Ground based light curve follow-up validation observations of TESS object of interest TOI 7325.01

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Abstract

This paper discusses the results of an observation on TOI 7325.01. This observation was taken at George Mason University's research hall through the 0.8 m telescope with a red filter. The goal of the investigation was to determine whether planetary candidate TOI 7325 was actually a planet and not just a false positive signal found on the telescope observation. We wanted to take the data from the observation session for June 24th 2025 and create a plot so that we can determine the light curve transit to determine if our planetary candidate is a false signal or not. Through the use of finder charts for our observation night we can determine light curve transit through the use of software such as Astroimage j. This investigation first had to have telescope images for observation which were taken through the research hall at Geroge Mason university. Luckily June 24th was a good night for observation so a good amount of data could be collected and we used finder charts to determine the location of the object of interest to create a plot for. Then we created plots of the transit through usage of reference stars and an NEB plot to determine the existence of possible eclipsing binaries. Through the plots and data collected we found that a transit for TOI 7325 was detected and made it a plausible planetary candidate as well as the seeing profile further arguing that point. However the RMS was relatively high at 12.71 which may indicate that noise may have affected the signals we collected and the NEB plot came back as mostly not cleared which increases the chance that we had eclipsing binaries and may have gotten false signals. As a result of this, follow up would need to be done on this candidate as the results of it being a detection are inconclusive for this study.

Introduction

Searching for solar systems beyond our own is incredibly fascinating for us as humans. We have always strived to create better technology so that we can explore further out into space. This has led to humankind's fascination with exoplanets in other solar systems that may be important for our future as humans, should anything happen to our own planet. Exoplanets orbit other stars in our universe and that can be used to detect planetary transits through methods like spectroscopy and light curve data analysis. The development of new technology and research coming to light has further developed this as a way to check for planetary candidates to be possible planets. TESS is a transiting exoplanet survey satellite used by NASA to search for planets outside of our own solar system. It uses the brightness of stars near the planetary candidates over periods of time to check for dips or transits to verify exoplanets. It is a vital source of exoplanet research. Tess has exponentially increased the number of known exoplanets outside of our solar system and it's very important to space research right now and for the future.

The validation of Tess candidate is extremely important for further research and identification of things like false positives or eclipsing binaries. One paper that demonstrates this point is “Validation of TESS exoplanet candidates orbiting solar analogues in the all-sky PLATO input catalogue”. This journal article explores the critical process of identifying TESS candidates. It explores the validation of TOI 5612.01 and identifies it as a planet candidate due to its identified transit. The data collected used tools similar to ours such as Astroimage j and its data processor to accurately analyze data and plots. Similar to this study our research is an important study in the exoplanet identification of candidates. Exoplanet identification is done through the use of the TESS satellite and many data analysis tools that make transits easier to see and identify. Our research is an important part of this as well as many other research papers because it identifies the results of a possible candidate to help decide if it should be ruled out as a planet or not. Ruling out planets is just as important as identifying planet candidates and both ways contribute to future research.

The need for this paper may be questioned but in the world of exoplanetary research it is actually greatly needed. There have been a multitude of papers published on exoplanet candidates but none published on candidate TOI 7325.01. There is no research validating whether it is a false positive, eclipsing binary, or an actual exoplanet. It has simply been entered into the TESS database with no research to test the planetary candidate and no analysis done on the light curve. This paper takes the data from the telescope observation on 6-24-25 to analyze and come up with some research on the planet and any future steps that must be taken to identify it as a false positive of the planet. Without the research in this paper there would not be much for other scientists to work off of to determine this answer because the information that this study provides takes the scientific community a step closer in its identifications of other TESS objects as well as this one. This can help future missions or discoveries so whether or not this study finds something, it provides something for scientists to use in future work. This paper provides firsthand observations and analysis of TOI 7325 and provides evidence for follow up to be done with more research and evidence to help scientists conduct that research.

In this paper we present follow-up observations of TOI 7325.01 . The radius of the planetary candidate is about 0.00033 degrees and 26 pixels in the seeing profile. It lasts an orbital period of about 2.04 days and has a depth of 9.2 ppt. It has no stellar radius and orbits the star TIC 286857537. The goal of this investigation is to try and rule out false positives or identify eclipsing binaries that may be contributing to a false signal. We want to use RMS and transit plots to see if a clear signal can be identified and analyzed for the research of TOI 7325. Our goal is to investigate whether the transit occurs at the expected transit time at the depth of 9.2 ppt and duration of 2:38. This investigation will help further research about this TOI and its possibility of being a planet or not.

In Section 2 , we present our Observations from TESS and the George Mason University 0.8m telescope in a red filter on 06-24-25. In Section 3, we present our analysis of the TESS light curve for TOI 7325.01 and our ground-based light curve analysis. In Section 4, we present our light curve results. In Section 5 we discuss our results from the observations and provide thorough analysis. In section 6 we conclude the research study and provide possible future work that could be done to improve this candidate.

Observations

In section 2.1 we present the TESS object of interest 7325.01 and the properties associated with the exoplanet candidate and star. The properties are taken from the TESS input catalog, the GAIA mission, and other archived sources In Section 2.2 we present helpful information for the analysis portion of this paper. In Section 2.3, we present a short summary of the observational data collected with the George Mason University 0.8m telescope.

There were 195 images captured with 90 second exposures and 7 second exposures. The ones used for analysis were 90 second exposures in the r filter because of the darks also being 90 second exposures. The start time of the object of interest was 21:04. The TESS object of interest time ended at 1:43. This data was collected on June 24th 2025 through the George Mason University telescope for the purpose of observing TOI 7325's light curve and determining if it is a planetary candidate or not. The RA coordinates of this TOI were 20:54:44:914. The DEC coordinates were 20:35:49:98. These were used to find the object in the images and place an aperture on it. This helped accurately locate the object so that data could be created on plots.

This TESS object has no stellar radius and a depth of 9.2 which is very helpful in the later analysis in this paper of the plots that were created through astro-image j. The BJD-TBD start time was 0.6320 and end time was 0.7420 which was imputed into the multiplot portion of the data processing for the plots to generate a more accurate plot. Another important thing to discuss is the aperture photometry performed by the TESS team itself for this object candidate. Using the ExoMast database you can see where the transit occurs for observation and also visibility on the JWST data. This information helps provide better time frames for transit and create more accuracy in results.

The observational data collected by the 0.8m George Mason University telescope demonstrates the light curve and transit of TOI 7325.01. It shows the plot with a transit fit light curve and a set of comparison stars as well as detrending parameters to get the lowest RMS and least noise physically possible in this specific data set. The reference star plotting made the plot very messy so we found it necessary to remove them to only focus on the light curve of object 7325.01. The data presents finding of possible false positives/eclipsing binaries or the chance of it being an actual planet based on the RMS, light curve, and NEB plot. This produces very accurate results that can be replicated to further research on and create future work to support conclusions or create new accurate information to add onto the research.

Analysis

In Section 3.1 we discuss our tools used to analyze the TESS sector light curves using AstroImageJ/ExoFASTv1/ExoFASTv2. In Section 3.2, we present our analysis of the ground-based light curve using AstroImageJ.

The first thing we did was download a guide on astroimage j that was provided by people at George Mason for research. The data subsets from our night of observation were provided to me from the research team and their staff for me to input into astroimage j to analyze our data. We took our downloaded zip files and unzipped them into a folder and then went to the data processor to create a set of master darks and a set of master flats to create a master file for our science images. We then plate solved our images using the API key and removed any images that didn't plate solve or were in bad quality to be able to find our object or nearby objects in. This helped create more accurate data for use in our observations. We then let astroimage j plot a seeing profile and plots based on apertures we selected on our object and nearby comparison stars. The settings for the multi-plot y data and detrending parameters were experimented with to find the best fit for this data set. We used information published on TESS databases on TOI 7325.01 to create an accurate plot that could be replicated to produce the same results and provide an accurate analysis.

The analysis conducted used the multi-plot and NEB plot as well as a seeing profile to determine the presence of any false positives or signals to conduct more analysis on. It used the comparison stars near it to be plotted and required a very specific combination of reference stars to create a red flux transit fit with the lowest RMS we could manage to generate in this study on candidate 7325. This analysis could be reconstructed very easily by using the dataset collected on this object on 06/24/25 to validate the claims written in this report. The ground based light curve could be created using this data and allowed identification of transits on plots with different parameters mapped out as well. The light curve allowed the possible identification of noise signals and possible NEBs that required more in depth research into this target. To properly analyze the graph we created a normalized and fitted transit on the graph as well as plotted multiple detrend parameters with the lowest RMS possible as seen by figure 1 in the next section.

Results

In section 4.1 we discuss the use of the figures and what they demonstrate. In section 4.2 we reveal the results of the study based on fact and what we saw in the data.

The results of this study are very simple in analysis as we only ran some simple photometry on it to generate a light curve as well as some other graphs to supplement evidence for our research. Figure 1 demonstrates the light curve after it has been normalized and detrended in the time the candidate was seen and the possible transit. Figure 2 demonstrates a seeing profile which demonstrates how far the light is spread out for the candidate and the brightness of pixels as they are farther or closer to the celestial object/star near them. Figures 3 and 4 show the NEB plot generated with the files for the light curve and gaia stars to show any nearby objects that may be a possibility of eclipsing binaries with a dmas/rmg line curve. Finally figure 4 shows an image of the apertures placed in the sky on the scientific images that were collected.

The plot in figure one shows a depth of 65.63 ppt which differs from the known transit depth of 9.2. The normalized plot seemed to line up well with transit but it seemed to differ greatly from depth. The seeing profile in figure 2 shows the brightness not differing much and staying in a good relative brightness for the candidate which means it may actually be a good candidate. However, the NEB plot comes out as not clear for every nearby star and figure 3 is an example of that which can lead to a possibility for eclipsing binaries but no certainty on that subject until other tests are done. The radius and mass are very important to analyze an exoplanet and classify the object as a possible candidate or not. The radius has been determined by the seeing profile as 26 pixels through the science images and provides accurate measurements for the apertures placed on the target candidate. These results help provide evidence for the results of the analysis for this study in the next section.

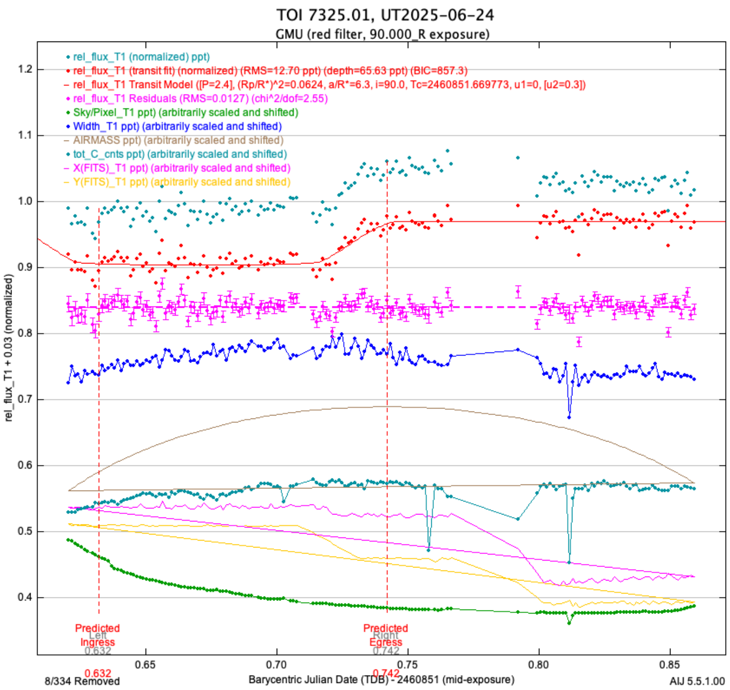


Figure 1

This figure shows the light curve plot of the data on a fitted transit curve and The detrending factors. The y axis shows the red flux of T1 normalized and x axis Shows the TDB time with the predicted ingress and egress lines.

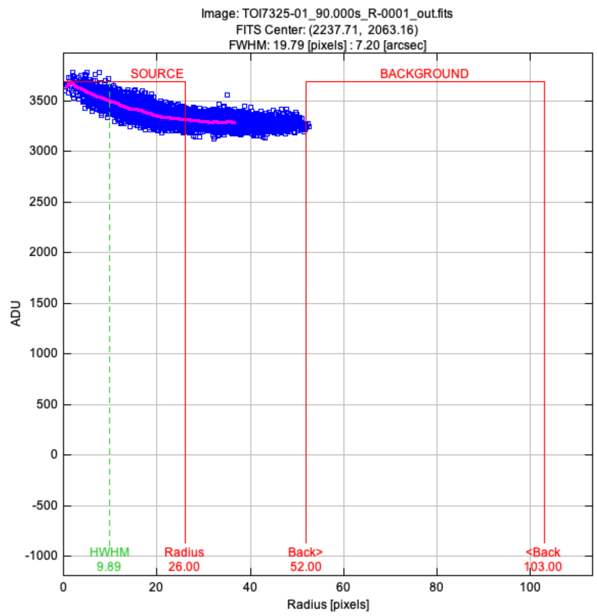


Figure 2

The seeing profile of object 7325 with the radius pixels determined through calculation of pixels on the science images and shows the light variation

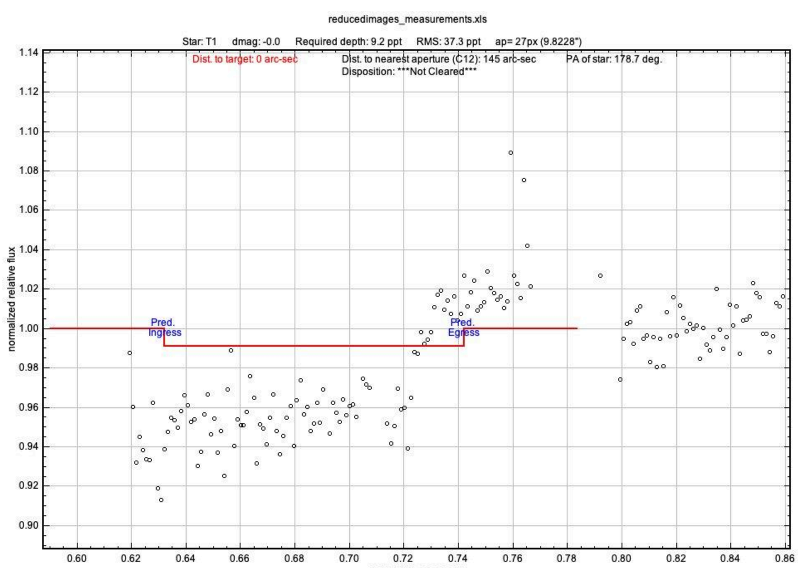
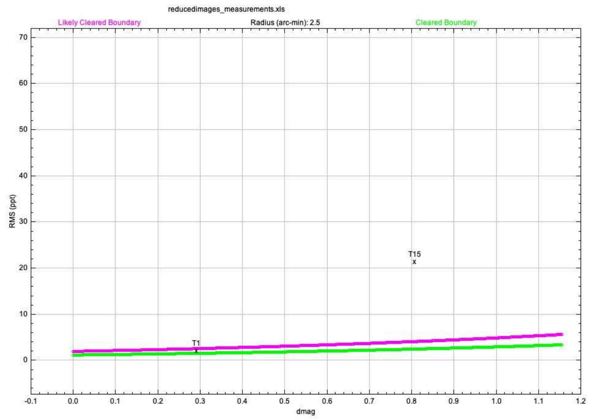


Figure 3

These figures show the likely cleared boundary and not cleared boundary which shows T1 is cleared and nearby comparison stars are not that close or in the boundary. It also shows the normalized predicted flux of a nearby star to compare.

Figure 4



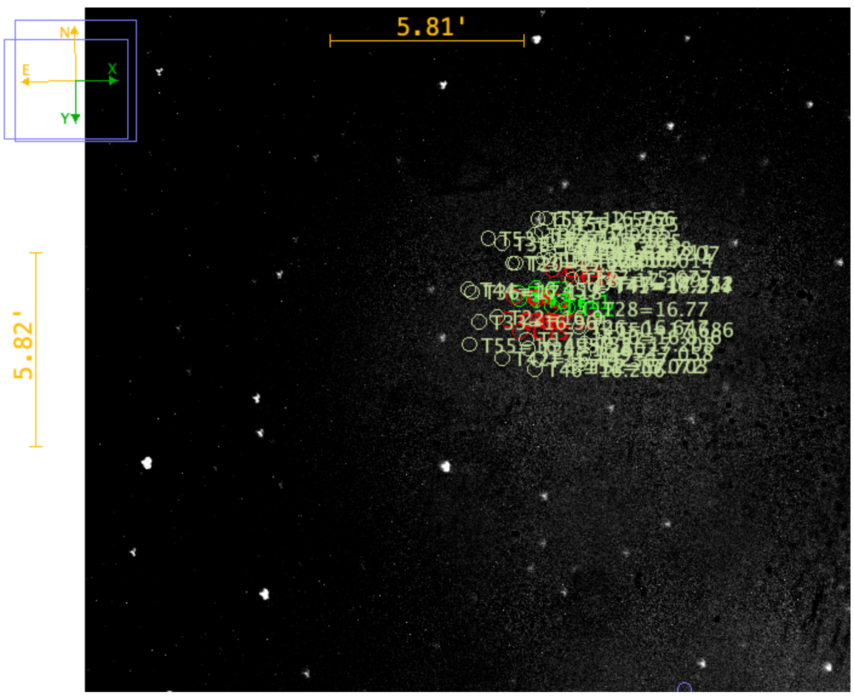


Figure 5

The apertures are placed in the sky after the first step of plate solving to create a multi aperture plot for the graphs of the images. This is taken from the science images of the set of 195 science images

Discussion

In section 5.1 we discuss our analysis of our results and what we gather from it. In section 5.2 we place our study and its results in a greater context of NASA TESS exoplanet research missions with similar candidates. The discussion of our candidate is placed with past research and similar mission studies.

We believe our detection in this study and analysis is a false positive but we cannot be completely sure because of other factors in the data. We detected a possible transit in the data but the depth was quite high for the predicted depth. We ended up at a depth of 65.63 ppt when it was actually supposed to be 9.2 ppt. We believe the transit depth did not match what was expected from TESS because

A TRES observation found in the observation notes of ExoFOP for TOI-7325 states that a late F star with a modest rotation is detected. That means the planet candidate rotates a cooler star in the F range in classification and rotates at an average pace of neither too slowly nor too fast. Since this star has been observed to be a cool star it would not be a hot Jupiter and this candidate, therefore , revolves around a cooler star instead. There were not many planet candidates near the star that could serve to create false signals because of the amount of distance between the objects. The object of interest was seen to have a transit between the expected ingress and egress times but the depth is too high and the NEB check came out as not cleared for all nearby stars including T1 which shows there may be a chance for a false signal from an eclipsing binary. Although there is a good seeing profile match and transit detection we believe there to be a chance for a wrong signal/ false detection because of a high RMS and it cannot be deduced whether this is a planet or not based on this study and previous studies alone.

Conclusions and Future Work

This study was a small study dedicated to the planetary findings of candidate 7325.01. Although we were hoping for conclusive results on the candidate we were not able to provide conclusive results of this due to more analysis being needed and possible different methods. However we did find more research on the candidate that can be used in future research on the candidate. We found that a transit detection did occur in the allotted ingress and egress times but some false signals may have been given due to a high RMS that can cause noise in the data and possible NEBS, although that is not likely because other candidates are very far from the star.

There can be some future work done on this research to attempt to find conclusive findings of the validity of the planetary candidate and develop the research on this planet. The light curve generated in this research study on TOI 7325 can help to validate the existence of this planet candidate as well as the light curve observed in figure 1. This candidate is a strong planetary candidate but more follow up needs to be carried out in future research to rule out any false positives and determine its validation as a planet. Some methods that future research could carry out are spectroscopy and direct imaging to try and lower RMS, get rid of noise that may cause false signals, and get a closer transit detection.

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