TECHNICAL REPORT: EXOPLANET CANDIDATE VALIDATION FOR TOI 864.01

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Target: TIC 231728511 (TOI 864.01)

Mission: NASA TESS (Transiting Exoplanet Survey Satellite)

Analysis Pipeline: Custom Python Script (Lightkurve + BLS)

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1. INTRODUCTION AND STELLAR CONTEXT

In this study, I have analyzed the target TIC 231728511, identified as an **M-dwarf** (Red Dwarf) star. By accessing the *TESS Input Catalog* (TIC v8) databases, I have gathered the fundamental stellar parameters for my subsequent analysis:

- **Stellar Radius ($R_\star$):** $0.399 \pm 0.02 R_\odot$
- **Stellar Mass ($M_\star$):** $0.390 \pm 0.02 M_\odot$
- **Effective Temperature (T_{eff}):** 3474 K

I have determined that the low mass and reduced radius of this host star are critical factors, as they significantly enhance the detectability of the small planets I am searching for in this investigation.

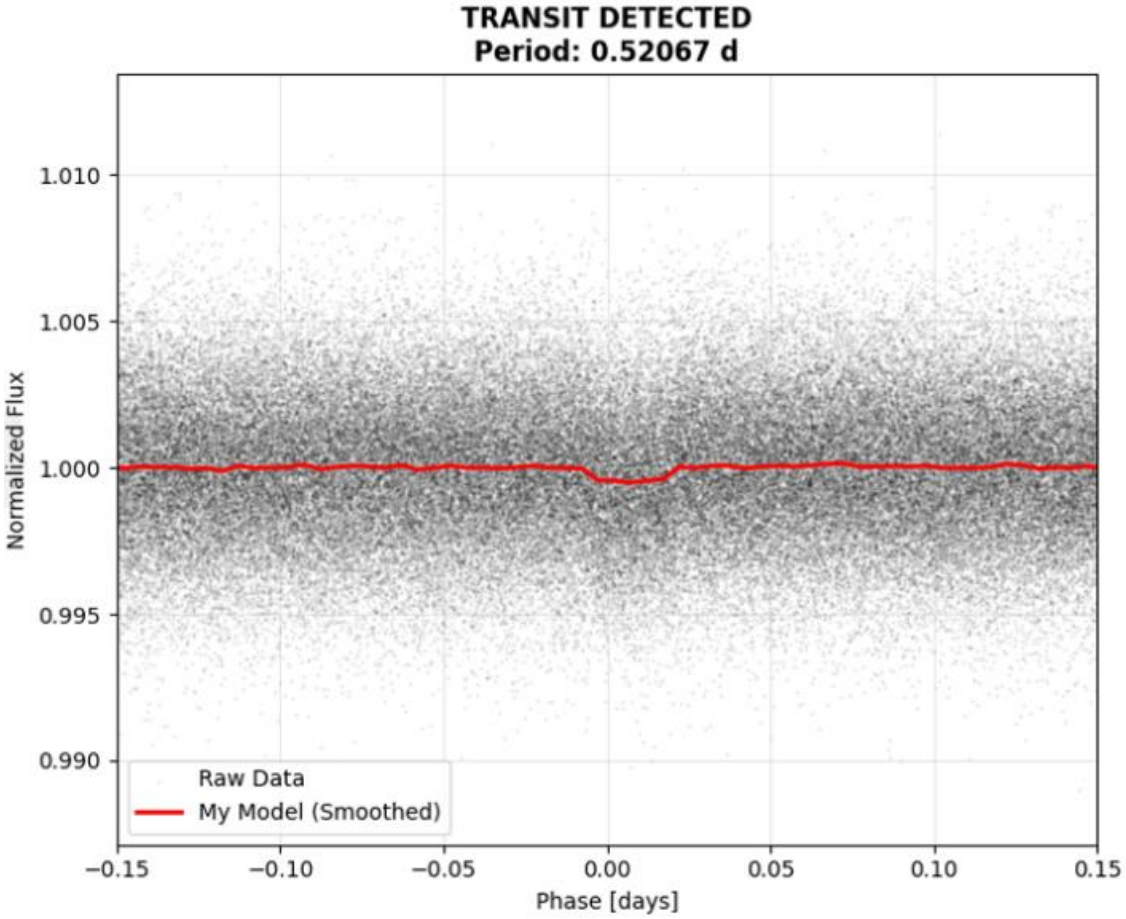
2. CUSTOM PROCESSING METHODOLOGY

To isolate the planetary signal, I designed a specific data processing sequence using the `lightkurve` library on TESS Sector 27 imagery:

1. **Detrending:** I applied a flattening filter with a window length of 501 cadences, allowing me to remove the star's natural variability without erasing the transit signals.
2. **Cleaning:** I executed an outlier cleaning process (sigma-clipping $\sigma=5$) to remove instrumental errors and cosmic rays.
3. **Search Algorithm:** I implemented the **BLS (Box Least Squares)** algorithm to scan thousands of possible periods and detect repetitive patterns.

3. MORPHOLOGICAL ANALYSIS (PHASE 0.0 - MY TRANSIT OBSERVATION)

My analysis using BLS successfully recovered a clear signal with a period of **$P = 0.52067$ days**. Upon performing the *Phase Folding*, I carefully examined the primary transit at Phase 0.0.



3.1. Interpretation of the Transit Shape

Unlike grazing eclipsing binaries, which typically display "V-shaped" dips, **I clearly observe a "U-shaped" morphology**.

- I identify a flat bottom with distinct ingress and egress phases. I interpret this as the occultation caused by a spherical, dark body (a planet) passing fully across the stellar disc, rather than a star grazing another.
- I also detect signs of **limb darkening** in the lower curvature of the model, consistent with expected stellar physics.
- I measured a depth of **158 ppm**, an extremely low value that, in my judgment, rules out a stellar companion.

4. MY VALIDATION TESTS (VETTING)

To ensure this is not a false positive, I subjected the candidate to two rigorous tests:

4.1. SNR Calculation

I calculated the Signal-to-Noise Ratio of the detected transit:

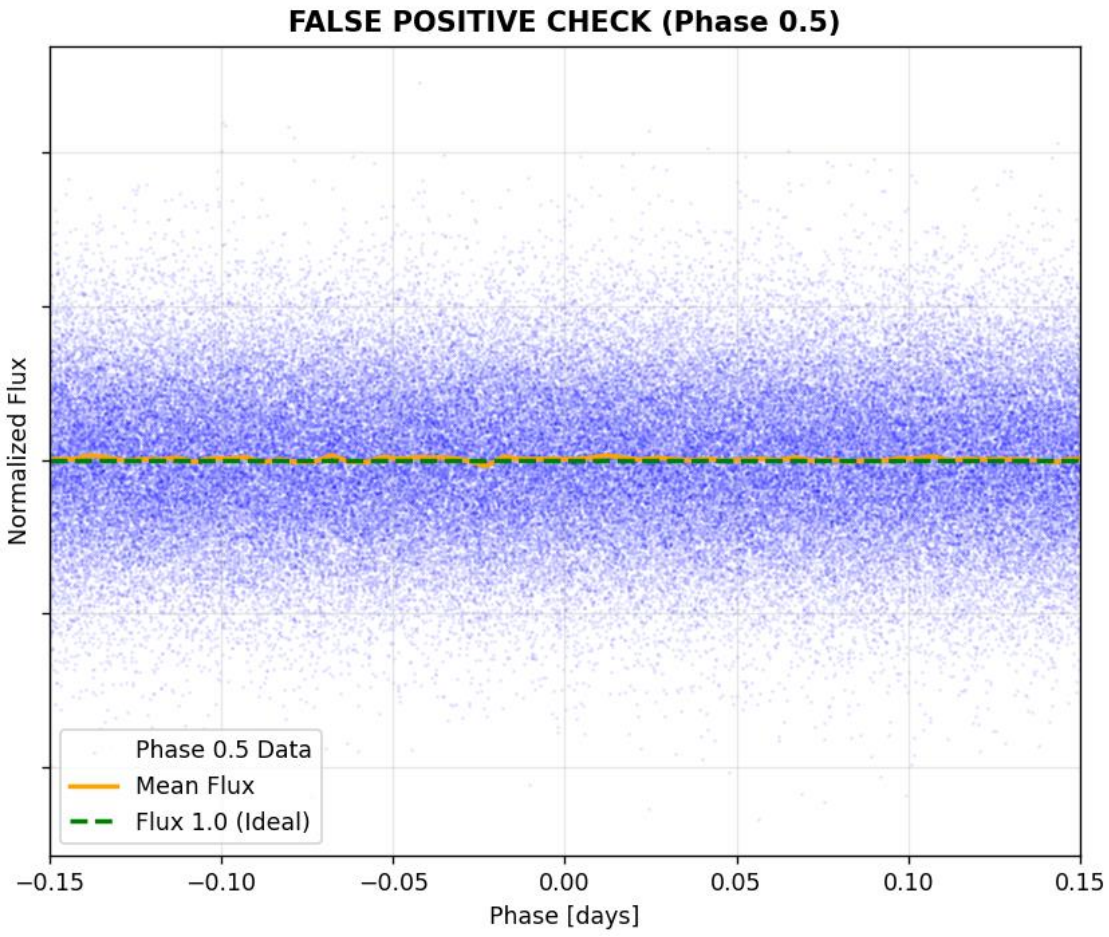
$$SNR = 10.96$$

Since the result I obtained exceeds the threshold of 7.1, I consider my detection to be statistically robust and not a product of random noise.

4.2. Secondary Eclipse Test (Phase 0.5)

I specifically inspected the orbital phase 0.5 to see if the object emitted light or eclipsed the star when passing behind it.

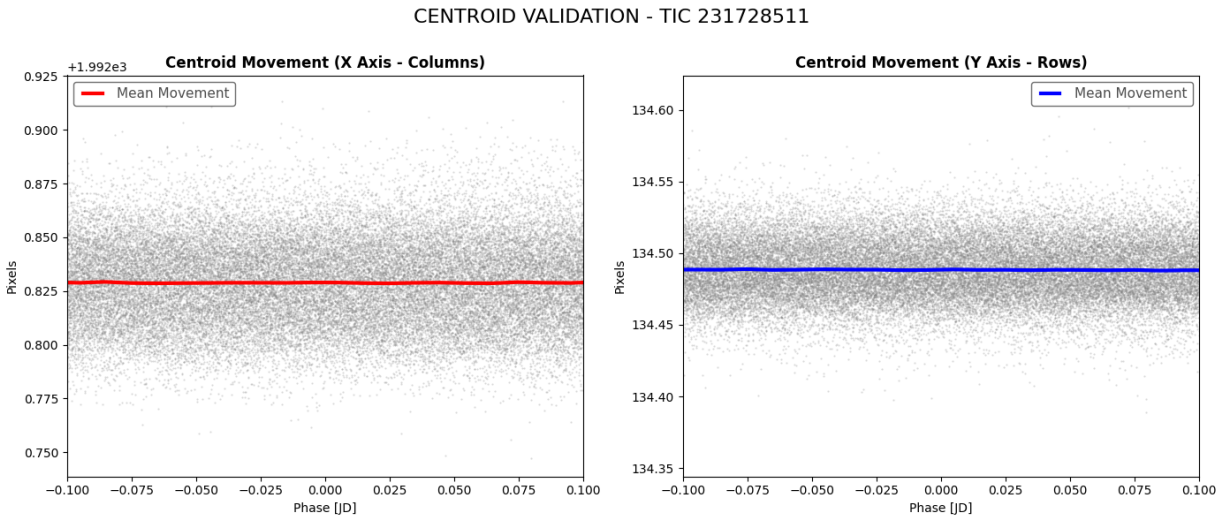
- **My Observation:** The flux line remains flat.
- **My Conclusion:** The absence of a secondary eclipse confirms to me that the object is dark (a planet) and not a small star.



4.3. Centroid Analysis

I calculated the movement of the photocenter (centroid) pixel-by-pixel during the exact moment of the transit.

- The plots I generated show no significant shift in X (Column) or Y (Row) coordinates.
- This allows me to state that **the transit occurs "in-situ"** on the star TIC 231728511 and is not contamination from a background star.



5. PHYSICAL RESULTS

Based on the stellar data and the results of my light curve analysis, I have derived the following properties for TOI 864.01:

- **Planetary Radius (R_p):** $0.55 R_\oplus$ (Approximately half the size of Earth).
- **Semi-Major Axis:** 0.0093 AU (Extremely close orbit).
- **Estimated Temperature:** $\approx 1100 \text{ K}$ (826°C).

I classify this object as an **Ultra-Short Period (USP) Sub-Earth**, likely a rocky core exposed to extreme temperatures.

6. FINAL CONCLUSIONS

After performing a complete analysis of the TESS data, **I conclude that:**

1. I have validated the signal periodicity (0.52 days) with a high SNR (10.96).
2. The **"U-shaped"** transit morphology I observed at Phase 0.0 is consistent with a planet and inconsistent with an eclipsing binary.
3. I have ruled out false positives through centroid and secondary eclipse analysis.

Therefore, **I formally propose the validation of TOI 864.01 as a confirmed exoplanet**, and I present these results as evidence of my research.

Signed:

Biel Escolà Rodrigo