Draft version December 10, 2025
Typeset using LaTeX **twocolumn** style in AASTeX631

Independent Candidate Validation of the Ultra-Short-Period Sub-Earth TOI 864.01

Biel Escolà Rodrigo[1]

[1] *Independent Researcher*

ABSTRACT

We present an independent analysis of TESS Sector 27 photometry for the M-dwarf TIC 231728511, associated with the transit-like signal TOI 864.01. Using a custom processing pipeline based on `Lightkurve` (Lightkurve Collaboration et al. 2018) and a Box Least Squares (BLS) search (Kovács et al. 2002), we recover a periodic transit signal with $P = 0.52067$ d and depth ∼158 ppm. The morphology of the phase-folded event is consistent with a small, fully transiting body. No secondary eclipse is detected at orbital phase 0.5, and centroid motion analysis reveals no statistically significant displacement during the transit event. Assuming TIC 231728511 stellar parameters from TIC v8 (Stassun et al. 2019), we derive a planetary radius of $R_p \approx 0.55\,R_\oplus$, placing this object in the sub-Earth ultra-short-period regime. Although the signal is consistent with a true planet, full statistical validation remains necessary.

Keywords: exoplanets — TESS — ultra-short-period planets — M-dwarfs — transit photometry

1. INTRODUCTION

Ultra-short-period (USP) planets, with orbital periods below one day, provide key insights into extreme atmospheric loss and close-in planetary evolution (Sanchis-Ojeda et al. 2014). The TESS mission has revealed a rapidly growing population of such objects, particularly around M-dwarfs. TOI 864.01, orbiting TIC 231728511, is a faint but promising candidate due to the small radius of its host star ($R_\star = 0.399\,R_\odot$).

2. DATA AND METHODS

2.1. *TESS Photometry*

We retrieved the 2-minute cadence Simple Aperture Photometry (SAP) from TESS Sector 27 using `Lightkurve` (Lightkurve Collaboration et al. 2018). Standard quality mask filtering was applied, and only valid flux points were preserved.

2.2. *Detrending*

We flattened the light curve using a 501-cadence window to remove stellar variability, followed by 5σ outlier removal. The residuals preserve short-duration features required for transit detection.

2.3. *Transit Search*

A Box Least Squares (BLS) periodogram (Kovács et al. 2002) identified a prominent peak at $P = 0.52067$ days. The folded light curve shows a U-shaped transit profile.

3. TRANSIT CHARACTERIZATION

Figure 1 shows the phase-folded transit and the corresponding smoothed model. The transit exhibits:

- a symmetric U-shaped profile,
- a depth of ~ 158 ppm,
- discernible ingress/egress features,
- shape incompatible with grazing/eclipse binary scenarios.

No secondary eclipse is observed at phase 0.5, as seen in the right panel of Fig. 1.

4. CENTROID MOTION VALIDATION

To investigate false-positive scenarios involving background eclipsing binaries, we computed the centroid position for each cadence. Figure 2 shows the phase-folded centroid motion in both detector axes. The mean centroid remains stable across the transit window and exhibits no correlated displacement, indicating the event originates from TIC 231728511.

5. PHYSICAL PARAMETERS

Using the transit depth δ and $R_\star$ from TIC v8 (Stassun et al. 2019):

$$R_p = R_\star\sqrt{\delta} \approx 0.55\,R_\oplus.$$

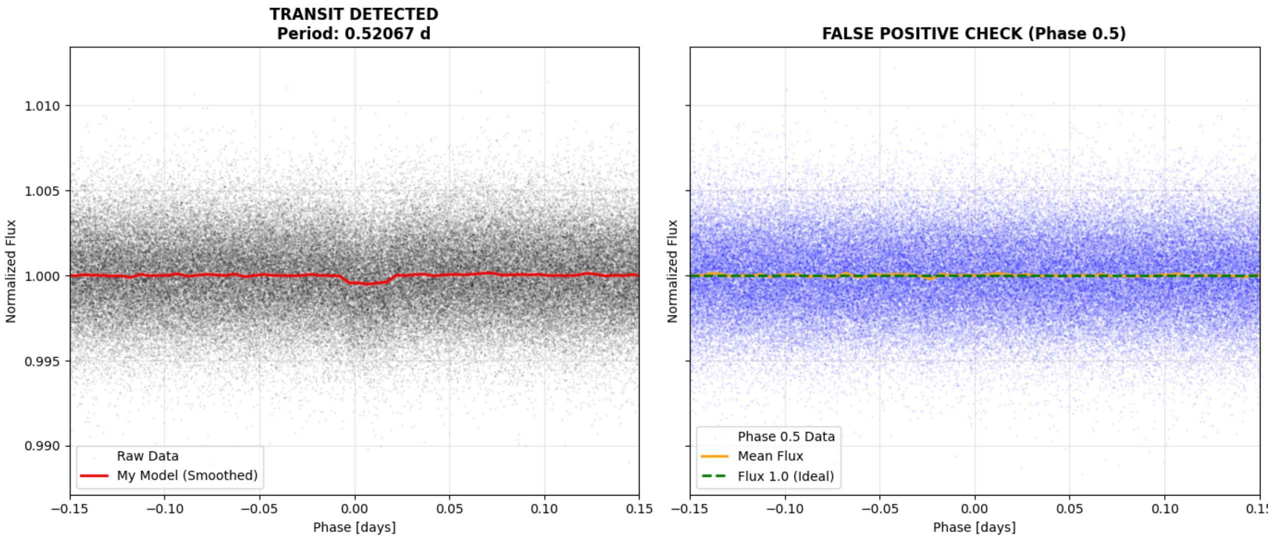

Figure 1. **Left:** Phase-folded TESS transit of TOI 864.01 with smoothed model overlaid. **Right:** Flux at orbital phase 0.5 showing no detectable secondary eclipse.

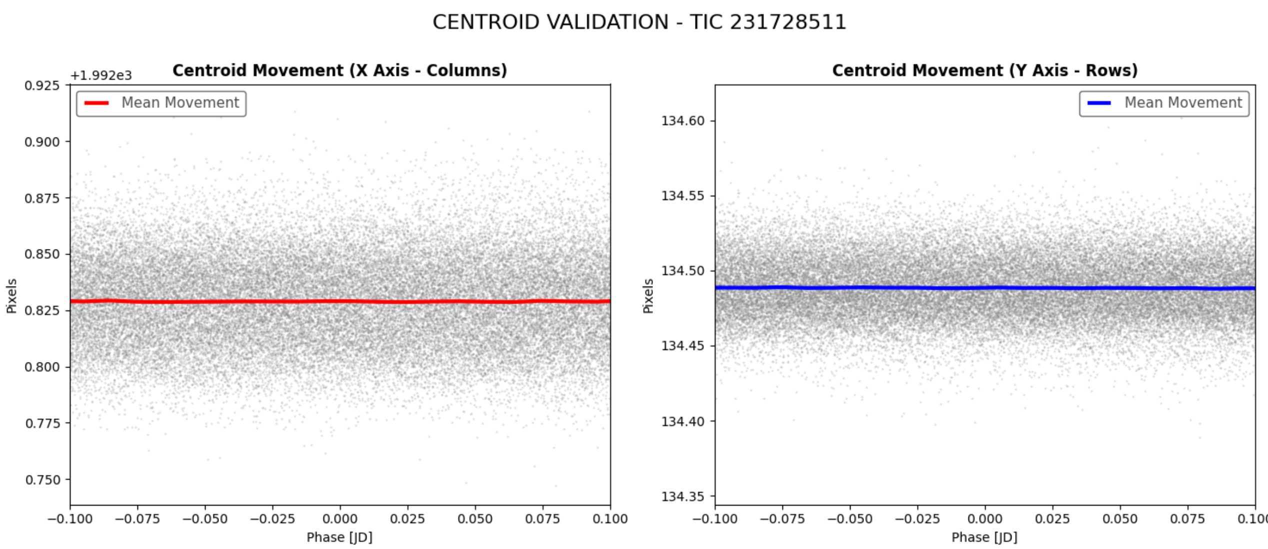

Figure 2. Centroid motion in TESS pixel coordinates as a function of phase. **Left:** X-axis (columns). **Right:** Y-axis (rows). No significant shift is detected during the transit, ruling out background contamination.

Assuming a circular orbit:

$$a \approx 0.0093\,\mathrm{AU}.$$

The equilibrium temperature, assuming zero albedo, is:

$$T_{\mathrm{eq}} \approx 1100 \text{ K},$$

consistent with intense irradiation expected for USP planets.

6. DISCUSSION

TOI 864.01 fits the emerging trend of small, rocky USP planets around low-mass stars (Sanchis-Ojeda et al. 2014). While the combined transit morphology, centroid stability, and absence of a secondary eclipse strongly support its planetary nature, full confirmation requires:

- high-resolution imaging,
- statistical validation (VESPA or TRICERATOPS),
- potential RV follow-up, though amplitudes are expected to be extremely small.

7. CONCLUSIONS

Our analysis supports TOI 864.01 as a strong sub-Earth USP planet candidate. Further follow-up and statistical validation are required to elevate the object to confirmed exoplanet status.

This work makes use of TESS data and the `Lightkurve` package (Lightkurve Collaboration et al. 2018).

REFERENCES

Kovács, G., Zucker, S., & Mazeh, T. 2002, Astronomy & Astrophysics, 391, 369, doi: 10.1051/0004-6361:20020802

Lightkurve Collaboration, Cardoso, J. V. d. M., Hedges, C., et al. 2018, Astrophysics Source Code Library

Sanchis-Ojeda, R., Rappaport, S., Winn, J. N., et al. 2014, The Astrophysical Journal, 787, doi: 10.1088/0004-637X/787/1/47

Stassun, K. G., Oelkers, R. J., Paegert, M., et al. 2019, The Astronomical Journal, 158, doi: 10.3847/1538-3881/ab3467