Characterizing Exoplanets across the Radius Valley using Data from NASA's TESS Mission.

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Background

Abstract

Since its launch, the Transiting Exoplanet Survey Satellite (TESS) has detected over 7000 exoplanet candidates, yet only ~700 have been confirmed as planets. In our work, we investigate a sample of 13 exoplanet candidates spanning the Radius Valley to identify important planetary parameters using a custom pipeline that we have developed.

Radius Valley

The Radius Valley is a range of Radii with a lower abundance rate of Exoplanet detections. The Valley spans from 1.5 Earth Radii, to ~2.0 Earth Radii, and blurs the line between Super-Earth and Sub-Neptune exoplanets. Multiple theories explaining the Radius Valley are still under investigation, including mechanisms such as Photoevaporation from young host stars as well as Core Powered Mass-Loss. **Fig 1** highlights the Radius Valley and our sample of 13 targets.

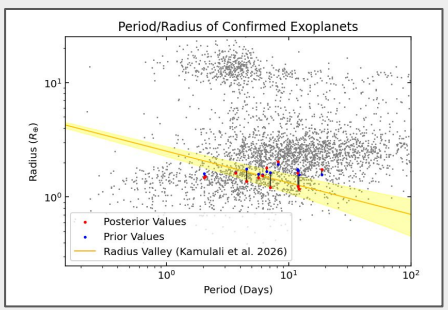


Fig 1: The Orbital Period and Radii of all confirmed Exoplanets. The Radius Valley lies within the yellow region. Our 13 targets are highlighted with red dots representing the posterior values we found in our analysis.

Modeling

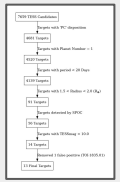


Fig 2: Our Target Selection from all available TESS Planet Candidates

Data

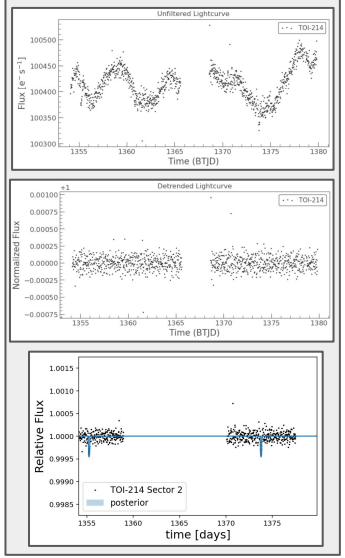
Using the ***Lightkurve*** Python tool, we download the raw TESS data of each target from the MAST Archive. The data has to be processed before it is modeled, which involves flattening out any long-term trends using a Savitzky-Golay filter with a window:transit ratio of 4 for all targets. Excess data points are trimmed off of the flattened light curve. Our MCMC modeling process using the ***PyMC*** tool, and samples our processed data to find the best fits for the measured parameters.

Parameters

Our MCMC modeling pipeline samples raw data of each target to detect the following parameters:

- ***Orbital Period***
- ***Planet Radius***
- ***Mid-Transit Time***
- ***Impact Parameter***
  - How far from the center of the host star does the planet transit
- ***Limb Darkening Coefficients***
  - How much darker the edge of the host star is from its center

Fig 3: The three panels show the steps we take to prepare our data for analysis. First, the raw data is downloaded. Then, it is flattened with a Savitzky-Golay filter, removing long term trends. Finally, unnecessary data is trimmed and the final light curve is modeled with an MCMC sampler.



Results

Posteriors

We find convincing transits for 11 of our 13 targets, as shown in **Fig 4**. Our average error of our posterior radius values from the expected values from **ExoFOP** is **14.889%**.

The Gelman-Rubin statistic for all our measured parameters across all targets is < 1.01, meaning our modeling process was well converged for our entire sample.

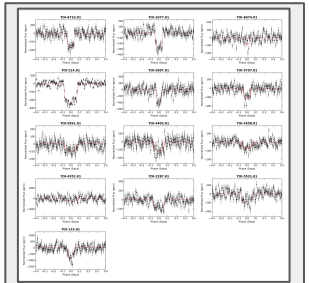
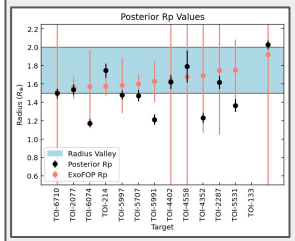


Fig 4: The final folded transit plots of our 13 targets using binned data.

We do not find a convincing transit for TOI-6074.01 or TOI-4558.01

Fig 5: The red dots represent the preliminary radii reported by TESS. The black dots represent the posterior radii values we found with our modeling.



Future Work

In our work, we aim to constrain planetary parameters of a sample of planet candidates that fall within the Radius Valley, expanding the range of planets we can learn more from in our investigation of the Valley. We are preparing a paper outlining my results to be submitted to a peer reviewed journal for publication.

Statistical validation is an essential step in Exoplanetary Astronomy. we aim to confirm/deny the existence of these candidates using the ***TRICERATOPS*** Python tool. By learning more about these candidates and others like them, we can learn more about what makes the Radius Valley unique, and what that might mean for planetary formation.