TOI-4468 and the Emerging Trends in Systems Hosting Hot Jupiters with Nearby Companion Planets

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The TOI-4468 discovery effort is led by Joseph Livesey

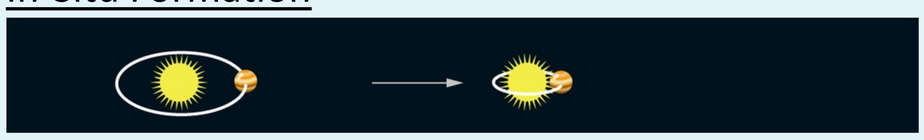
Summary

Recent discoveries with the Transiting Exoplanet Survey Satellite (TESS) have challenged the notion that hot Jupiters lack nearby companion planets. The discovery of TOI-4468 is one such example of a system hosting a hot Jupiter and a nearby transiting planet. With this growing sample, trends are beginning to emerge among planetary systems with this unique architecture, leading to potential insights into formation history, dynamics, and prospects for growing the sample further

Hot Jupiter Formation Mechanisms

Figures adapted from (1)

In-Situ Formation



Nearby planets

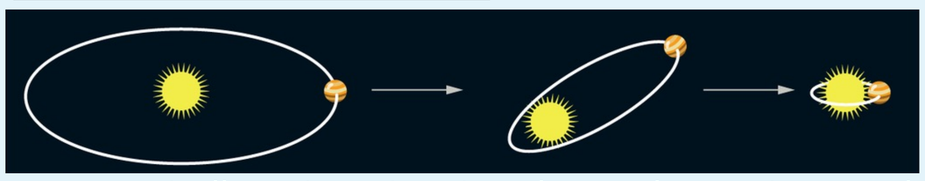
- System architecture remains largely the same from formation
- Potentially difficult to make a core large enough to accrete a large gaseous envelope at close distance to the host star

Disk Migration

Nearby planets

- Preserves the relative architecture of the planets in the system
- High likelihood of resonant and aligned orbits between the planets and low spin-orbit misalignment with the star

High-Eccentricity Migration

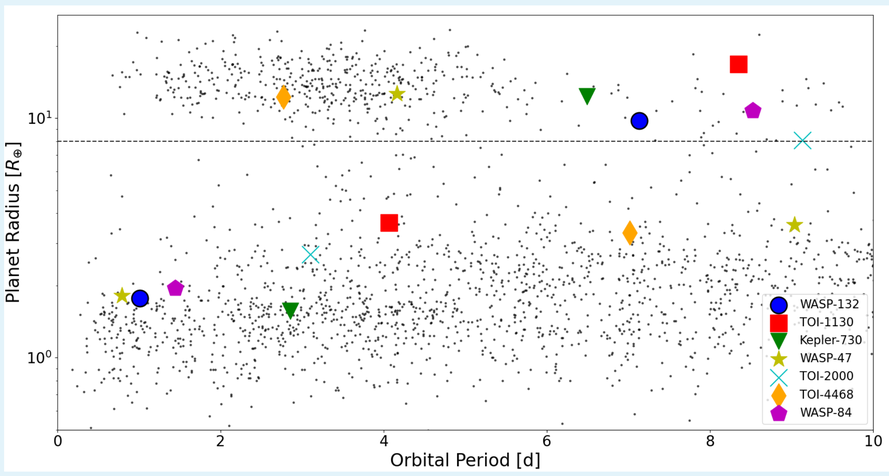


Nearby planets

- Dynamically active migration almost always ejects or destroys planets formed interior to the migrating gas giant
- Potential for mildly eccentric hot Jupiter orbits and may result in large spin-orbit misalignment with the host star

Out of >500 hot Jupiters, less than a dozen have nearby planets, traditionally interpreted as evidence for high-eccentricity migration

Hot Jupiter Companion Population

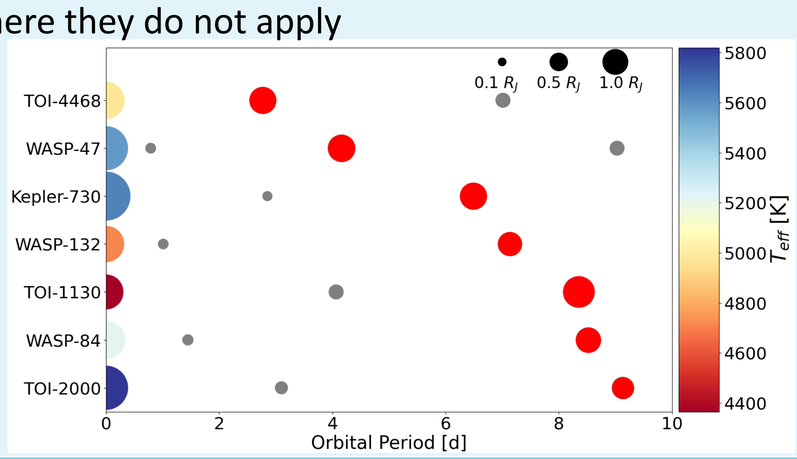


All systems with a hot Jupiter + companion have a planet interior to the hot Jupiter except TOI-4468. This could be an observational bias or due to one or more physical effects:

- Crowding out of giants by dwarves[4]: long chains of smaller resonant planets exterior to the hot Jupiter gradually leech its orbital angular momentum, shrinking the orbit and causing engulfment into the star
- Orbital tilting[5]: resonances with the star's quadrupole moment cause the orbits of any outer planets to tilt out of the plane of the hot Jupiter's orbit, making the companions undetectable by transit surveys

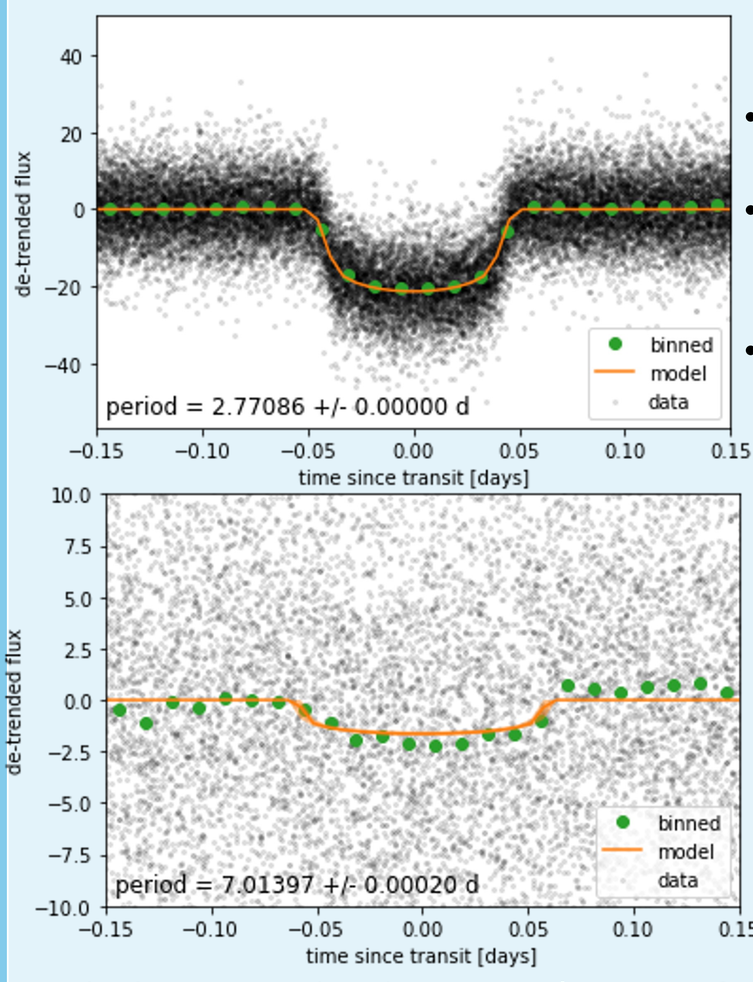
TOI-4468 is either currently undergoing one/both of these processes or exists within a regime where they do not apply

- Many of the hot Jupiters with nearby companions are on the smaller end of hot Jupiters and their companions are close to the upper edge of the radius valley



The Discovery of TOI-4468

Parameter	Planet b	Planet c
Orbital Period	2.77 d	7.01 d
Planet Radius	11.43 +/- 0.58 $R_\oplus$	3.22 +/- 0.26 $R_\oplus$
Equilibrium Temp	1058 K	752 K
Transit Duration	2.17 +/- 0.05 hrs	2.97 +/- 0.41 hrs
	Host Star	
Effective Temp	4975 +/- 122 K	
Stellar Mass	0.822 $M_\odot$	
Stellar Radius	0.789 $R_\odot$	



Transit Detection

- Originally detected by the TESS SPOC pipeline and announced as a TESS Object of Interest on Oct 10, 2021 with the shallower signal announced on Mar 2, 2023
- Observed in 31 TESS Sectors across 5 years
- Independently recovered with the Transit Least Squares search algorithm
- Modeled using the software exoplanet[2]

Statistical Validation

- Ground-based photometric follow up cleared the field of nearby eclipsing binaries
- The TRICERATOPS[3] statistical validation software calculated false positive probabilities (FPPs) of 5.69e-4 +/- 8.93e-4 for the larger signal and 1.52e-2 +/- 0.10e-2 for the smaller signal
- Applying the multiplicity boost of x20 for the two signals pushes both well below the 1.50e-2 FPP threshold for statistical validation

Ongoing and Future Work

- TOI-4468 is currently undergoing radial velocity observations with the WIYN telescope to confirm the planet and measure its mass
- Searches for additional systems containing a hot Jupiter + nearby companions using data from TESS. Studies have indicated that up to 20% of hot Jupiters may have nearby companion planets[6]
- An investigation into the scale of observational bias in the lack of companion planets exterior to hot Jupiters is ongoing using a series of transit injection simulations to probe TESS' sensitivity to these planets
- Measuring additional parameters such as spin-orbit alignment, atmospheric composition, mutual inclination, and long-term transit timing variations is critical to uncovering additional trends in the sample of these systems to constrain hot Jupiter formation
- Many systems with a hot Jupiter and companion planet(s) are excellent targets for atmospheric characterization with JWST or the upcoming Pandora mission, providing an excellent opportunity to use comparative planetology to constrain the origins of each planet in their respective systems

References

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