# Data Science Validation and Ground-based light curve follow-up of TESS object of interest TOI 5907.01

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Abstract

The Transiting Exoplanet Survey Satellite (TESS) is designed to discover thousands of exoplanets in orbit around the brightest dwarf stars in the sky [1]. Possible exoplanet candidates are marked as Objects of Interest and selected for follow-up ground-based observation. The goal of this research study was to conduct further ground-based observations, analyze data, and further classify TESS Object of Interest (TOI) 5907.01 as an exoplanet. Our observations showed that the transit occurred with all the expected characteristics. This indicates that TOI 5907.01 is likely an actual exoplanet.

## 1. Introduction

Humanity has always been fascinated with life and planets outside of our home planet, Earth. Many organizations have been formed to lead missions to explore areas outside of Earth, with the origins of space exploration being in what we now call the “Space Race,” a conflict between the USSR and the United States. The USSR was the first to launch objects, live animals, and humans into space, with the first satellite being launched on October 4th, 1957 [2]. Since then, many subsequent missions have been formed, with the first successful moon landing being accomplished by NASA’s Apollo 11 mission. Astronomers studying the skies have since then discovered evidence of more planets far beyond our solar system, with the first planetary disks being found in 1984 [3]. The Hubble Space Telescope was then launched to provide further information about distant stars and planets that were hard to observe using instruments on Earth [3].

The first exoplanets were soon after discovered, being found in January 1992 by Aleksander Wolszczan and Dale Frail [3]. This sparked an interest in discovering more exoplanets, and eventually led to the creation of the NASA TESS program in 2018 [3]. This program was launched to create a map of the entire sky and send back information to ground stations when needed. The mission gathered enough information to officially put the total planet count over four thousand planets. TESS observed possible exoplanets, called TESS Objects of Interest (TOIs), and sent information about these targets back to ground observatories.

This report focuses on one specific Tess Object of Interest, TOI 5907.01, and attempts to determine whether TOI 5907.01 is an exoplanet or not. TOI 5907.01 was discovered in 2022, and this candidate

exoplanet has a radius 8.32 times that of the Earth, an orbital radius of 0.66 days, and a transit duration of 0.796 hours [4]. The goal of this paper is to investigate if TOI 5907.01 has a transit and whether the transit happens during the expected time with the expected depth.

Section 2 presents observations and properties from TESS and the George Mason University 0.8m telescope. In Section 3, we present our analysis of the TESS light curve for TOI 5907.01 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 discuss exoplanet properties associated with TOI 5907.01, characterization from the TESS input catalog. In section 2.2 we present the light curve and in section 2.3, a summary of the observational data collected with the George Mason University 0.8m telescope.

## 2.1 Tess TOI 5907.01 properties

The TESS Input Catalog ID of our object of interest TOI 5907.01 is TIC 387318486. The candidate was first added to the TOI catalog in November 2022 and data was last updated in February 2024. The candidate's transit midpoint is approximately 2459823.85046 BJD, the transit duration is approximately 0.796 hours and the transit depth is approximately 3740 ppm. It has an approximate radius of 8.32 times the Earth. Its insulation is approximately 2467 Earth fluxes and has an average temperature of approximately 1963 K.

## 2.2 Observational Data

TOI 5907.01 was observed at the George Mason University observatory on June 20, 2024, using a red filter to obscure the mostly blue surroundings and an exposure time of 85 seconds. There were a total of 205 science exposures; 20 dark and 10 flats. The predicted ingress and egress times were 2:09 and 2:57, while data collection began at 21:50 and ended at 04:32 EST.

# 3. Analysis

In Section 3.1, we describe the tools we used to analyze the TESS sector light curve(s) using AstroimageJ and in Section 3.2 we cover the analysis of the ground-based light curve data using AstroimageJ.

## 3.1 Tools

The light curve analysis was conducted using the AstroimageJ software. AstroimageJ is an extension of the ImageJ platform that includes specialized astronomy-focused macros, enabling it to perform data reduction, analysis, modeling, and visualization tasks for astronomical applications [5]. Using AstroimageJ, we were able to carry out aperture differential photometry, a well-established technique for measuring changes in the flux from a star. This allowed us to characterize the exoplanet in question through the transit method.

## 3.2 Analysis

We began our analysis of the images for TOI 5907.01 captured using the GMU telescope on July 20, 2024, by first separating the darks, flats, and sciences. We visually inspected each of these images to identify and remove any that had potential defects like streaks, shifting, or ones in which the target was out of bounds.

We then used AstroimageJ to data reduce these images. Data reduction is important as it helps remove noise and focus on specific features like light curves and thus allows for precise analysis. It also condenses large data sets into manageable sizes, helping drive focus on the most relevant information.

The next step in our analysis was to plate solve and assign coordinates. This plate-solving process allows the software to identify and recognize the astronomical objects present in the image. Once the plate solving is completed, AIJ then assigns the corresponding right ascension (RA) and declination (DEC) coordinate values to the image.

Once the data had been plate-solved and reduced, we utilized the Aperture Photometry tool within AstroimageJ to generate a seeing profile for the target of interest. This seeing profile provided us with the optimal photometry radius, inner annulus radius, and outer annulus radius to use. We then entered these predicted values into the Aperture Photometry Tool settings, allowing us to place the appropriate apertures on both the target star and the reference stars. The resulting measurement table contained the flux variations over time for both the target star and the reference stars.

# 4. Results

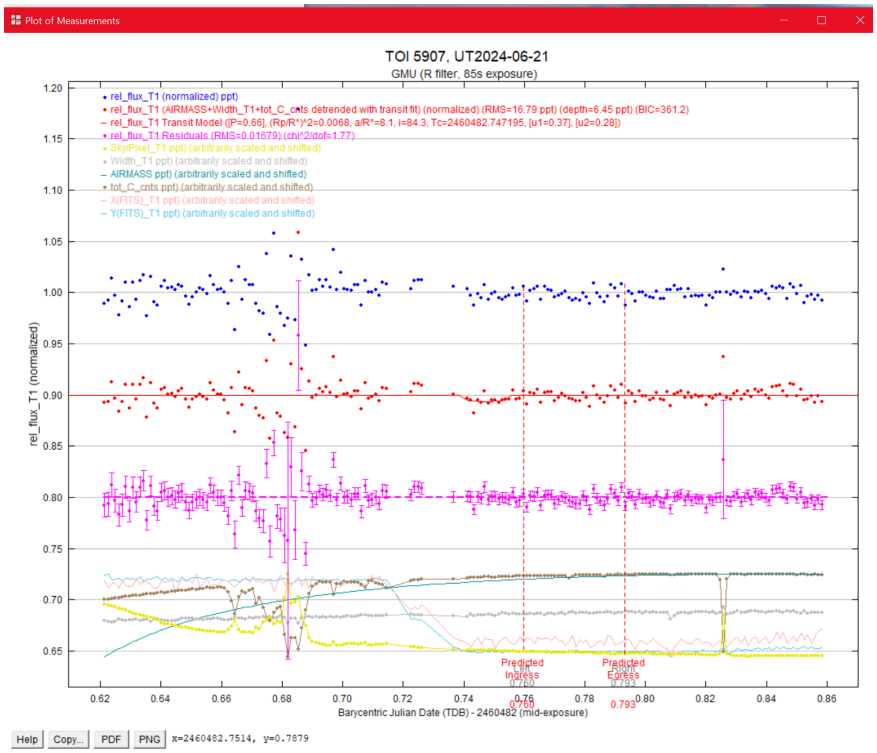


Figure 1: Plot of Ground Based Light Curve
The light curve implies a transit at around 0.68 Julian Date.

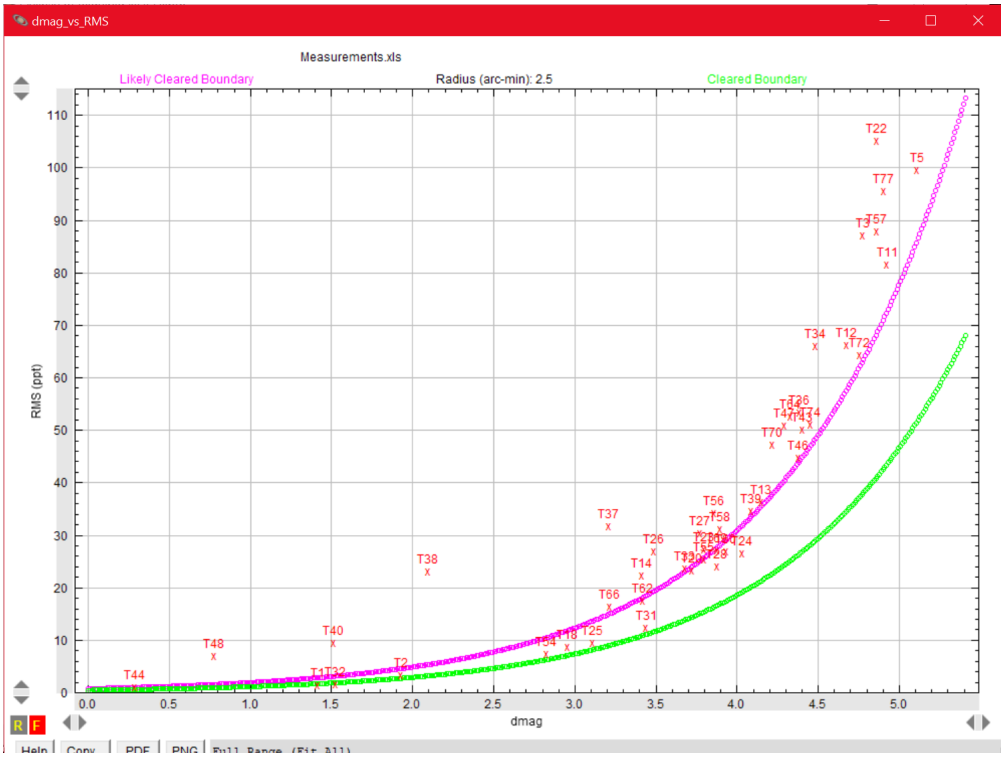


Figure 2: NEB Analysis Plot
NEB Analysis was performed to check for false positives

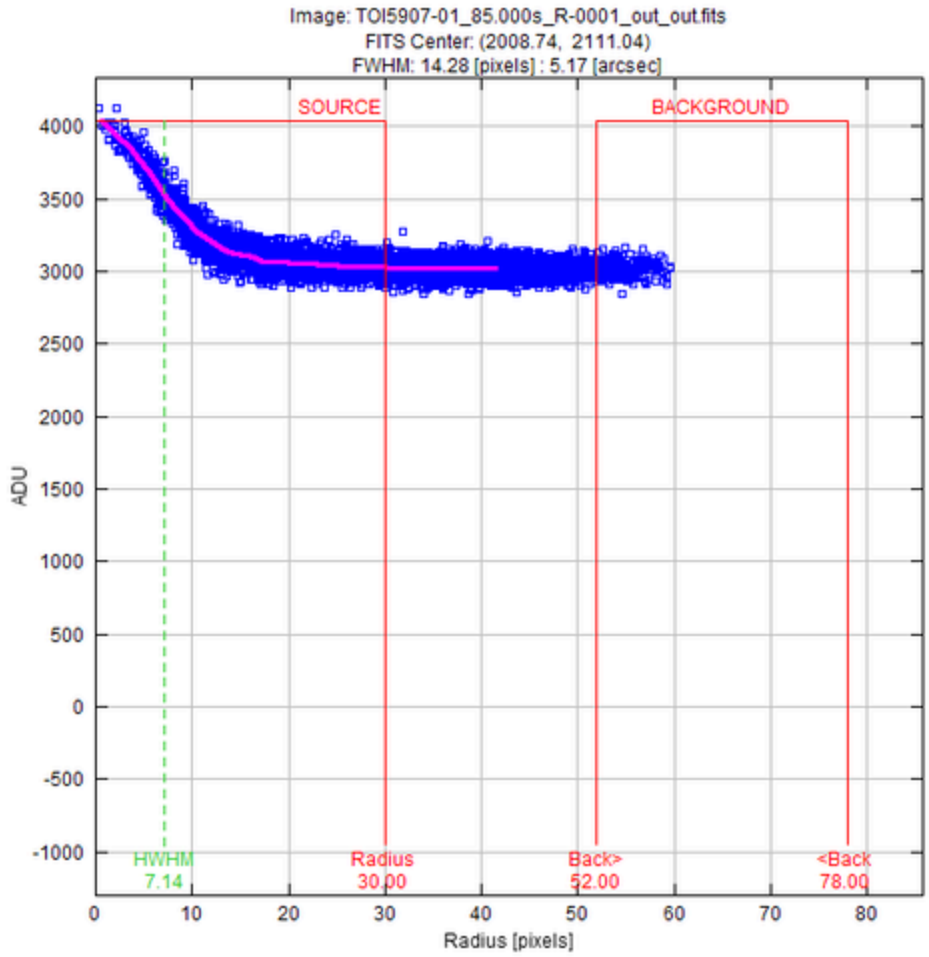


Figure 3: Seeing Profile of TOI 5907.01

# 5. Discussion

In Section 5.1 we present our interpretation of our results. In Section 5.2 we place our results into the context of the greater field of follow-up of candidate exoplanets from the NASA TESS mission."

## 5.1 Interpretation of Results

Our ground-based observations largely support that TOI 5907.01 is an exoplanet. The large fluctuations in Figure 1 at around 0.68 Julian Date imply the presence of a detected transit. After detecting the transit, AstroImageJ's nearby eclipsing binary (NEB) check was performed to check for false positives. The NEB analysis returned results proving that this was not a false positive. The detection of a transit event at the predicted time, with a depth and duration similar to TESS predictions, strongly implies that the candidate is an exoplanet.

The successful detection of a transit from a ground-based observatory underscores the importance of follow-up observations from other sources in confirming TESS candidates. Our results show that even with the challenges that have their root in ground-based observations, including light pollution and atmospheric effects, it is possible to detect and characterize exoplanet transits for objects first identified by space-based telescopes.

### 5.2 Context in TESS Follow-up Efforts

Our study of TOI 5907.01 contributes to the broader effort of following up on TESS Objects of Interest. The NASA TESS mission has identified thousands of candidate exoplanets, but ground-based follow-up observations are crucial for confirming these candidates and refining their properties.

Our results demonstrate the value of smaller, ground-based observatories in this effort. While not as sensitive as space-based telescopes, ground-based facilities like the George Mason University telescope can provide crucial data to confirm or deny candidate exoplanets.

This work also highlights the importance of a global network of observers in exoplanet research. As TESS continues to identify new candidates, the ability of researchers to quickly follow up on these observations becomes increasingly important. Our successful observation of TOI 5907.01 adds to the growing number of confirmed TESS exoplanets.

## 6. Conclusions and Future Work

Our goal was to confirm the planetary nature of TOI 5907.01 using data reduction and multi-aperture photometry to generate a light curve and conduct NEB analysis. We were able to detect a transit between 0.66 and 0.69 in $BJD_{TDB}$ time leading us to conclude that TOI 5907.01 is most likely a potential exoplanet.

It fits the profiles of both a hot Jupiter and an ultra-short-period planet. To confirm these profiles, further study would have to be done to find properties such as its mass and density.

Further statistical false positive validation analysis needs to be conducted to remove any false positives and ensure less than 1% chance of errors

# 7. Acknowledgements

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