Evaluation of Exoplanet Validation Metrics for TESS Objects of Interest Using Light Curves

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ABSTRACT

This study presents a systematic evaluation of transit-based validation metrics for TESS Objects of Interest (TOIs) using photometric light curve analysis. The primary objective is to assess the reliability of identifying true exoplanet candidates using only transit data, without relying on resource intensive follow-up observations such as radial velocity measurements. Light curves obtained from the Transiting Exoplanet Survey Satellite (TESS) were processed using the Lightkurve package, with transit signals identified through the Box Least Squares algorithm. A set of validation metrics was applied, including transit signal-to-noise ratio (SNR), odd–even transit depth comparison, secondary eclipse search, and transit shape diagnostics. Derived parameters were compared with values from the ExoFOP repository to evaluate consistency. The methodology was benchmarked using known systems, including confirmed exoplanets and false positives, and further tested on a selected sample of TOIs. Out of the analyzed candidates, several exhibited strong planetary characteristics such as symmetric U-shaped transits, consistent depths, and absence of secondary eclipses, indicating high likelihood of being genuine planets. Conversely, a subset of candidates showed features typical of false positives, including V-shaped transits, depth variations, and short orbital periods. The results demonstrate that transit-based diagnostics, when combined with careful visual inspection, are effective in distinguishing likely exoplanets from false positives. This work highlights the potential of photometric only validation as a practical approach for prioritizing candidates in large scale surveys, particularly in the context of the growing number of TOIs and limited availability of follow-up resources.

1. INTRODUCTION

The **Transiting Exoplanet Survey Satellite (TESS)** has revolutionized exoplanet discovery by monitoring millions of stars for periodic transit signals. However, many detected TESS Objects of Interest (TOIs) are false positives caused by eclipsing binaries, stellar variability, or instrumental effects. Therefore efficient photometric validation is important to identify promising planet candidates before costly follow-up observations.

2. OBJECTIVE

This study evaluates the reliability of **transit-based validation metrics** using TESS light curves. The validation pipeline was first benchmarked against previously validated candidates from the TESS Triple-9 Catalog and then applied to selected TOIs to identify likely planetary candidates based only on photometric observations.

3. METHODOLOGY

TESS SPOC light curves were downloaded using the ***Lightkurve*** package and pre-processed through normalization, detrending, and outlier removal. Transit signals were detected using the **Box Least Squares (BLS)** algorithm, which provided estimates of orbital period, transit epoch, depth, and duration.

The detected signals were evaluated using four commonly used validation metrics:

- **Signal-to-Noise Ratio (SNR ≥ 7.3)**
- **Odd–Even Transit Depth Test**
- **Secondary Eclipse Test**
- **Transit Shape (U-shaped vs V-shaped)**

This pipeline was first applied to 100 candidates of TT9 Catalog to check the robustness and then applied to selected TOI candidates

Formulas Used

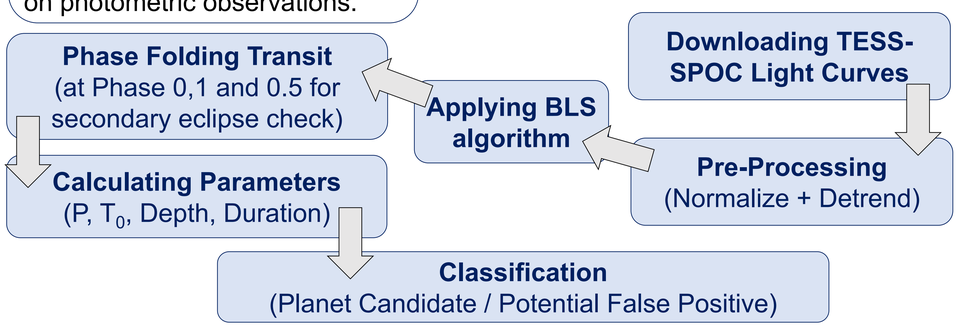
Radius of Planet:

$$R_p = R_* \sqrt{\delta}$$

Signal-to-Noise Ratio:

$$SNR = \frac{\rho}{\sigma} \sqrt{N_{tr}}.$$

Validation Pipeline



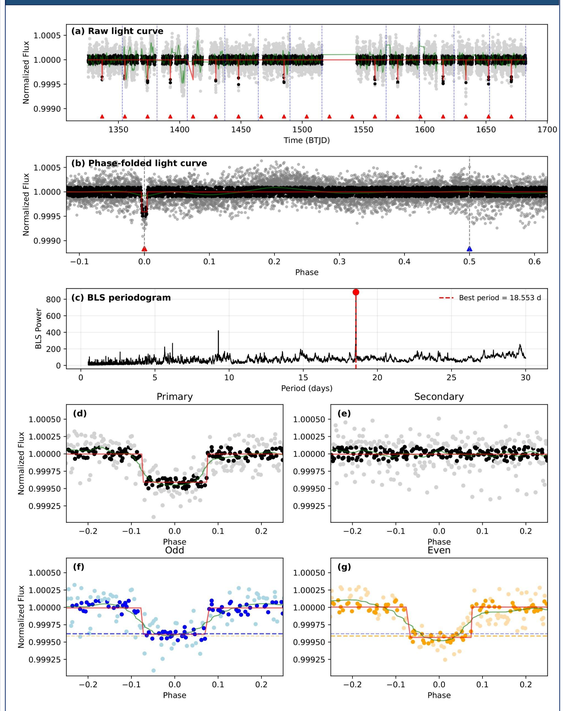
4. RESULTS & ANALYSIS

BENCHMARKING RESULTS

Parameter	Agreement Criterion	Recovery Rate
Orbital Period	< 1%	~ 95%
Epoch (BJD)	$\Delta t < 0.1$ day	~ 61%
Transit Duration	< 5%	~ 19%
Transit Depth	< 5%	~ 10-11%
Planet Radius (R_{jup})	< 5%	~ 35-37%

CANDIDATE ANALYSIS

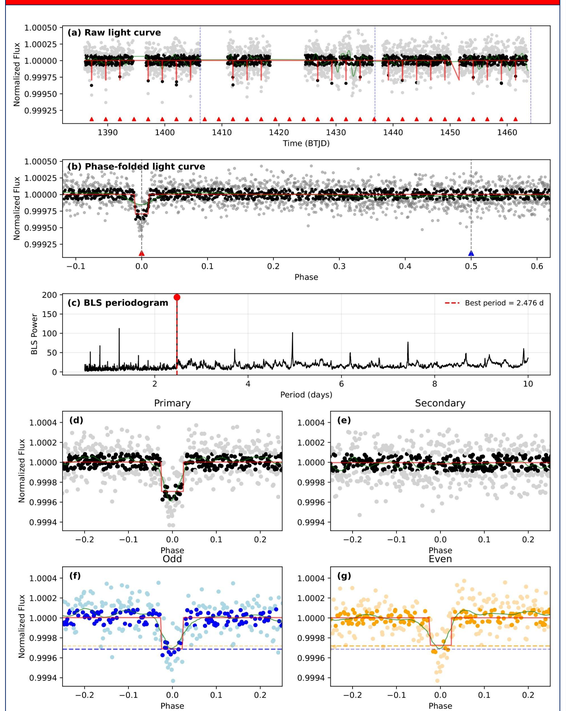
PLANET CANDIDATE: TOI-214



✓ U-Shaped Transit
✓ No Significant Secondary Depth
✓ Similar Odd-Even Depth

Classified as Planet Candidate

POTENTIAL FALSE POSITIVE: TOI-271



○ V-Shaped Transit
✓ No Significant Secondary Depth
✓ Similar Odd-Even Depth

Potential False-Positive

5. CONCLUSION

The validation pipeline achieved **~95% recovery of orbital periods**, confirming the reliability of BLS for detecting periodic transit signals. While shape dependent parameters showed greater uncertainty, combining **SNR, transit shape, odd–even depth, and secondary eclipse tests** allowed robust identification of likely planetary candidates. These results demonstrate that **photometric validation provides an efficient method for prioritizing TESS/ROMAN candidates for future follow-up observations.**

6. FUTURE SCOPE

- Bayesian validation using **TRICERATOPS** and **VESPA.**
- Machine learning for automated candidate classification.
- Application to larger TESS and future ROMAN candidates.

7. REFERENCES

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