Ground-based light curve follow-up validation observations of TESS Object of Interest TOI 5516.01

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Abstract
The function of this study is to assist in the greater examination of Transiting Exoplanet Survey Satellite (TESS) Objects of Interest (TOI) through the analysis of transit data for TOI 1519.01. TOI 5516.01 was observed through the George Mason University Observatory telescope, then processed, reduced, and plate solved through AstroImageJ with the intention to form a recognizable light-curve from which a transit might be observed. Due to the absence of a visible transit, we note that TOI 5516.01 is likely not an exoplanet, but we encourage future research.

Intro

In 2018, TESS was launched with the prime directive to observe the night sky and search for exoplanets. By imaging in 26 strips for 27.4 days, TESS observed over 200,000 stars and processed data received for future reference through the transit model (MIT TESS Mission, n.d). Transits are observed and either discarded or processed for further analysis based upon the dimming of light observed in front of the star an object orbits. If this dimming of light shows up on the light curve, it is highly possible that an object is an exoplanet, but not confirmed until later study. Even then, it is possible that they are “False Positives" like a Near Eclipsing Binary (NEB) contaminating the aperture, chromatic transit depth like a Blended Eclipsing Binary (BEB), or a Eclipsing Binary’s (EB) depth being far too deep for a transit (Conti, 2020). Because of this, astronomers must individually observe transits.

By observing objects’ transit and then sending that transit in Full Frame Images (FFI) to Earth where it is then converted to light-curve format, TESS was able to compile various objects for further research from astronomers. As light curves need to be validated by human processing, astronomers need to process the data through programs such as AstroImageJ for greater analysis. As the number of TESS datasets are still high and have not been dramatically reduced, there is still a need for astronomers to follow up the validation process. This paper exists as a development on this validation process, the likes of which can be compared to *Ground-based light curve follow-up validation observations of TESS object of interest TOI 3792.01* (Ellis and Plavchan, 2023) or other Astro-Scholar research.

This paper details the follow-up validation of TOI 5516.01. It has a planet (Earth) radius of 12.3407 ± 1.22493 with a transit midpoint of 2459574.484627 ± 0.0067373 (in BDJ) and a planet orbital period of 4.3776584 ± 0.0013685 days. TESS first spotted TOI 5516.01 on April 20, 2022, and last modified information on April 26, 2024 (NASA Exoplanet Archive, n.d). We are looking to see a transit once in light curve form.

In Section 2, we present our observations in conjunction with TESS. Then, in Section 3, we dive into our analysis of our data. In Section 4, we clarify the results and in Section 5 we participate in a discussion of the scientific elements involved. In Section 6, we conclude and discuss theoretical future work. In Section 7, we present our references.

Observations

In Section 2.1, TOI 5516.01 is presented in terms of TESS data. In Section 2.2, we summarize the observational data collected.

2.1

TOI 5516.01 has a Right Ascension (RA) of 10h23m21.17s and a Declination (DC) +13d28m20.18s (both in sexagesimals). It has a PMRA of -26.906 ± 0.103 and a PMDec of 9.553 ± 0.099 (both in mas/yr). It's Planet Equillibrium Temperature in Kelvins of 1281 and a Stellar Log (g) of 3.88 ± 0.09. Due to these factors, TOI 5516.01 was considered to be an exoplanet candidate.

2.2

Observed through the George Mason University (GMU) .8 telescope, TOI 5516.01 had an ingress of 21:31, (0.396528) and an egress of 0:23 (0.515972). It had a start time of 19:30, and an end time of 5:10. It was observed with the R filter. Exposures were taken at a time of 75 seconds.

Analysis

In Section 3.1, we present the tools and methods we used during observation. In Section 3.2, we analyze the data received.

3.1

After receiving the darks (images where the shutter is closed), flats (images with the shutter open), focuser images (in which the camera is focused), and sciences (images with a target we wish to analyze) from the GMU telescope, we sorted the darks into their processing times (5 seconds for those tied to flats and 75 seconds for those tied to sciences respectively). A few images were removed from the set, as images where the stars seem to smear would lead to bad data. We also deleted photos where the noise was too loud to see anything, as it would create a plate-solved image with no stars in it. We then turned to astronomical image processing software AstroImageJ, due to its abilities as a light-curve generator and photometer (AstroImageJ). We started out in data reduction to clear up the noise in the images. We set the DP Coordinate field according to TOI 5516.01's RA and Dec, as well as its pmRA and pmDec. Moving to the CCD Data Processor, we formed our base dark. Base darks are made by reducing all the data found in the group of photos into one singular image. Due to our previous separation of darks due to exposure time, we built a dark with the same exposure time. We then built a

master flat. Along with the sciences we built a new dark that encompassed those images with the same exposure time as the sciences and processed the image.

After the science had been built we used AstroImageJ's aperture facilities in conjunction with website Astrometry.net in order to identify TOI 5516.01 in the image. AstroImageJ also identified reference stars from which TOI 5516.01 could be compared against. A seeing profile was created to analyze the chances of a light curve, and we generated a measurement table which a light curve would then be plotted from. We also examined our target star (labeled T1) and the reference stars so that we could remove any stars that may contribute bad data due to jumps in the plot. We made sure to mark our Linear LD u1 and Quad LD u2 from data calculated from EXOFAST - Quadratic Limb Darkening (Eastman et al, 2013). We then plotted our light curve.

3.2

Through the points of ingress and egress, we must find an identifiable transit from the data seen in the light curve, indicated by a dip in the data.

Results

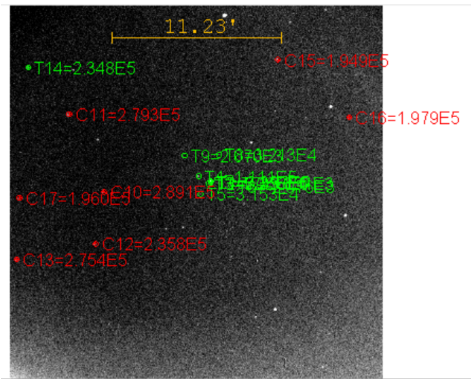

Fig 1: The plate-solved science, with reference stars and TOI 5516.01 in green, as well as reference stars in red.

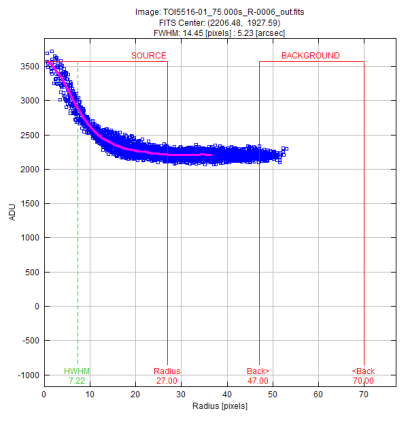

Fig 2: Seeing Profile of TOI 5516.01

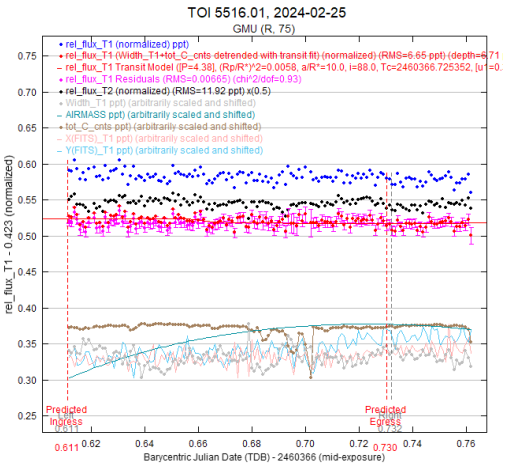

Fig 3: Light curve of TOI 5516.01

Discussion

In Section 5.1 we discuss our results and interpret them. In Section 5.2 we explore the data in the larger discussion of TESS Exoplanets.

5.1

While there were some initial issues due to our built science not showing any stars, the removal of images with what we presumed to be weather interference fixed the issue. There was a slight dip in the data which might indicate a light curve, but due to the amount of sciences that needed to be removed, we are wary to call TOI 5516.01 an exoplanet.

5.2

Due to the considerable amount of images that had to be removed from the data set due to imaging errors (such as smearing or blurring attributed to either the camera moving or weather in the atmosphere), there would be a considerable movement for re-examination.

Conclusion and Future Work

Through the production of a light curve in AstroImageJ with data from GMU's .8 telescope we concluded that the object 5516.01 first identified by the TESS NASA Mission was not an exoplanet.

However, due to images that had to be removed, we would suggest a follow up to TOI 5516.01. We recommend another set of sciences be taken on a night with no interference. In addition to that, we recommend statistical analysis be performed on this and any further research.

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