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Astrobiology Research & Outreach at Truman State University

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Abstract

We present light curves for three potential exoplanet candidates: **TIC 950525831.01** and **TIC 346015394.01**. These targets were chosen from the TESS Follow-Up Observing Program (TFOP) database[1]. The primary goal of the TESS Follow-up Observing Program (TFOP) Working Group (WG) is to provide follow-up observations that will facilitate achievement of the Level One Science Requirement to measure masses for 50 transiting planets smaller than 4 Earth radii[2]. Students remotely used the 1-m NPOI Lowell telescope on Anderson Mesa near Flagstaff, Arizona to target these objects. In total, students observed eight "TFOP" potential exoplanet targets. Students are working on analyzing data and generating lightcurves on several of these objects and have completed and submitted analyses on three objects we discuss here.

Background & Perspective:

The Transiting Exoplanet Survey Satellite (TESS), is the most comprehensive all-sky survey of exoplanets in the Milky Way. TESS was designed to detect exoplanets smaller than Neptune around the brightest stars in the night sky; in order to utilize the quantity of data that TESS collects, the mission relies on community efforts to conduct ground-based follow-up observations of TESS exoplanet candidates. The TESS team has assembled a catalog of exoplanet candidates, but with a relatively low resolution of 21 arcseconds per pixel. An exoplanet candidate cannot be characterized as an exoplanet until higher resolution photometric analysis of the target is conducted. These higher resolution follow-ups, largely from ground based telescopes, help ascertain if the variation in the target is indeed due to an exoplanet, and not due to any variable stars in its vicinity that produces light curves that mimic exoplanet transits. For this reason, the TESS team has developed the TESS Follow-Up Observing Program (TFOP) to confirm the findings of TESS or detect false positives.

We are a part of the TFOP Sub Group 1 or TFOP SG1. This sub group conducts differential photometry to:

- detect false positives that would be caused by nearby eclipsing binary systems that contaminate the field,
- check and improve light curves and ephemerides and,
- measure transit timing variations (TTVs).

Our ground based observations for TFOP were taken using a 1 meter telescope at Lowell Observatory in Flagstaff. Targets were selected as described in the Methodology section, and the resulting time-series observations for these targets were analyzed using AstroImageJ to conduct differential photometry in order to examine the light curve of the target as well as all other stars within a 2.5 arcmin radius of the target.

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[1] *https://astro.swarthmore.edu/transits/transits.cgi*
[2] *https://tess.mit.edu/followup/*

Results:

Participating students were responsible for selecting targets during our observing run (19th November 2022 to 22nd November 2022) to utilize the entire night. The list of targets are shown in Table 1 below. One of the primary objectives of the TFOP group is to study candidate exoplanet transits and determine of these are caused by nearby variable stars, usually eclipsing binaries, and thus eliminate these "false positives" from the list of possible exoplanets detected by the TESS mission. Students carried out data collection, reduction, and light-curve generation following the prescription by Dennis Conti of the TFOP group[3]. This guide lays out the general principles involved in observing exoplanets and then described data reduction and analysis using the AstroImageJ software. The TFOP data submission process involves generation of several data and images files (see Figure 1 for examples) – this procedure is outlined in the TFOP Observation Guidelines document[4]. Students followed this procedure and have successfully submitted data for three targets, and are working towards submitting data from the other three targets by the end of April 2023.

Date	Object Name	RA/Dec	Tess-mag	Comments
11/19/2022	TIC 467615239.01	05:12:41.45 22:30:21.33	13.2	Clouds interfered, focusing issues leading to ambiguous results
11/20/2022	TIC 458876004.01	02:23:21.09 60:53:23.87	12.0	Clouds interfered, focusing issues leading to ambiguous results
	TIC 346015394.01	03:21:17.96 63:43:57.08	13.2	**Results submitted to TFOP 85 possible contaminants, 75 ruled out**
11/21/2022	TIC 432761635.01	00:56:39.46 39:53:29.8	13.3	**Working on this**
	TIC 950525831.01	12:01:02.14 55:50:46.32	12.4	**Results presented to TFOP 7 possible contaminants, 6 ruled out**
11/22/2022	Wasp-52b	23:13:58.75 08:45:39.89	12.2	Target image saturated
	Hat-57b	04:03:47.59 -19:03:24.55	12.33	Transit Observed – **data submitted to ETD**

Table 1: List of targets observed in Fall 2022 with the 1-m NPOI telescope at Lowell Observatory near Flagstaff, Arizona. The observations were carried out remotely. All targets with names starting with "TIC" are potential exoplanets, and our analyses hope to "clear" them as such. Data analysis and submission of appropriate files as per the TFOP protocol has been completed for the objects shown in boldface. Wasp-52b and Hat-57b are known exoplanets.

[3] https://astrodennis.com/Guide.pdf
[4] https://astrodennis.com/TFOP_SG1_Guidelines_Latest.pdf

Figure 1 below shows a few of the images and plots generated by the software AstroImageJ based on the procedure outlined in the TFOP guide. The plot on the left shows a shallow but distinct dip in the light from the target between the two dashed vertical magenta lines – these dashed lines represent the expected location of the transit based on TESS observations. There are quite a few stars in close proximity of the target (see star-field in the bottom right of Figure 1), which could be a possible source of contamination in the TESS measurement. Students were able to perform photometry on each of these potential contaminants (top right plot in Figure 1), and eliminate them as sources of the dip in the target's lightcurve. Students have successfully submitted these artifacts (and about 12 other data files and images) to the TFOP data submission portal for further analyses by the TFOP group.

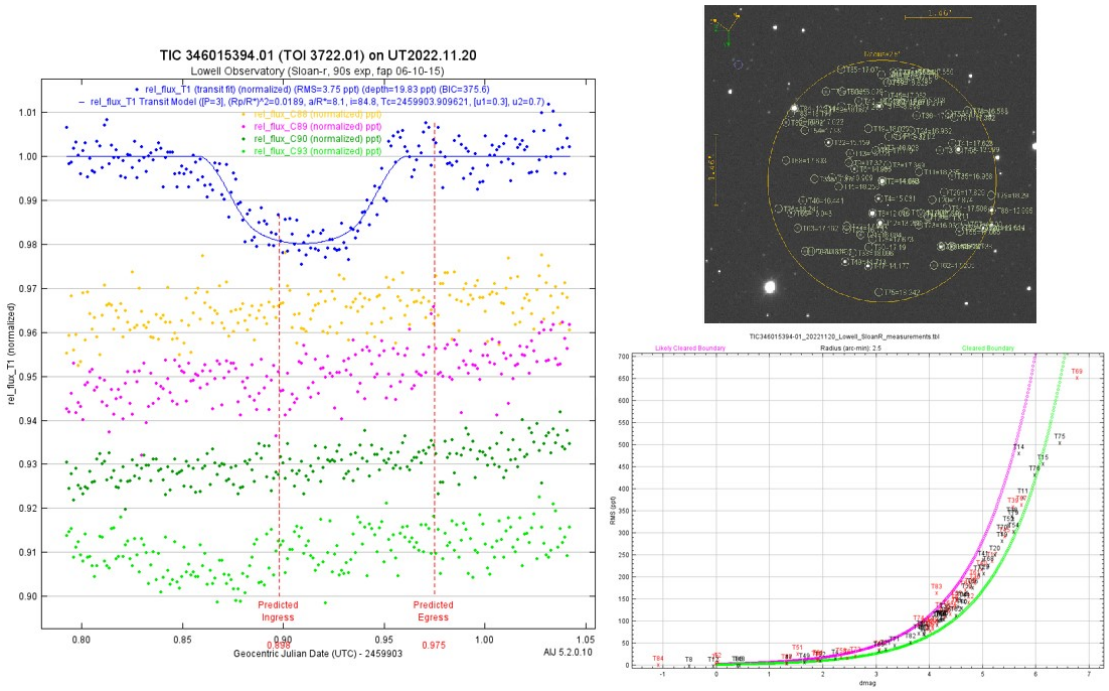

Figure 1: Left panel: Light curve of target candidate exoplanet TIC 346015394.01(blue dots) and the best fit (blue curve) along with light curves of comparison stars. The top right panel shows the target (T1) with 85 other potential contaminating stars within a 2.5 arc-minute radius (yellow circle). Each of these are plotted on the graph on the bottom right, where any star below the green curve is ruled out as a contaminant, stars between the green and magenta curves are "likely cleared" contaminants and any stars above the magenta curve are not cleared. Based on these analyses, we can conclude that the "dip" seen in the target lightcurve is not from seventy-six of the nearby objects. Ten objects could not be cleared; follow up observations from space-based telescopes might be needed to eliminate these.

Other Activities:

Astronomy Outreach: Students participated in numerous outreach activities in Kirksville, Arrow Rock, and New London. These outreach events included setting up and operating telescopes, using LASER pointers to do constellation runs, handing out brochures related to astronomy and dark skies, and answering questions from the audience. Events in Kirksville were held at the Truman State Observatory, at Thousand-Hills State Park, and the Adair County Public library.

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Figure 2: Stargazing event at Thousand Hills State Park in March 2023. More than 50 people showed up for this particular event. Students set up and operate the eVScope which is capable of providing views as shown on the right panel (M51, the Whirlpool galaxy). At such events, Dr. Gokhale does a short 15 minute presentation on the importance of dark skies, not just for stargazing, but also from the ecological and environmental health point of view. Q&A usually results in discussions about light pollution, exoplanets, life on other planets, and NASA missions in our solar system and beyond.

Student Biographies

Nathan Shaw is a sophomore physics major with emphasis in astrophysics at Truman State University. Nathan joined the astronomy research group at Truman State in the fall of 2021, with focus on the TESS Follow-Up Program. In his future, he sees a Ph.D. in astronomy or astrophysics, with career ambitions to become a research professor or scientist.

Autumn Winslett is a senior biology student at Truman State University who will graduate in May 2023. She will also graduate with a minor in astronomy and has been a part of astronomy research for a year. After graduation, Autumn plans to pursue a career in conservation and animal care, and hopes to one day become a zookeeper.

Daphne Zakarian is a junior at Truman State University who is majoring in physics with a concentration in astrophysics. Daphne has been a part of the astronomy research team at Truman State since the fall of 2021, and she will be graduating in the spring of 2024. After graduation, she plans to pursue a PhD in astrophysics.

Faculty Biographies

Vayujeet Gokhale is an associate professor of Physics at Truman State University. He earned his BSc. in physics (’96) and MSc. in nuclear physics (’98) from the University of Bombay, followed by a PhD in astronomy from Louisiana State University. Dr. Gokhale loves the night sky and National Parks, and dreams of becoming an astronomy park ranger at the Arches National Park in Utah.