Analyzing FFIs to Identify False Positives within TESS Candidates

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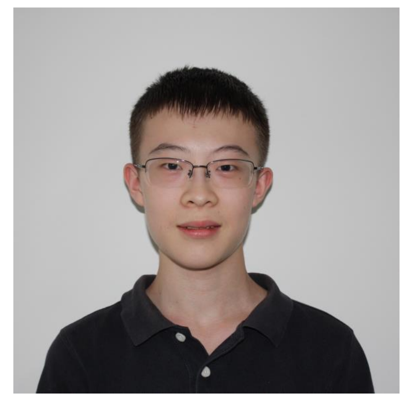

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Abstract

TESS pixels are large and numerous faint stars are often blended in the r ~ 3-pixel Quick-Look Pipeline apertures. Nearby eclipsing binaries (NEBs) blended in these apertures create eclipses that often masquerade as transiting planet signals. QLP in-transit to out-of-transit centroid analysis is often not provided as part of the data validation reports, and sometimes when provided, is not conclusive. An alternate method of detecting NEBs is to extract light curves from FFIs using small 1-pixel apertures placed at the known locations of Gaia stars near the target.

Significance

- Benefits of using FFIs to eliminate NEBs before follow-up:
  - Avoids wasting observing resources on NEBs
  - Increases percentage of follow-up data that is published
- NEBs account for 50% of all TESS false positives
  - Potential for significant impact

Our Sample

- 34 planet candidates (PCs) that had yet to be followed-up
- Quick-Look Pipeline TOIs
- Data validation reports show signs of NEBs
  - Centroid offsets
  - Depth-aperture correlation
  - Secondary transits (for small candidates)

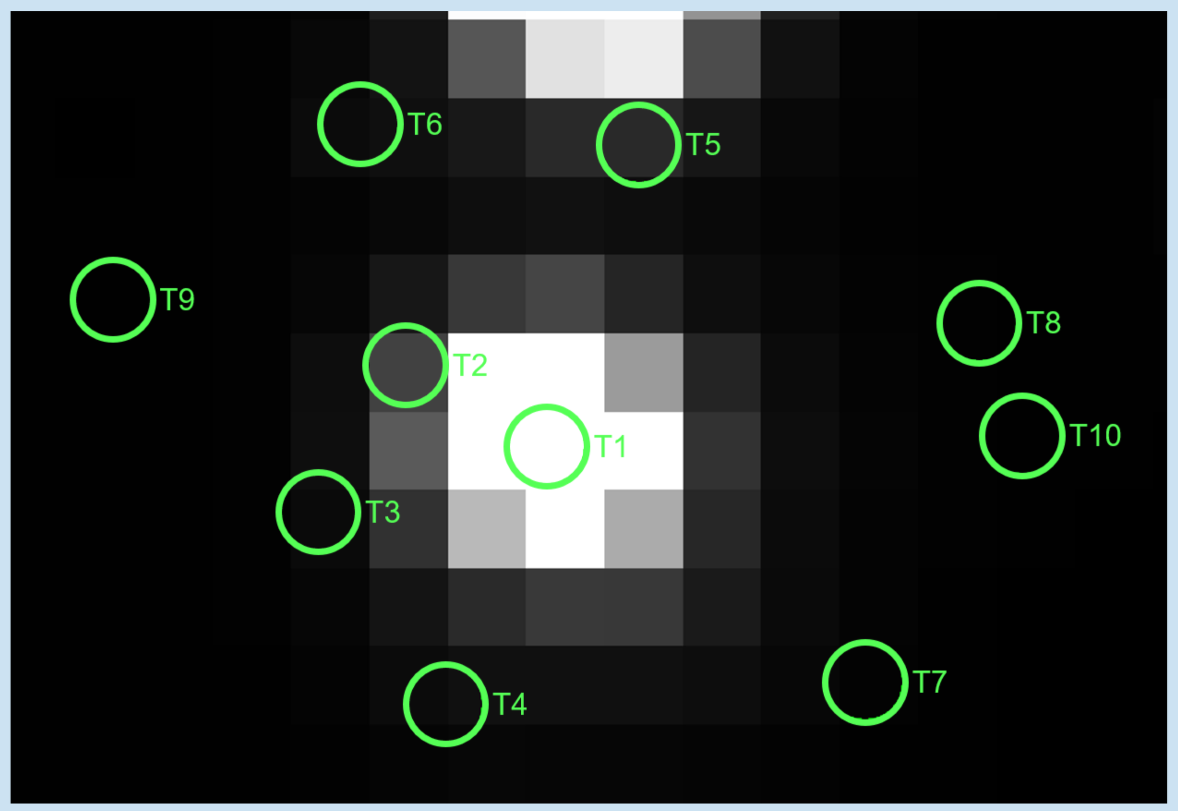
TOI IDs

1538	**1625**	2162	2332	**2468**
1542	1792	2163	2333	2496
1585	**1950**	2172	2394	2515
1594	**2029**	2183	2417	2516
1602	**2118**	2229	2430	2532
1604	**2150**	2326	2432	2538
1613	2153	2331	2448	

In bold: retired as NEBs as a direct result of our work

Our Method

1. Photometry with AstroImageJ
   - Phase light curves using released T0 and period values
   - Search for events in stars within 2.5′ of target star



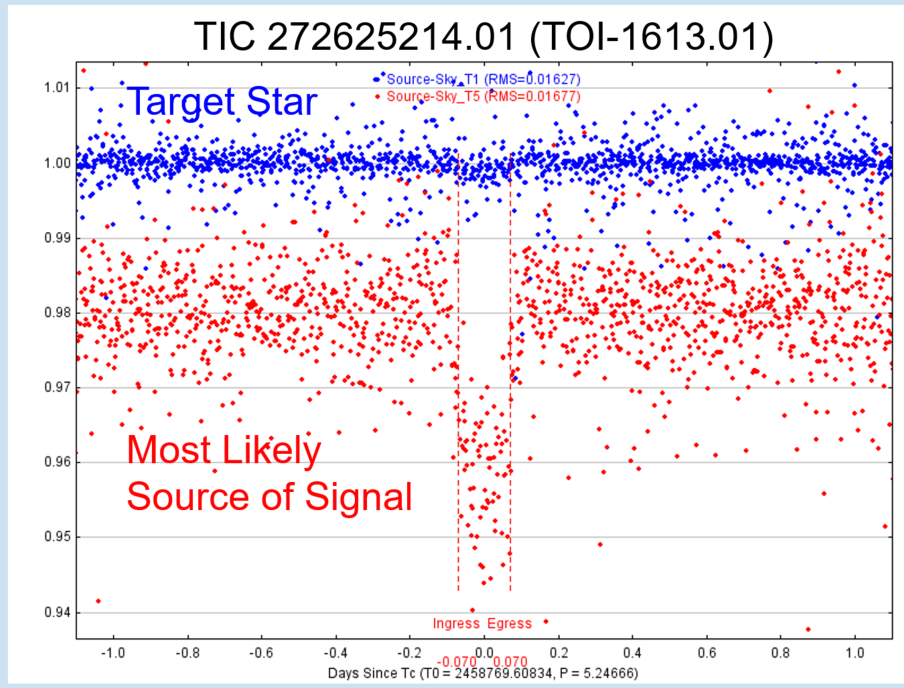
TOI 2118 (labeled as T1) and 9 closest Gaia neighbors

2. Signals detected by TESS: on- or off-target?
   - Null hypothesis: on-target
   - Criteria for rejecting null hypothesis:
     - Transit ruled out on target (rare)

       and/or

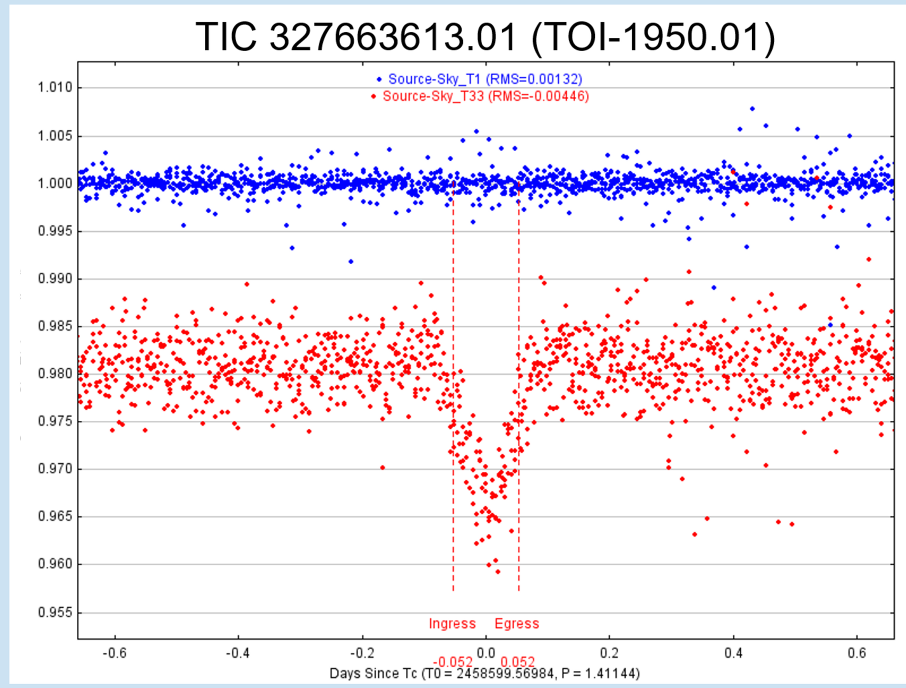
     - Signal is stronger on neighboring star(s) (common)

- Multiple off-target signals are due to blending and should be found in the same vicinity
- Off-target examples:



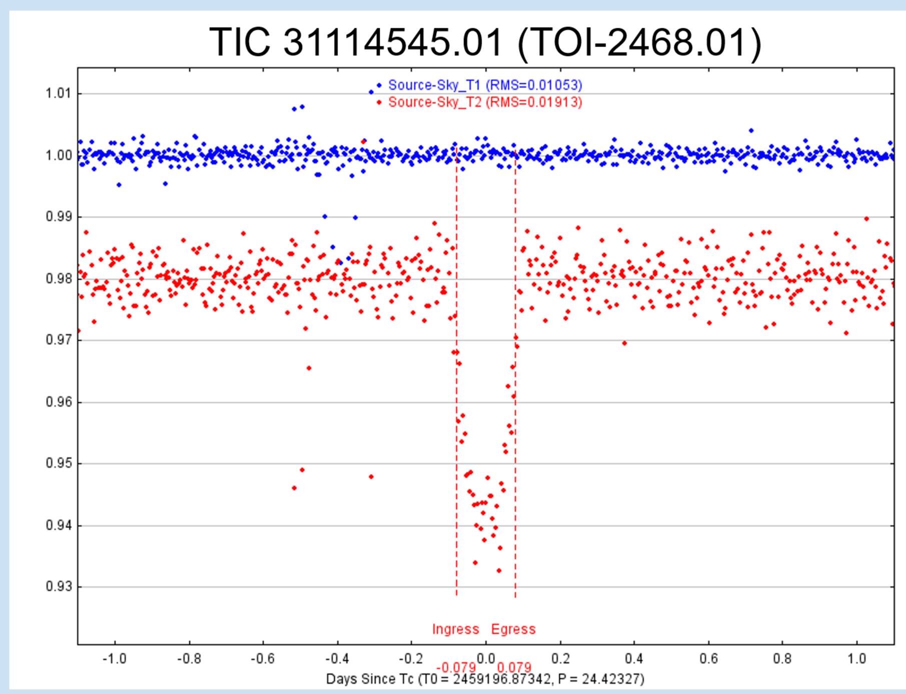
Target-NEB Separation: 23.1″

Expected transit of 1.600 ppt is seen on target… but a deeper event is seen on T5



Separation: 56.8″

Expected 0.414 ppt transit cannot be ruled out… but there is a strong signal on T33



Separation: 47.7″

A 1.920 ppt transit is ruled out on target… and T2 exhibits a deep event

3. Off-target companion: star or planet?
   - Find ΔT-mag of the likely source(s)
   - Calculate the transit/eclipse depth for each source:

$$Depth_{source} = Depth_{TOI} * 10^{\Delta T/2.5}$$

   - Calculate companion size:

$$R_C = \sqrt{Depth_{source} * R^2_{source}}$$

   - Compare with substellar radius limit (roughly 25 R_E)
     - Larger → NEB
     - Smaller → Nearby PC

Results

- 10 NEBs found
  - 29% of original sample
  - ~30 hours of telescope time saved
- 1 NPC
- FFI analysis effective for identifying NEBs with separations of ~20″ or more

Further Work

- We are currently developing a tool that will automate much of this process
  - Will increase efficiency by an estimated factor of 6
  - To be used on hundreds of TOIs

TESS Science Conference II

Aug 2 - 6 2021, Online