

# Using TESS to Unearth the Frequency of Habitable Zone Earth-size Planets

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## ABSTRACT

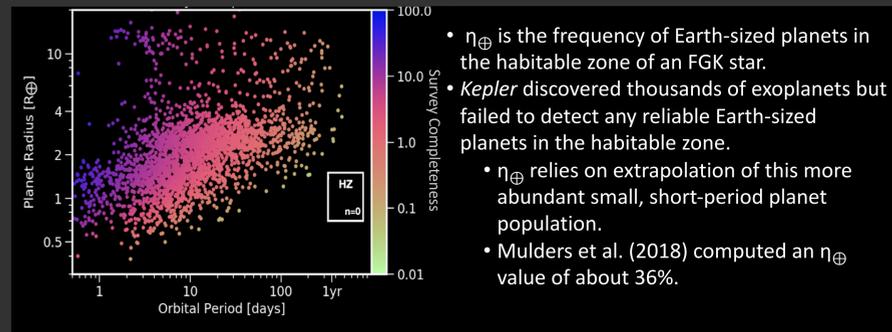
While *Kepler* discovered a large number of exoplanets close to their star, the lower detectability toward small planet radii and large orbital periods resulted in the detection of just one Earth-size planet in the habitable zone of a solar analogue. Hence, determining the frequency of habitable zone Earth-size planets, hereafter  $\eta_{\oplus}$ , requires extrapolations based on the more abundant population of close-in, small planets. However, it is known that this population is contaminated by stripped cores of once sub-Neptune planets. Here, we show that when considering only planets beyond 30 days, where stripping mechanisms become inefficient, the value of  $\eta_{\oplus}$  drops from 40% to ~5-10%. Thus, quantifying the contamination of sub-Neptunes to the small, close-in planets becomes crucial to obtain a more reliable  $\eta_{\oplus}$  estimate. One way to quantify this contamination is by measuring the occurrence of primordial sub-Neptunes in young clusters (<1 Gyr), before their envelope is stripped away. We will present our ongoing effort with TESS to de-contaminate the short-period small planet population from photoevaporated mini-Neptunes and thus provide more reliable estimates of  $\eta_{\oplus}$ .

## CONTACT



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## The $\eta_{\oplus}$ Problem



Thompson et al. 2017 using Kepler dr25

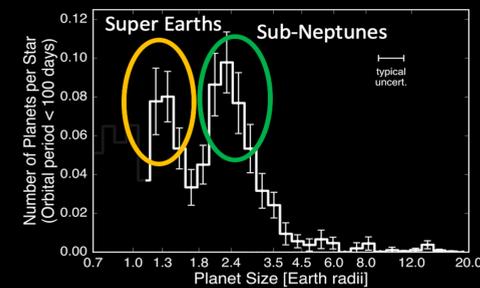
- Population of small planets is contaminated by planets that didn't really form like Earth.
- Planets that initially formed as sub-Neptunes could have been stripped off their atmospheres → mimic Earth-sized planets.

- The "Radius Valley" (Fulton et al. 2017)

- Bimodal distribution → super-Earths and sub-Neptunes.

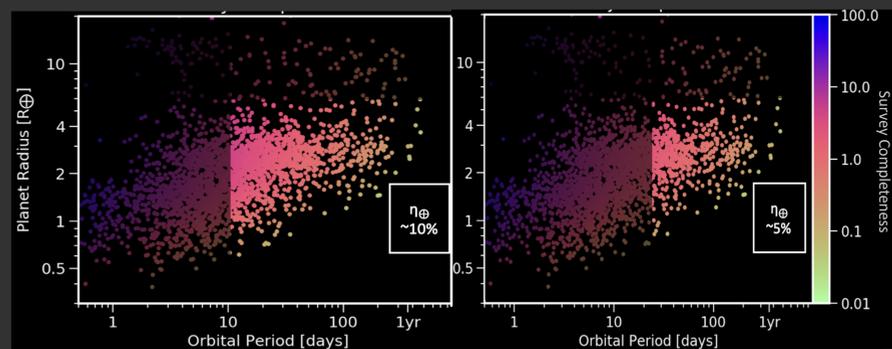
- Evolutionary:

- XUV photoevaporation (Owen & Wu 2013, 2017).
- Core-powered mass loss (Gupta & Schlichting 2019, 2020).



Fulton et al. 2017

- Pascucci et al. (2019) → impact of close-in stripped cores on  $\eta_{\oplus}$ 
  - beyond 10 days,  $\eta_{\oplus}$  → 10%.
  - beyond 25 days,  $\eta_{\oplus}$  → 5%.

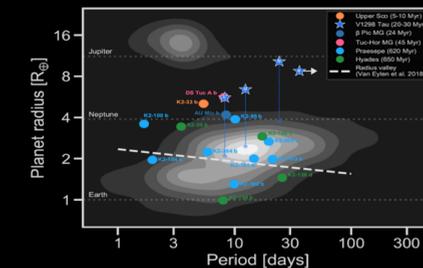


Pascucci et al. 2019 using Kepler dr25

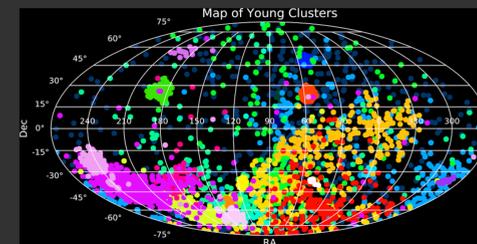
## The Solution: Young Clusters with TESS

- Transiting Exoplanet Sky Satellite (TESS)

- Detect sub-Neptunes in young clusters → closer to primordial population; before losing atmosphere.
- Young planets detected so far → populate the gaps in the *Kepler* distribution.



David, T. et al. 2019



- Sample of 8000 stars
  - 30 young clusters and moving groups
  - 10 Myr - 1 Gyr
  - within 200 pc.

## pterodactyls

- Young stars are highly variable → notoriously hard to detrend
- pterodactyls is customized to detect planets in young clusters using TESS Full Frame Images
  - Able to detrend fast rotating stars
  - Computes the amount of flux contributed by the star → contamination estimate

## pterodactyls

Python Tool for Exoplanets: Really Outstanding Detection and Assessment of Close-in Transits around Young Local Stars

Extract Light Curves from Full Frame Images using eleanor (Feinstein+ 2019)

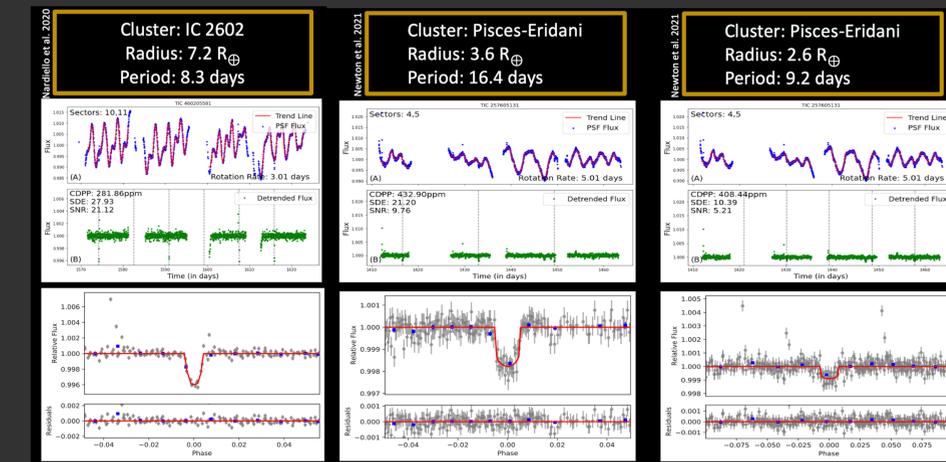
Detrend Light Curves using a penalized spline from Wotan (Hippke+ 2019)

Search for Planets using TLS (Hippke+Heller 2019)

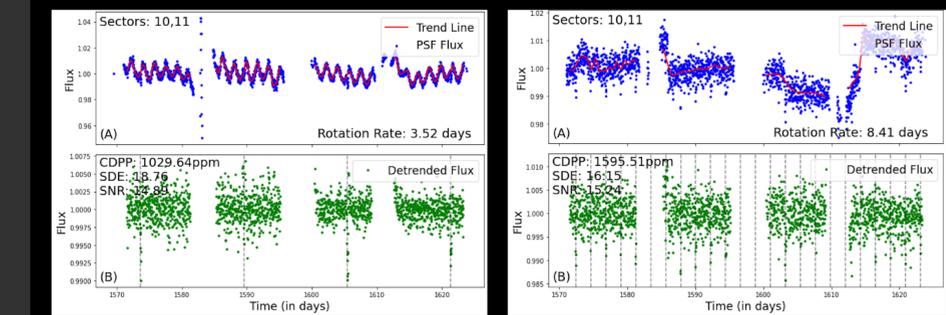
Vet exoplanet candidates using triceratops (Giacalone et al. 2020)

Fit phase-folded light curve using EXOTIC (Zellem et al. 2020)

## Recovery of Known & Multi-Planet Systems



## New Detections



- Summary:

- Many of the short-period Earth-sized planets might be the stripped cores of once sub-Neptunian planets. An extrapolation of this population to the HZ leads to an overestimation of  $\eta_{\oplus}$ .
- By measuring the occurrence of yet unstripped short-period sub-Neptunes in young (<1 Gyr) stellar clusters with TESS, we can quantify the contamination of stripped cores in the short-period planet population.

- Next steps:

- Search and vet planet candidates in entire sample.
- Community follow-up of planet candidates.
- Uniform characterization of stars in young clusters.
- Measure occurrence of young super-Earths and sub-Neptunes.