# Physics-Informed Transit Diagnostics for Limited-Data Triage of TESS Planet Candidates

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## Introduction / Research Question

**Research Question:** Can physically interpretable TESS and Gaia catalog parameters improve the prioritization of TESS planet candidates before expensive follow-up observations?

**Introduction:** Thousands of TOIs are classified as PCs (Planet Candidates), showing transit-like signals but lacking enough evidence for confirmation. Existing validation often requires spectroscopy, high-resolution imaging, or additional telescope time, which are all expensive. This study tests whether public TESS and Gaia catalog parameters can provide an initial, physically interpretable prioritization step before these resource-intensive observations.

Here, Limited-data triage refers to ranking candidates using existing public catalog information before obtaining new observations.

## Research Methods

**Data Sources:** Catalog parameters were obtained from the NASA Exoplanet Archive TOI table, including TESS measurements and Gaia-derived stellar properties. Exo.MAST will be used for future light-curve analysis.

**Methodology:**
TOIs were grouped by TFOPWG disposition into CP, FP, and PC. Physical parameters, including orbital period, transit duration, transit depth, candidate radius, equilibrium temperature, stellar temperature, stellar radius, and surface gravity, were compared between CPs and FPs.

Distribution differences were evaluated using Mann-Whitney U and Kolmogorov-Smirnov tests. Correlation analysis examined relationships among parameters, while multivariate logistic models tested whether combining transit and host-star properties improved CP-FP discrimination. PCs were interpreted relative to the CP and FP reference populations for follow-up prioritization.

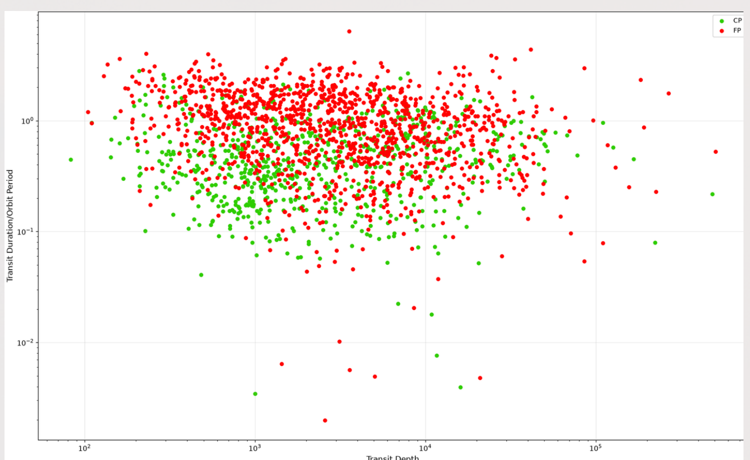
## Results/Interpretations

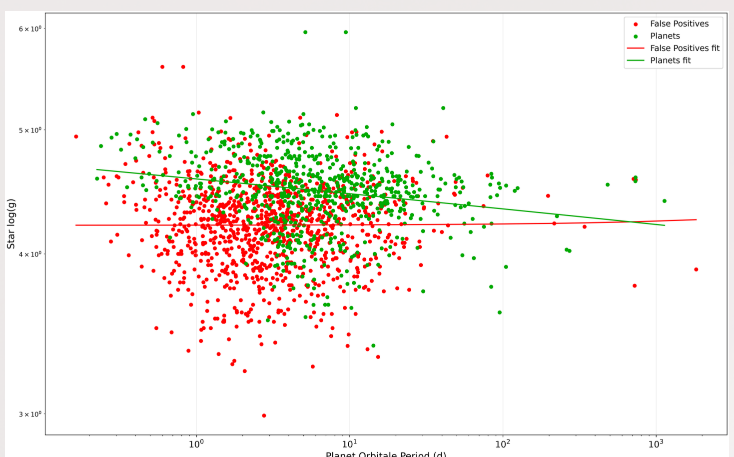
| Diagnostic | Confirmed | False positives | KS D |
|---|---|---|---|
| Candidate radius | 3.30 Earth radii | 9.90 Earth radii | 0.404 |
| Stellar radius | 0.864 solar radii | 1.516 solar radii | 0.426 |
| Stellar surface gravity | log g = 4.49 | log g = 4.23 | 0.397 |
| Stellar temperature | 5,271 K | 6,054 K | 0.369 |
| Orbital period | 5.65 days | 2.85 days | 0.316 |
| Transit duration | 2.52 hours | 2.59 hours | 0.069 |

**Results:**
Candidate radius showed one of the largest physically meaningful distribution difference between the confirmed and false positives among tested diagnostics (KS D = 0.404), while transit duration showed minimal separation (KS D = 0.069).

Also, confirmed planets generally had smaller inferred radii and orbited smaller, cooler, higher-surface-gravity stars than false positives. They also had longer orbital periods on average. Candidate radius and host-star properties showed the clearest physical differences, while transit duration was nearly identical between the two groups.

**Interpretation:**
The larger inferred radii among false positives are consistent with eclipsing stars or blended binary systems being mistaken for planetary transits. The stellar-radius and surface-gravity differences suggest that false positives occur more frequently around larger or more evolved stars. However, the two populations still overlap, so no single parameter provides reliable classification.





**Left:** Transit Depth plotted against the transit duration divided by orbital period. Confirmed planets and false positives overlap substantially.

**Right:** Orbital period plotted against the host star's log g. A visible discrepancy is present between false positives and planets.

## Case Study: TOI 5282.01

| Diagnostic | TOI 5282.01 | CP median | FP median | Interpretation |
|---|---|---|---|---|
| Candidate radius ($R_\oplus$) | 9.78 | 3.30 | 9.90 | Near FP median |
| Stellar radius ($R_\odot$) | 1.45 | 0.864 | 1.516 | Near FP median |
| Stellar surface gravity (log g) | 4.17 | 4.49 | 4.23 | FP-leaning |
| Stellar temperature (K) | 6,082 | 5,271 | 6,054 | Near FP median |
| Transit depth (ppm) | 4,390 | 1,984 | 2,860 | FP-leaning |
| Orbital period (days) | 1.39 | 5.65 | 2.85 | FP-leaning |
| Transit duration (hours) | 1.21 | 2.52 | 2.59 | --- |

Several properties of TOI 5282.01 are closer to the false-positive reference population, although a hot-Jupiter interpretation remains physically plausible. Its candidate radius, stellar radius, surface gravity, temperature, and short orbital period are closer to the false-positive reference population than to confirmed planets. However, a radius of 9.78 Earth radii remains physically consistent with a close-orbiting giant planet, so these parameters cannot determine its disposition alone. TOI 5282.01 therefore demonstrates the value of limited-data triage: it should be prioritized for phase-folded light-curve analysis, including odd-even transit comparison, transit-shape inspection, a secondary-eclipse search, and contamination checks. Exo.MAST provides TESS Data Validation time series and phase-folded and odd-even plots for these tests.

TOI 5282.01 demonstrates how physics-informed catalog diagnostics can identify candidates whose follow-up priority differs from what would be inferred from the simple planet-candidate label alone.

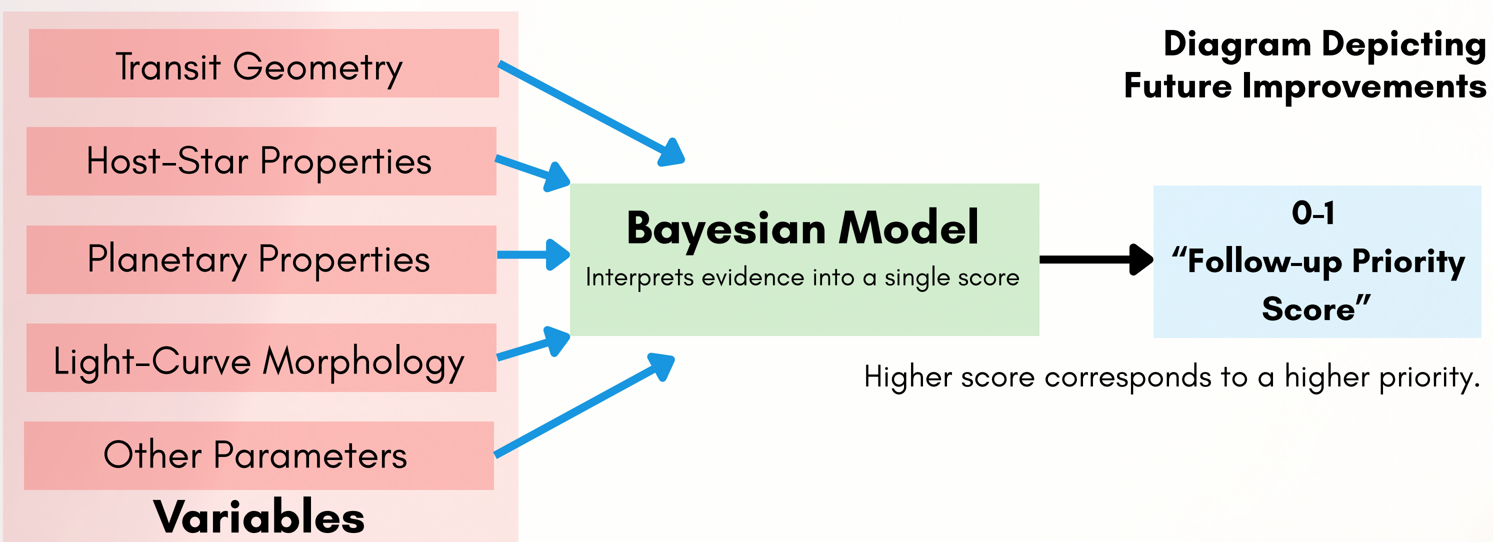
## Conclusion

- Candidate radius and host-star properties showed meaningful distributional differences between confirmed planets and false positives.
- Transit duration alone provides almost no useful discrimination.
- Combining several physical parameters can support follow-up prioritization, but cannot independently confirm a planet.

## Limitations and Extensions

**Limitations:**
- Catalog parameters do not describe transit shape, ingress/egress asymmetry, odd-even differences, or secondary eclipses.
- Stellar variability, including periodicity and RMS scatter, was not measured directly.
- Several parameters are correlated and may not provide independent evidence.
- The current analysis distinguishes known groups, but has not yet been validated on unseen candidates.

**Extensions:**
- Add transit-shape and ingress/egress diagnostics from TESS light curves.
- Measure stellar variability using periodicity, Fourier features, and RMS scatter.
- Combine transit geometry, host-star properties, and stellar stability in a Bayesian reliability score.
- Validate the score on unresolved candidates whose classifications are later updated.




## References

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