The Eccentricity Distribution, Occurrence Rates, and Companions of *TESS* Warm Jupiters

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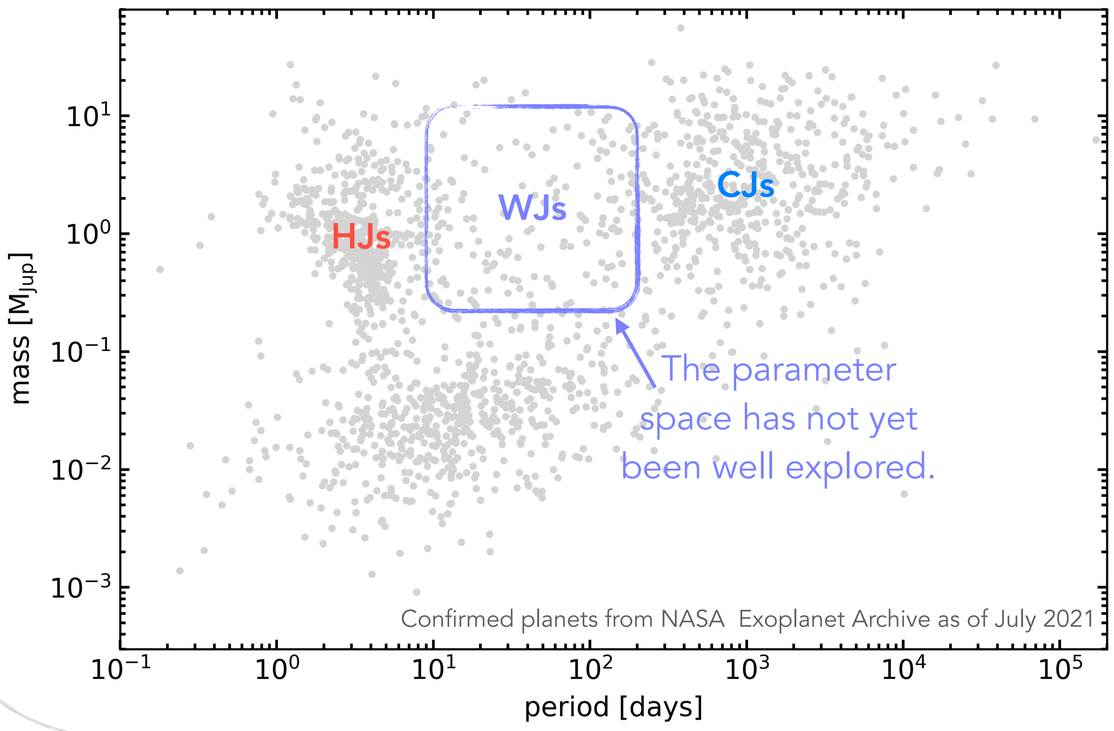
Warm Jupiters are a key missing piece in our planet formation and evolution theory.



Warm Jupiters versus Hot Jupiters

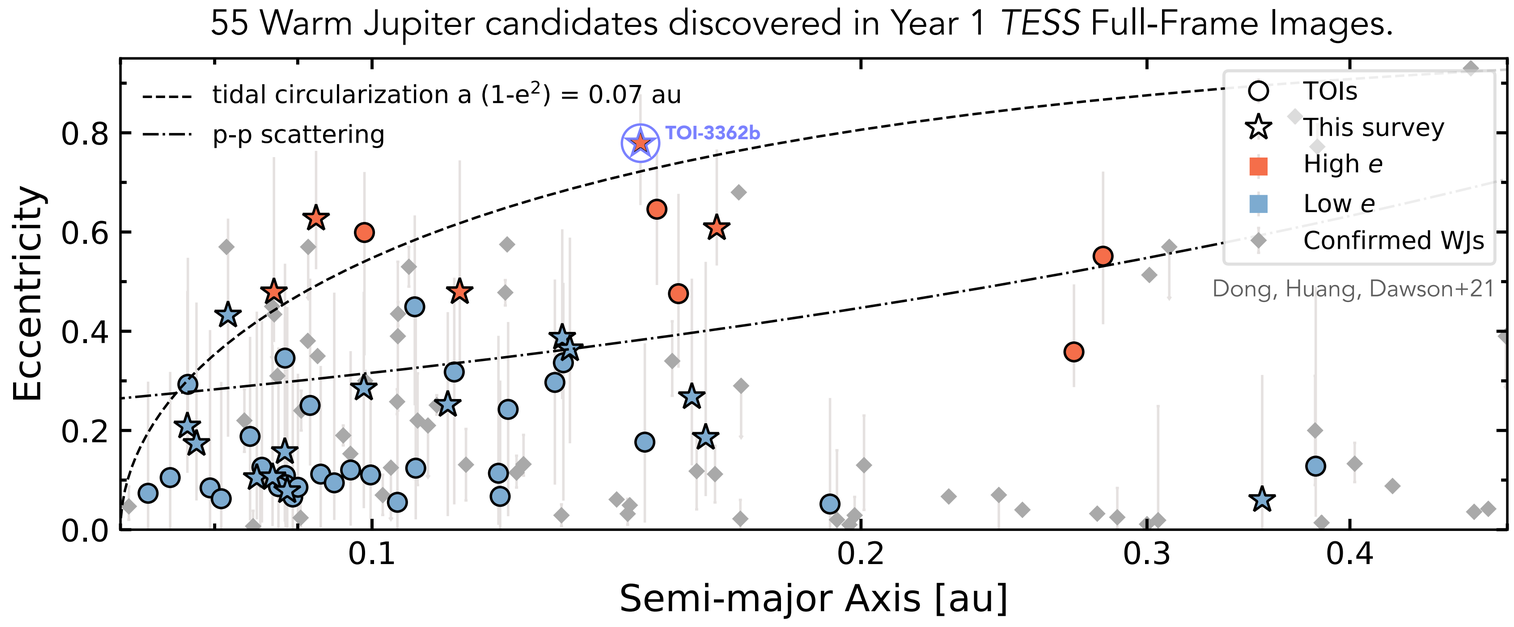
- Warm Jupiters are close-in giant planets with orbital periods (P ∈ 8–200 days) slightly longer than Hot Jupiters (P < 8 days).
- Warm Jupiters have a smaller sample size (~150) than Hot Jupiter (~450) since they are less favored to be detected by transit surveys (orbital period ↑ transit probability ↓).
- Similar to Hot Jupiters, it is unclear whether Warm Jupiters are formed in situ, or via disk or high-eccentricity tidal migration (see Dawson & Johnson18 for a review).

TESS is discovering a large sample of Warm Jupiters in its Full-Frame Images!

Warm Jupiters in *TESS* Full-Frame Images

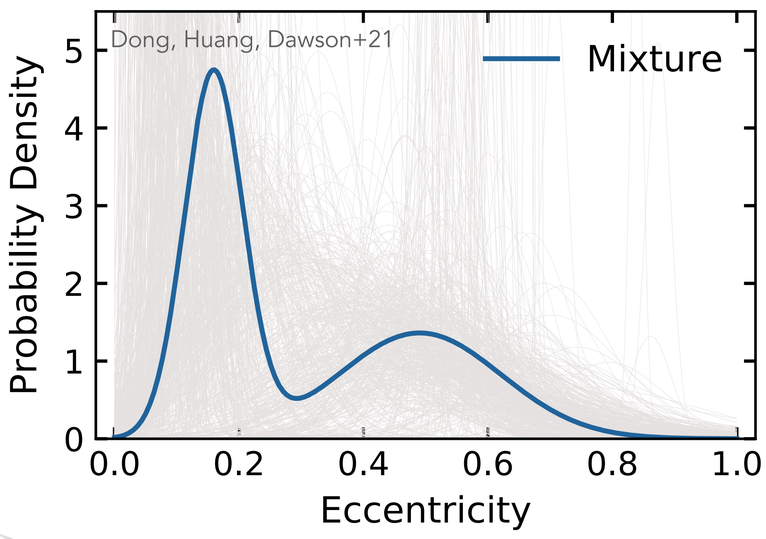
- In Dong, Huang, Dawson+21, we systematically searched for Warm Jupiters in Year 1 *TESS* FFIs and introduced a catalog of 55 candidates.
- We further validate the catalog using photometry and spectroscopy in collaboration with TFOP SG1/2 groups. The validated catalog allows a full statistical study.
- Eccentricities tell about the dynamical history of Warm Jupiters. We highlight a confirmed, super-eccentric proto-Hot Jupiter TOI-3362b that is likely undergoing high-eccentricity tidal migration (Dong, Huang, Zhou+submitted).

55 Warm Jupiter candidates discovered in Year 1 *TESS* Full-Frame Images.



In situ formation: eccentricities are limited by the planet-planet scattering (below the dotted–dashed line)
High-eccentricity tidal migration: expecting eccentricities high enough to allow tidal circularization (above the dashed line)
Disk migration: expecting low/moderate eccentricity from a smooth disk migration

Understand *TESS* Warm Jupiter as a Population.



Statistical Study on *TESS* Warm Jupiters

- With the sample of Warm Jupiter candidates, we conduct preliminary study on the eccentricity distribution of *TESS* Warm Jupiters using hierarchical Bayesian modeling (Dong, Huang, Dawson+21).
- The mixture model of the eccentricity distribution suggests about half of *TESS* Warm Jupiters have moderately eccentric orbits (e > 0.3).
- Now with the fully validated catalog (42/55 planets, 13/55 false positives), we are able to update the eccentricity distribution and infer the occurrence rates. Stay tune for the results!

What *TESS* teaches us about Warm Jupiter origins?

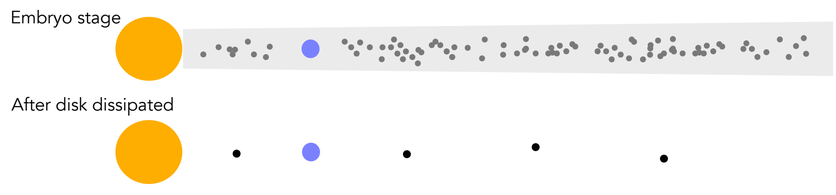
***TESS* Warm Jupiters on Extreme Orbits**

- *TESS* discovered a group of Warm Jupiters on highly elliptical orbits (e.g., TOI-3362b), shedding light on the high-eccentricity tidal migration origin of Warm Jupiters.
- Spin-orbit angle measurements will help to better reveal their dynamical history.
- Comparing the expected number of super eccentric *TESS* Warm Jupiters to the actual number observed is critical to tell the prevalence of the high-eccentricity tidal migration.

***TESS* Warm Jupiters with Nearby Companions**

- A group of *TESS* Warm Jupiters are discovered with nearby companions (e.g., TOI-216, TOI-1130), which could be an outcome of in situ formation, disk migration, or mixed.
- *N*-body simulations at the planetary embryo stage predict different system architecture on these two origins. Preliminary simulation results are available. Feel free to reach out with any questions/comments (jdong@psu.edu or see you in Gather.Town)!

In situ formation



Disk migration

Disk migration may facilitate the formation of inner companions.
The nearby pair may or may not get captured into orbital resonances. Our preliminary N-body simulations suggest the capturing depends on the migration rate and disk dissipation rate.
Disk migration allows no nearby outer companion, whereas **in situ formation** allows so.