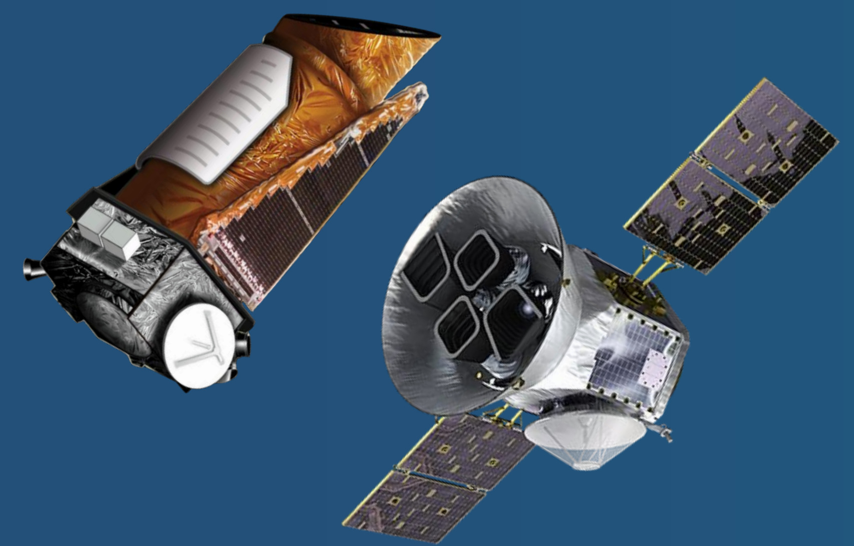

A Tale of Two Telescopes: Identifying Kepler False Positives Using TESS Data

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Introduction

There are many planet candidates identified by Kepler and TESS space telescopes that have yet to be confirmed as planets or false positives. False positives are signals that look like there is an exoplanet orbiting a star, but the exoplanet does not actually exist. There are many causes behind false positives. One common cause is background eclipsing binary stars. These eclipsing binaries emit enough light to contaminate the data of nearby stars, making it seem like there is an orbiting exoplanet. Another cause behind false positives are detector artifacts like column anomaly and image crosstalk. These technical problems causes smearing and pixel bleeding which can contaminate many stars with false positive signals.

Having false positives in the catalogs of real planets damages the integrity of these lists. It is important that we identify these false positives and remove them from the sample of possible planets. This way, we boost our confidence in the surviving signals.

In order to investigate possible false positives, we use a method called ephemeris matching. To do this, we combine data collected by TESS and Kepler space telescopes to create light curves from many unrelated stars that are close to each other. From these light curves, we can find the orbital period of exoplanet candidates and eclipsing binaries. However, if multiple light curves show the same period, then the exoplanet in question is likely a false positive. This is because it is very unlikely that two different and unrelated stars would give the same exact orbital period.

We need data collected by TESS in addition to Kepler, because Kepler only collects data from specific pixels (see figure A for an example). However, TESS takes full frame images every 30 minutes. By combining both data sets, we can confirm or rule out more planets than either would by itself.

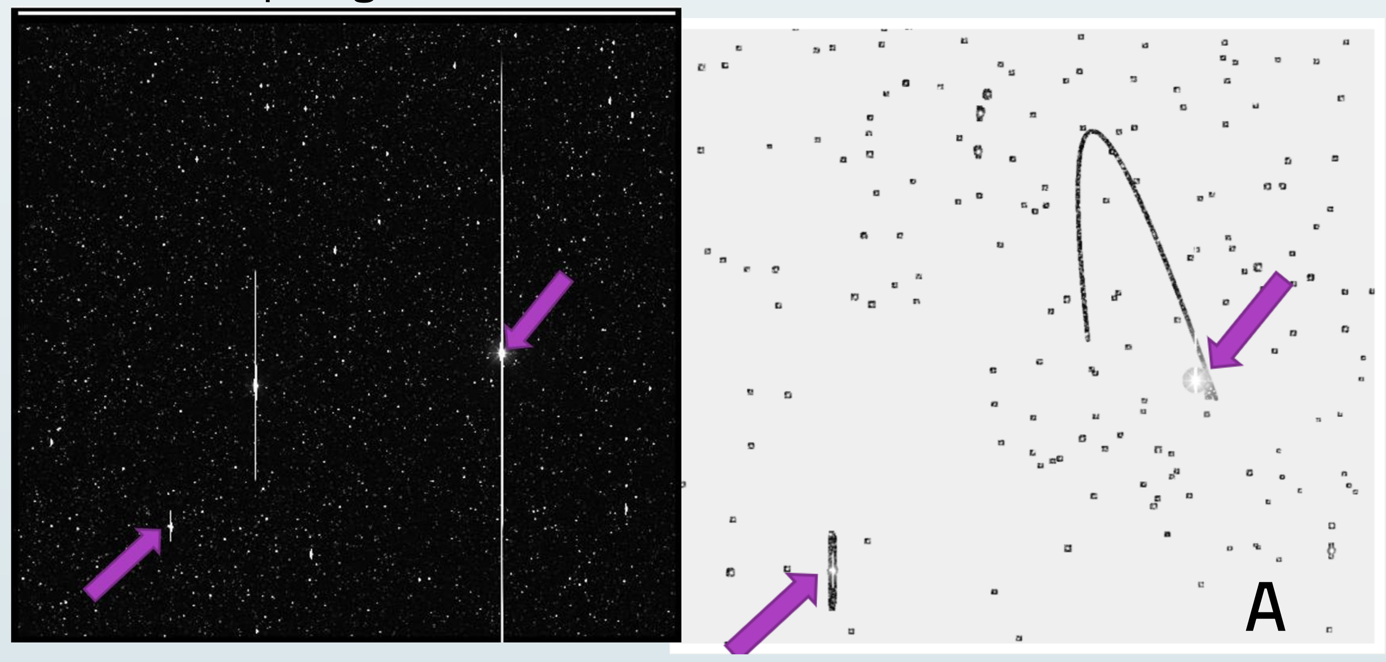
Approach

Our first step is to write code that plots the light curves of stars from both Kepler and TESS that are close to each other and line up the orbital periods of the potential exoplanets. This is so we can see what a single false positive looks like in a plot. We show an example of this in figure B.

Our second step is to write code that searches for ephemeris matches using the procedure provided by Coughlin et al. (2014). We will test this code on Kepler data, to work out any bugs we find with incorporating TESS data.

Our next step is taking a sample of eclipsing binaries from TESS to compare and match to Kepler planet candidates. We can reuse the code from our initial test with only Kepler data and rewrite it to incorporate a sample of TESS data.

Our last step is matching all planet candidates from Kepler with all eclipsing binaries from TESS for final results.

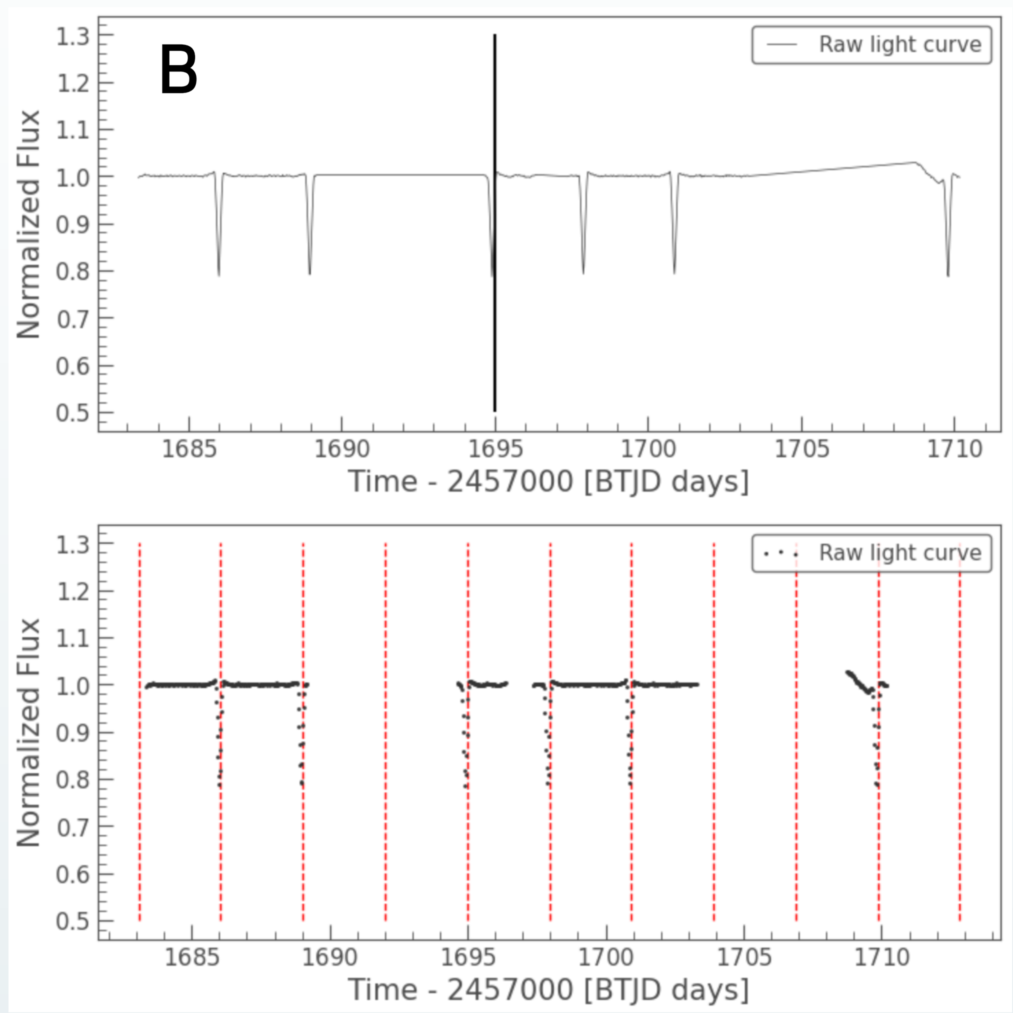


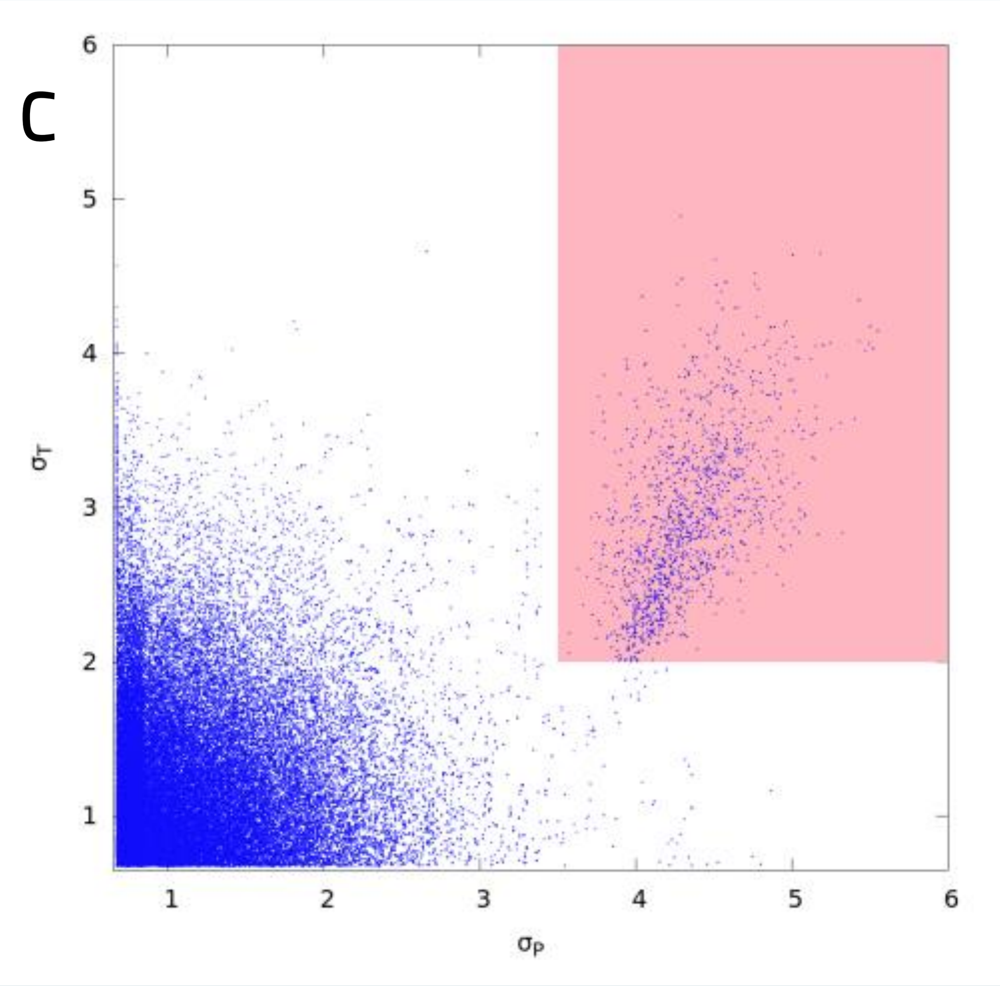
Above on the left is a Kepler full frame image. On the right is the partial data that is downloaded from Kepler. TESS can provide us with full frame images at least every 30 minutes and observe the stars Kepler missed, which is why we want to use both TESS and Kepler images.

Current Results

So far, we've written code to plot the light curve of a star and line up the orbital period of the potential exoplanet with the dips of light. We've confirmed that this works by testing known false positives.
On the right, we show an example of finding the light curve and matching the orbital period from another star close by. Because the lines line up with the dips, this is most likely a false positive.

We have also recreated a plot by Coughlin et al. (2014) in which we match Kepler Objects of Interest to themselves. In these plots, sigma P is the closeness in period, and sigma T is the closeness in the time of transit. The red box in the Coughlin plot "...corresponds to significant, real, physically caused matches" (Coughlin et al. , 2014). These matches are likely false positives.





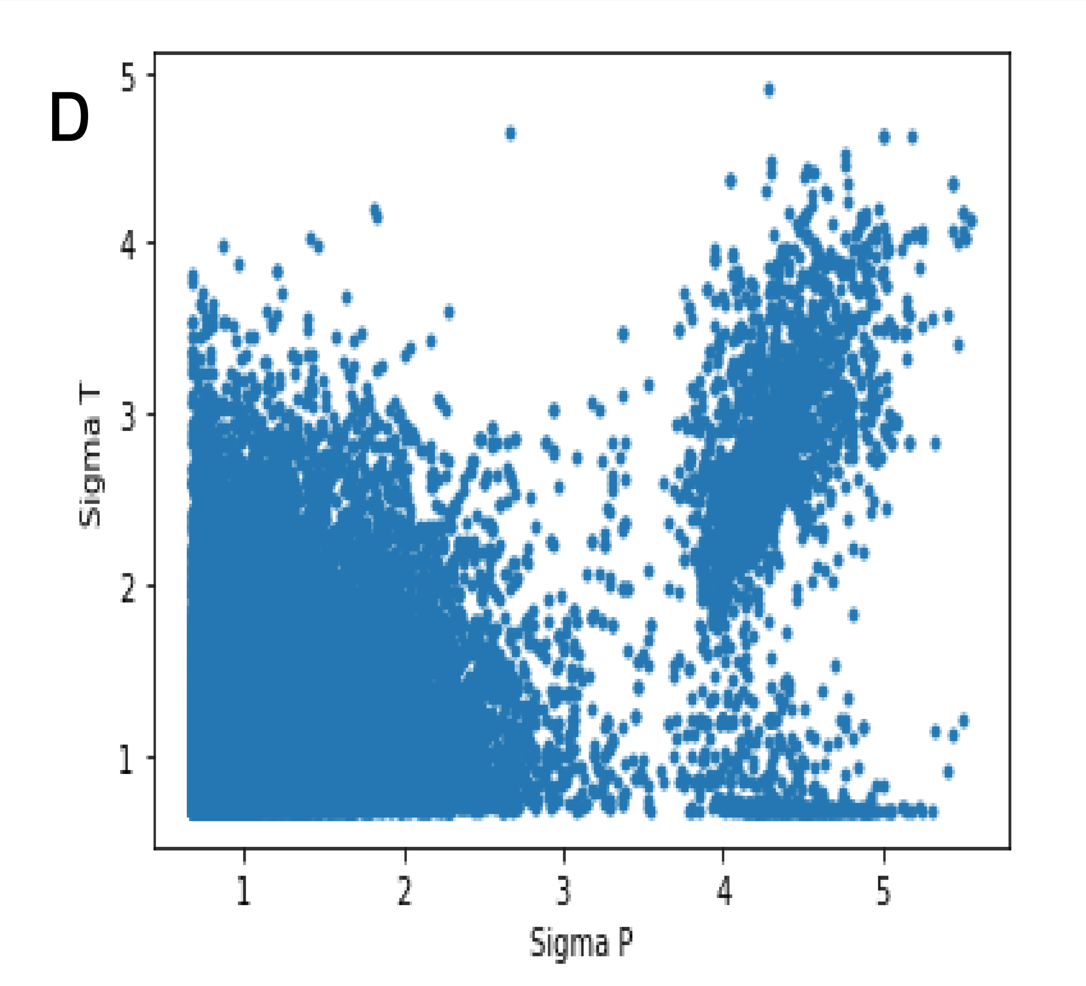


Figure C is Coughlin et al. (2014)'s plot and figure D is our recreation. This shows us that our code is successful in matching Kepler data. Now that we know our code works, we can move onto incorporating TESS data into the code.

Next Steps and Conclusion

We are currently working on incorporating TESS data into our code so we can use a sample of TESS data to search for Kepler matches.
Michelle Kunimoto and Chelsea Huang have kindly provided a list of eclipsing binaries detected by TESS in the Kepler field which we are using to match against Kepler planet candidates.

Once we've completed this work, we can be more confident in the surviving planets.

Acknowledgements

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I'd especially like to thank Andrew Vanderburg. Even if we don't find any false positives, the real false positives were the friends we made along the way. Or something like that!

References - Coughlin, J. L., Thompson, S. E., Bryson, S. T., et al. 2014, The Astronomical Journal, 147, 119