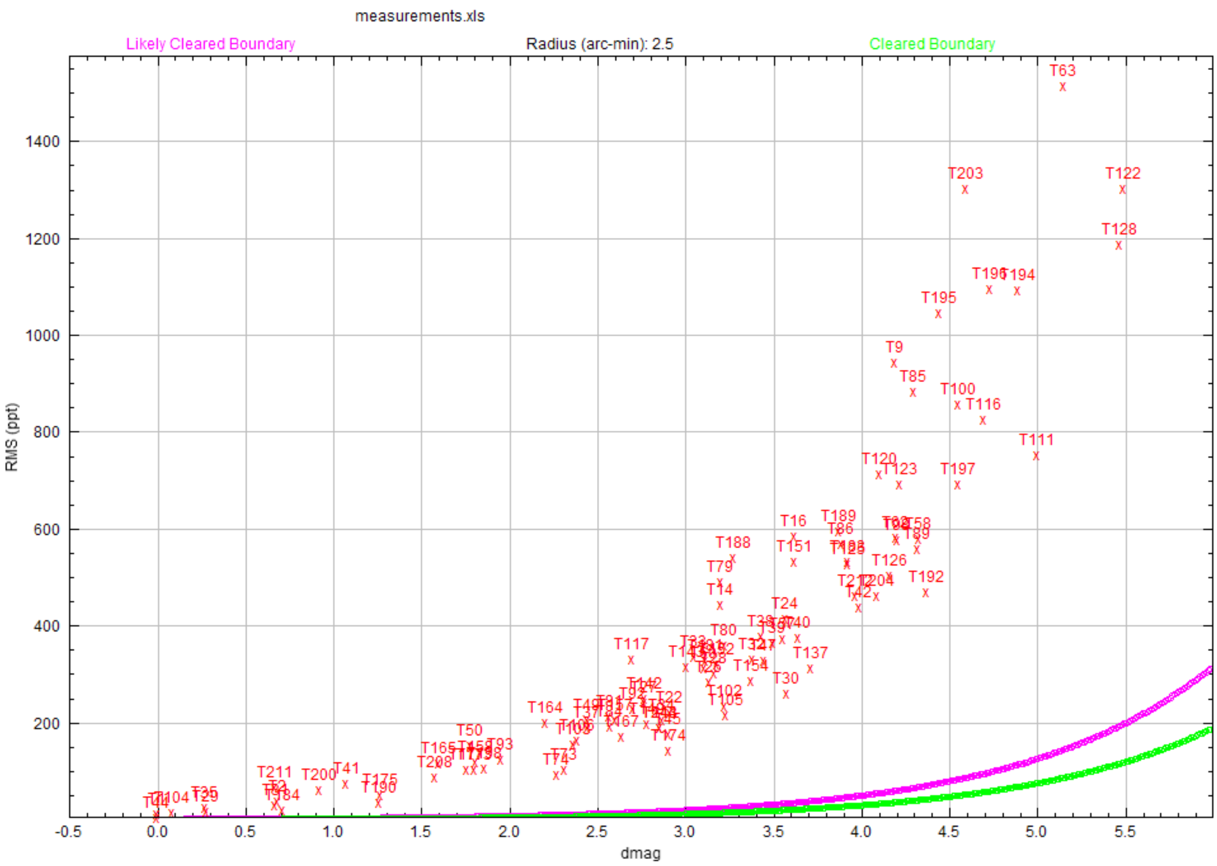

Figure 4: NEB graph.

Our reference star data is observed to be different at the transit time signals that it's most likely that the transit only happened to the target star, indicating that it is not an NEB. There appear to be gaps observed within the data, most likely due to bad images.

```
Summary count of dispositions:
         0 Likely cleared
         0 Cleared
         0 Cleared-too faint
       118 ***Not Cleared-flux too low***
        95 ***Not Cleared***
```

Figure 5: Summary count of dispositions in NEB table log.

Discussion

The outcomes of our research and analysis of our TOI, 6185.01, have provided insight into whether or not our target could be viable for life as an exoplanet or defined as a false positive. Our NEB check is shown to be inconclusive, meaning that we cannot tell if a false positive is present. The inconclusive data is observed in our reference stars being marked red in Figure 4 and can also be observed within our NEB table log. As seen in Figure 5, our summary count of dispositions shows that our reference stars did not pass the cleared check and are not below the curve for cleared or likely cleared. Additionally, a majority of our stars appear to have a higher PPT which conveys that there is more noise and less precision within our data, yet again pointing at our data being inconclusive

The results derived from our observations of the object's data should be interpreted with caution due to interference with the data and a false positive not being able to be proven. The possible interference with our data would be due to noise within the images, making it inconclusive to our study.

Conclusion

Based on our results and discussion, we can determine that our TOI-6185.01 is most likely not an exoplanet nor a false positive. The characteristics of our planet and stellar parameters did not indicate any specific sign of our target being an exoplanet under a particular category. From our NEB check it was determined that a false positive was not proven as our reference stars did not pass the clearance check. We have to take into account the possible noise interference of our data, which makes our data observation undetermined in that regard. From our analysis, it is presumed that our target, TOI-6185.01 is not an exoplanet.

Overall, we believe that our candidate should be open to more study and further analysis as the possibility of noise may have inhibited our data images. Currently, our candidate, TOI 6185.01 will remain a compelling case for future opportunities of study.

References

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