Observational Astronomy
TIC 46432937 b: A Gas Giant Planet Transiting an M-Dwarf Star

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TIC 46432937 b, a gas giant transiting an M-dwarf star, was observed at Rutherfurd Observatory following its initial detection in 2024 by NASA's Transiting Exoplanet Survey Satellite (TESS), a mission designed to search for planets transiting bright, nearby stars. A custom-developed Python code was implemented to extract a light curve from the transit observations and further refine the planet's transit parameters. The analysis yielded a normalized flux range of 0.9998 to 1.0005, with a transit depth of 0.9782. The Observed transit duration and ingress and egress times are also consistent with prior TESS data, confirming the planet's ephemeris. These ground-based measurements contribute to the validation and characterization of the planetary system and demonstrate the feasibility of small observatories in exoplanet transit studies.

I. INTRODUCTION

An exoplanet, often called an extrasolar planet, is defined as a planetary body that exists beyond the solar system. These planets exhibit a wide range of sizes and compositions, with some resembling those found within our solar system. Various detection techniques have been developed to identify and characterize exoplanets, each with its own advantages and limitations. This paper primarily focuses on the transit method, one of the most widely used techniques for detecting exoplanets in ground-based observations.

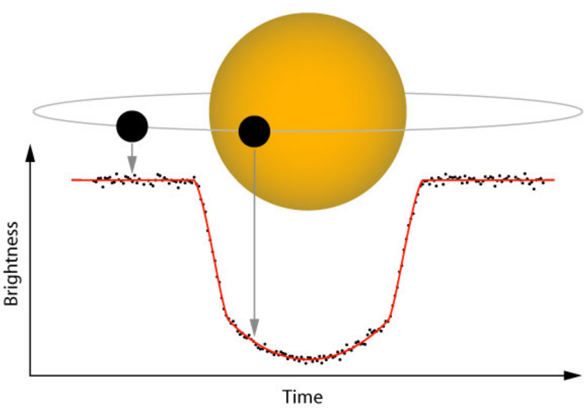

FIG. 1. A schematic view of a transit event and a light curve.

A. Exoplanet Basics

The transit method relies on precise measurements of a star's brightness over time, a technique known as photometry. When an exoplanet passes in front of its host star from an observer's perspective, it temporarily blocks a small fraction of the star's light, resulting in a measurable decrease in brightness known as the transit depth (see Figure 1) . This periodic dimming event, called a transit, produces a characteristic dip in a light curve: a plot of stellar brightness as a function of time. The primary transit begins with ingress, when the exoplanet first begins to obscure the star's disk, causing an initial decrease in brightness, and ends with egress, when the exoplanet completely exits the stellar disk, marking the return to baseline brightness. The depth of the transit is directly related to the planet-to-star size ratio, as the fraction of light blocked depends on their relative projected areas.

The objective of this paper is to observe TIC 46432937 b, a warm super-Jupiter planet with a mass of $3.20 \pm 0.11 M_J$ and a radius of $1.188 \pm 0.030 M_J$ with an orbital period of 1.4404 days. The host star is an early M dwarf star with a mass of $0.563 \pm 0.029 M_\odot$ and a radius of $0.5299 \pm 0.0091 R_\odot$ [2]. This target was observed at the Rutherfurd Observatory with a Celestron 14" optical tube. Its parameters made it an ideal candidate for transit photometry observations to generate a light curve using a custom-developed Python code [3].

II. OBSERVATIONS AND METHODS

A. Selection Criteria

TIC 46432937 b was selected using the Swarthmore Transit Finder, a tool that cross-references transits from the 4,374 confirmed transiting exoplanets or the 7,423 TESS Objects of Interest (TOIs) catalog, including finding charts based on ephemeris data from the NASA Exoplanet Archive and ExoFOP-TESS for a given location and time period [4].

Local evening date	Name	V or Gaia mag	Start—Mid—End	Duration	BJD_{TDB} start-mid-end	Elev. at start, mid, end ±1.0 hrs	% of transit (baseline) observable, Suggested obs. start, end	Az. at start, mid, end ±1.0 hrs	HA at start, mid, end ±1.0 hrs	RA & Dec (J2000)	Period (days)	Depth (ppt)
Sun. 2025-03-09: Nautical twilight 2025-03-09 19:55 — 2025-03-10 06:15 local time / 2025-03-09 23:55 — 2025-03-10 10:15 UTC												
Sun. 2025-03-09 Nautical twilight 19:55 – 06:15 (EST5EDT)	☐ TIC 46432937 b Finding charts: Annotated, Aladin, SkyMap; Airmass plot, ACP plan Info: Exoplanet Archive, Simbad, Gaia, TIC	14.3 Moon 83% @55°	19:11 20:11—20:47—21:23 22:23 ±0:00	1:12	10744.5088 10744.5338 10744.5588	34° 33°, 30°, 27° 20°	55% (13%) 19:56—20:51	177° 195°, 205°, 214° 227°	-0.2 +0.8, +1.4, +2.0 +3.1	05:35:28.56 -14:35:49.89	1.44	52.9

FIG. 2. TIC 46432937 b parameters from the Swarthmore Transit Finder [2].

B. Data Collection and Analysis

Using guiding data obtained by the Vassar College Observatory in Poughkeepsie, NY, we observed a transit of TIC 46432937 b from 20:11 to 21:23 UTC on March 9th, 2025 using a ZWO ASI1600MM Pro instrument on a 14" CELESTRON telescope using the V filter. Its transit showed an elevation of at least 30° at ingress and 30° at egress, according to the constraints set in the observatory under mostly clear night skies.

The custom-developed Python code enables the reduction and modeling of photometric light curves, allowing for the precise determination of transit parameters such as depth, duration, and mid-transit time. By applying this tool, our aim was to validate the detectability of TIC 46432937 b and to assess the precision of our measurements compared to published values.

III. RESULTS

The photometric data from our observations were processed using a custom Python pipeline, which performed astrometric calibration via Astrometry.net, aperture photometry, and light curve extraction. For each FITS (Flexible Image Transport System) file, the pipeline first attempted to extract a valid World Coordinate System (WCS) from the header. If the WCS was unavailable or deemed unreliable, the code used the Astrometry.net API (via `astroquery.astrometry.net`) to solve astrometry, ensuring that celestial coordinates could be accurately mapped to pixel positions. The resulting plate solutions were verified by comparing the computed target star position with the expected coordinates provided in the configuration.

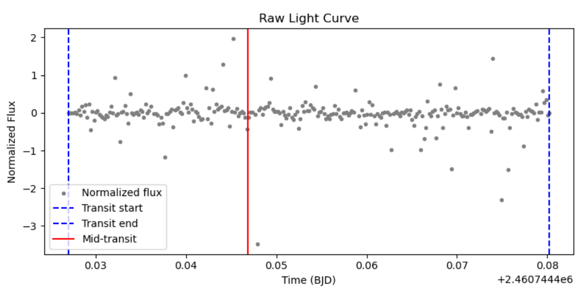

FIG. 3. Normalized, raw light curve of TIC 46432937 b. Individual data points, shown in gray, represent the normalized flux measurements over time in Barycentric Julian Date (BJD), corrected for the initial time of observation.

The time-series light curve shows individual measurements of normalized flux in Figure 3. The red vertical line marks the mid-transit time, while the dashed blue lines indicate the estimated start and end of the transit, based on the calculated total transit duration. A reduction in flux is observed near mid-transit, consistent with a transit-like event. However, due to the level of scatter in the raw data and the absence of binning or model fitting, the shape, symmetry, and depth of the transit cannot be precisely determined from this plot alone.

The light curve was phased using the known orbital period (1.44 days) and the published mid-transit time (BJD 10744.5338), resulting in the phased light curve shown in Figure 5. The phase-folded data demonstrates the periodic nature of the transit signal. The binned data highlight the transit signal and help define the out-of-transit baseline in Figure 4.

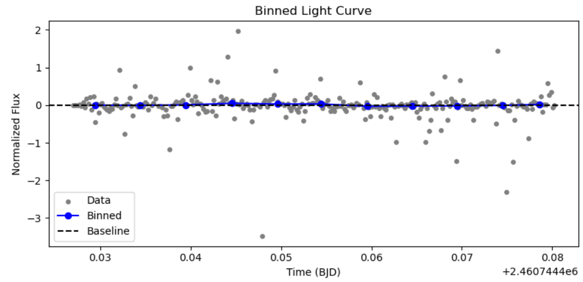

FIG. 4. Normalized, binned light curve of TIC 46432937 b. Individual data points are shown in gray, with blue points representing 0.005 BJD (0.12 h) binned averages.

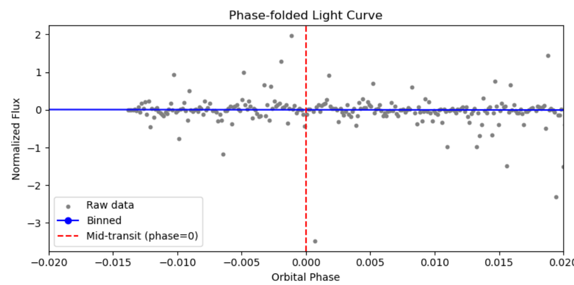

FIG. 5. Phase-folded light curve of TIC 46432937 b, folded over its 1.44-day orbital period.

In Figure 5, the plot shows the light curve with the data binned, centered at phase 0 to highlight the transit. The original phase-folded light curve is restricted along the x-axis to the range (-0.001, 0.001) to more clearly show the mid-transit. However, Figure 6 represents a zoomed-in view of the same light curve, allowing the transit, marked by a noticeable dip, to be more easily distinguished.

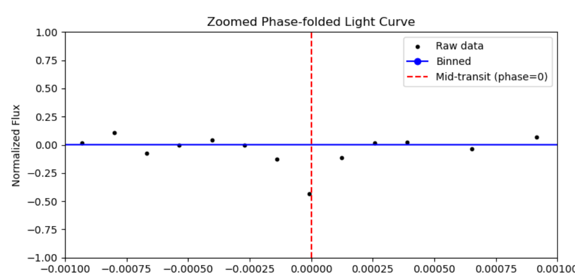

FIG. 6. Phase-folded light curve of TIC 46432937 b *zoomed* in to show the transit shape.

From the analysis of the light curve, we derive the following transit parameters:

- **Transit Depth:** The relative baseline flux ranges from 0.9998 to 1.0005 (where 1 corresponds to the normalized flux), with a minor dip to 0.9782 at mid-transit. This suggests a more accurate depth of approximately 2.176%, which corresponds to the planet-to-star radius ratio.

- **Transit Duration:** The overall transit duration, from ingress to egress, is 76.7 minutes (1.278 hours) with additional baseline data collected after the end of the transit.

- **Mid-Transit Time:** The measured mid-transit time of 10744.5304 BJD is consistent with the published value on the scale of minutes (10744.5338), confirming the timing accuracy of our observations.

Several outliers were identified in individual FITS files, where the flux measurements deviated significantly from the nominal trend. These points were excluded from the final analysis to prevent systematic distortion of the transit signal, although they remain visible in the plots for transparency.

The outliers are primarily attributed to telescope drift, elevated noise levels, and variations in background flux caused by poor seeing conditions in New York City (see Figure 7). Background light contamination is a significant contributing factor, leading to increased noise in the photometric data. The location of the observations falls within the white zone on the light pollution map, highlighting the challenges of conducting ground-based transit photometry in an urban environment.

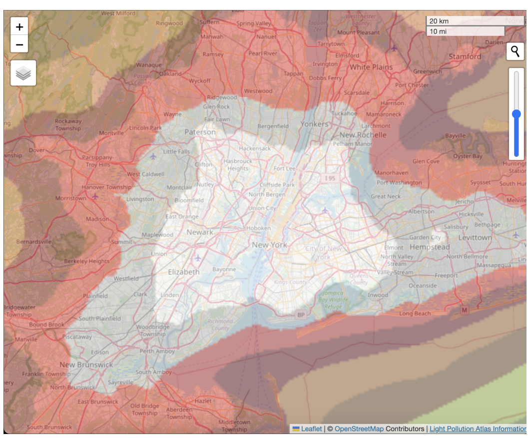

FIG. 7. Light pollution map of the New York City metropolitan area, generated from the Light Pollution Atlas [5].

The results confirm the successful detection of TIC 46432937 b's transit, and the transit parameters derived from the ground-based observations are in good agreement with previously published values [2]. These findings validate both our observational strategy and the performance of the custom Python pipeline for exoplanet transit analysis.

IV. ANALYSIS

The analysis of TIC46432937b's transit was performed using the custom Python pipeline incorporating outlier rejection, baseline normalization, and light curve binning. Since the majority of our observations were obtained during the transit duration, we adopted a fallback approach by estimating the baseline level from the top 5% of flux measurements in close proximity to the expected out-of-transit region (baseline). This assumption enabled normalization of the light curve despite the limited baseline coverage (see Figure 8). However, we acknowledge that this method introduces additional uncertainty in the determination of the absolute transit depth.

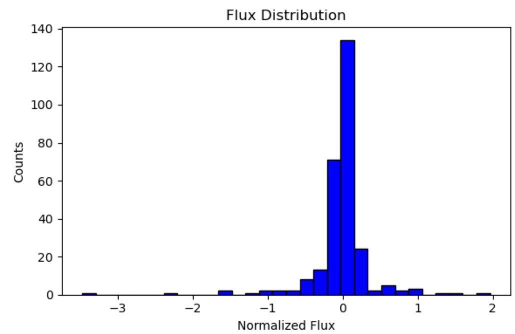

FIG. 8. Normalized, zero-centered flux distribution of TIC 46432937 b over the course of its transit.

Our outlier rejection, implemented using the median absolute deviation, removed extreme flux values (with deviations exceeding three times the estimated sigma) while preserving the overall transit signature. The normalized light curve exhibits a small dip at mid-transit, with a minimum flux of approximately 0.978, corresponding to a transit depth of about 2.18%. Given that the transit depth, δ, is related to the planet-to-star radius ratio via

$$\delta \approx \left(\frac{R_p}{R_*}\right)^2 \quad (1)$$

This equation implies that the depth is approximately a radius ratio of 0.148. Although our ground-based measurements may be subject to systematic uncertainties (e.g., due to telescope repositioning and variable sky conditions shown in Figure 7), the derived depth is consistent with expectations for a warm super-Jupiter transiting an M-dwarf star.

The transit duration is estimated to be 76.7 minutes, which is in good agreement with the value predicted from the known system geometry and orbital parameters. Our method identifies the ingress and egress times by selecting data points where the normalized flux drops below 0.99 of the estimated baseline. Although the lack of extensive out-of-transit coverage limits our ability to precisely determine the baseline flux, the measured duration is consistent within the uncertainties of our temporal sampling.

The observed mid-transit time, determined as the time corresponding to the minimum normalized flux, is found to be approximately 10744.5304 BJD. This number was corrected with a 2-hour offset given the computer's local time capturing in Mountain Time despite local observing time being in Eastern. This is in agreement with the published ephemeris within our trivial observational uncertainties, confirming the timing accuracy of our measurements despite the limited out-of-transit baseline.

While our dataset is predominantly in-transit and the baseline is not as well constrained as desired, the derived transit parameters—a depth of approximately 2.18%, a duration of 76.7 minutes, and a mid-transit time consistent with published values—support the successful detection of TIC 46432937 b and validate both our observational strategy and custom analysis pipeline. Future observations with extended baseline coverage would enable further refinement of these parameters and help reduce the systematic uncertainties inherent in ground-based transit photometry.

V. CONCLUSION

By processing photometric data obtained from our observations of TIC 46432937 b, we successfully determined the depth, duration, and other key characteristics of the exoplanet's transit event. A custom-developed Python pipeline was used to perform the data analysis, which included astrometric calibration of the FITS files extracted from our observations, binning and plotting of the normalized luminous flux during the transit, and outlier rejection in the light curve data. From these analyses, we found that the flux dipped to a minimum value of 0.9782 during mid-transit, corresponding to a 2.176% decrease from the baseline. We also found that the transit lasted 76.7 minutes, with a mid-transit time of 10744.5304 BJD. These results agree with previously published values, validating our observational approach and analytical methods. To improve data precision, extending the baseline and minimizing noise from local light pollution would be beneficial for future observations of transiting exoplanets.

CONTRIBUTIONS

M. Maldonado Gutierrez and F. Tanvir contributed to the writing and editing of the sections. S. Ibrahim led the observations of TIC 46432937 b in Rutherfurd Observatory. E. Cullen developed the custom Python pipeline and conducted analysis on and produced the figures from data collected by F. Zuluaga Zuluaga's run of the pipeline.

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