Misaligned Neptunes are more Tidally Inflated

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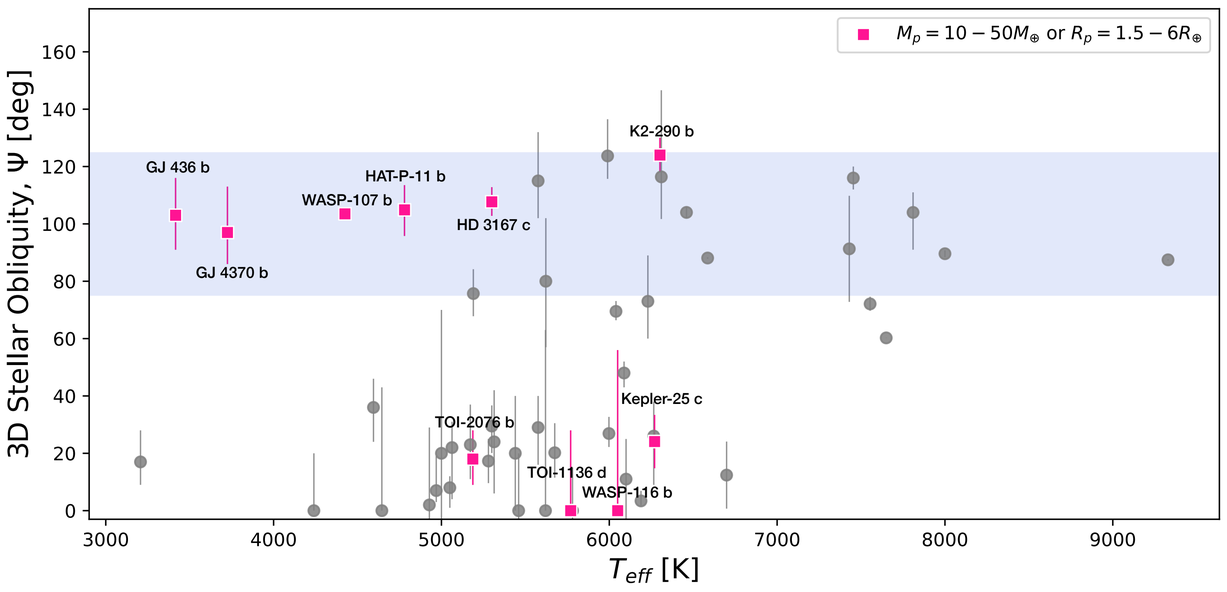
Coming soon: Sethi & Millholland (2025, submitted)) Email: rsethi@mit.edu



1. Neptune-sized planets are often found with polar orbits

Recent studies have shown that the distribution of 3D stellar obliquities, ψ in planetary systems is bimodal, with two distinct groups (Albrecht et al. 2021):

(1) orbits that are aligned (or nearly aligned) with the star

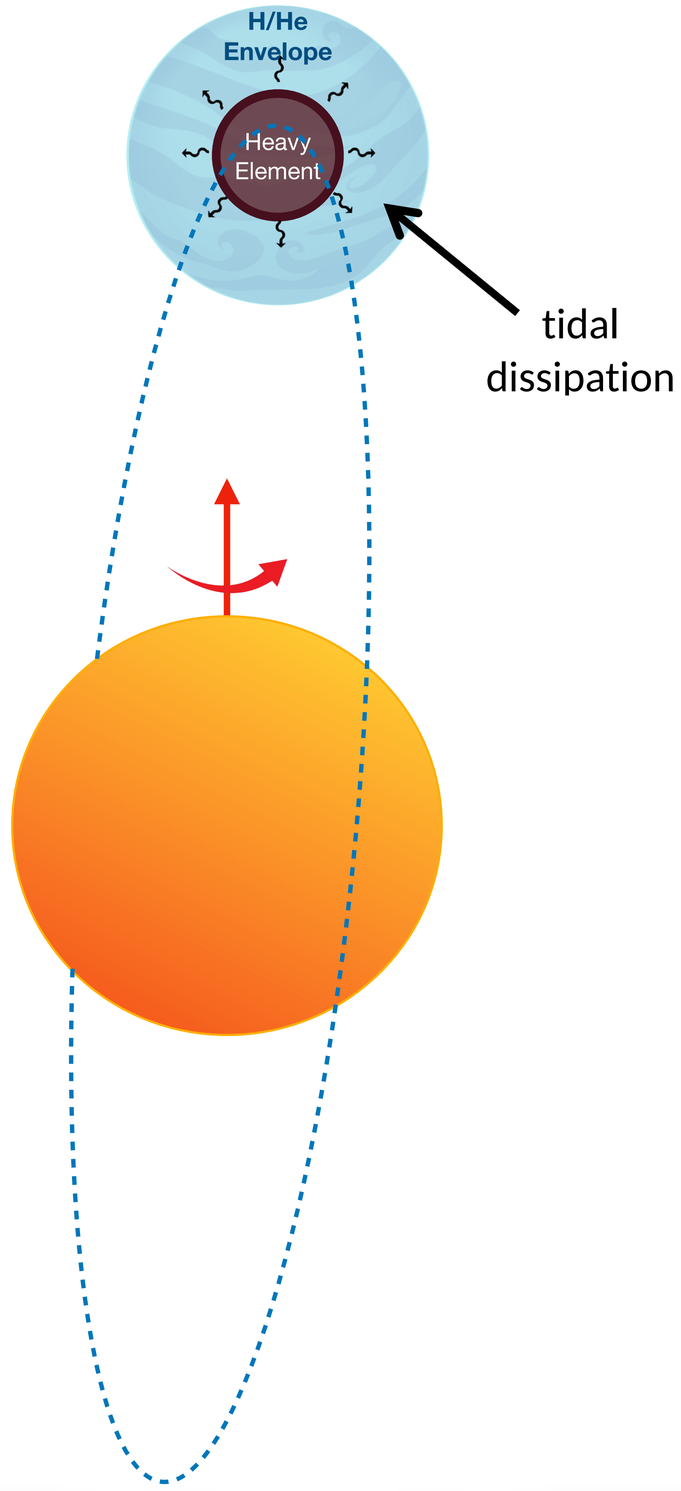
(2) orbits that are perpendicular (or "polar") with $\psi = 80^\circ - 125^\circ$

The reason for the tendency towards polar orbits remains unclear. Roughly a third of these polar planets are Neptune or super-Neptune-sized orbiting cool stars. They are also relatively puffy and are found inside or near the "hot Neptune desert".

Their inflated radii could possibly be due to enhanced tidal dissipation owing to their highly oblique and moderately eccentric orbits. We use observations of present-day properties (periods, eccentricities, radii, etc.) of polar Neptunes to estimate the degree of ongoing tidal heating and radius inflation.

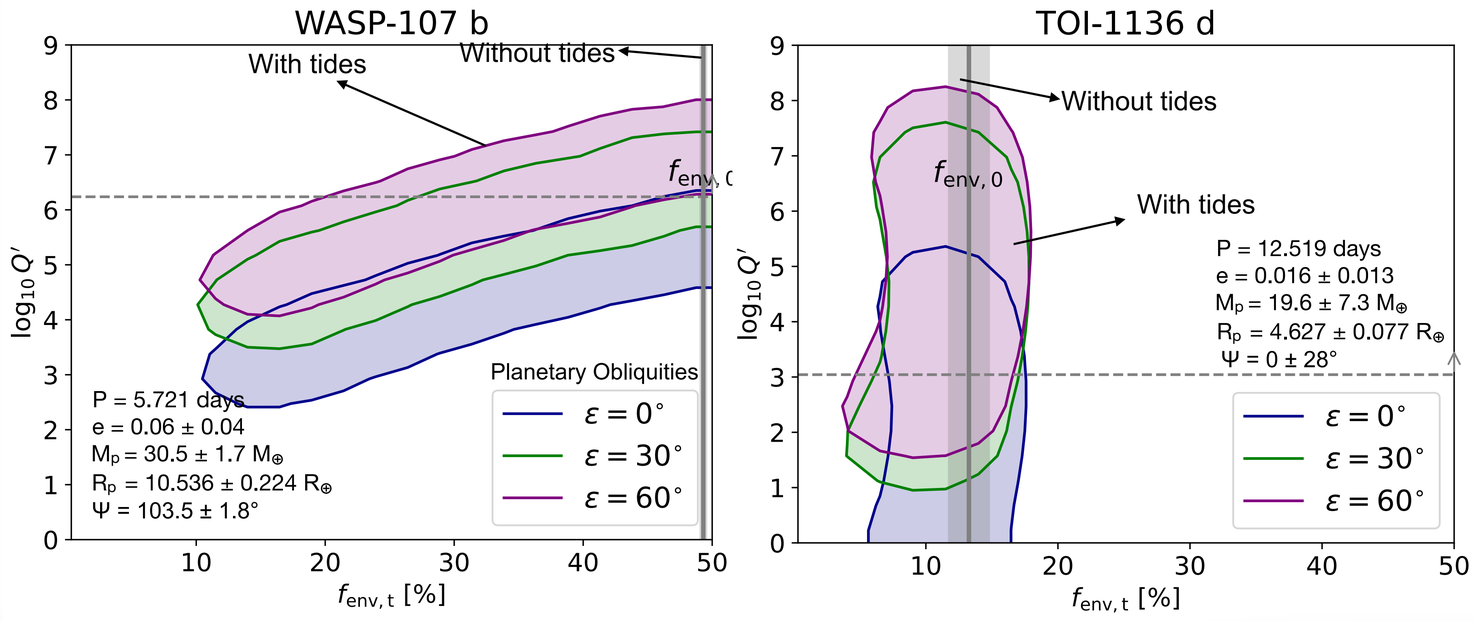
2. Radius Inflation from Tidal Heating

Tidal heating causes the H/He envelopes to expand, making the planet larger for a fixed envelope mass fraction, f_{env}. We use planetary structure models to infer the degree of radius inflation for a given tidal luminosity.

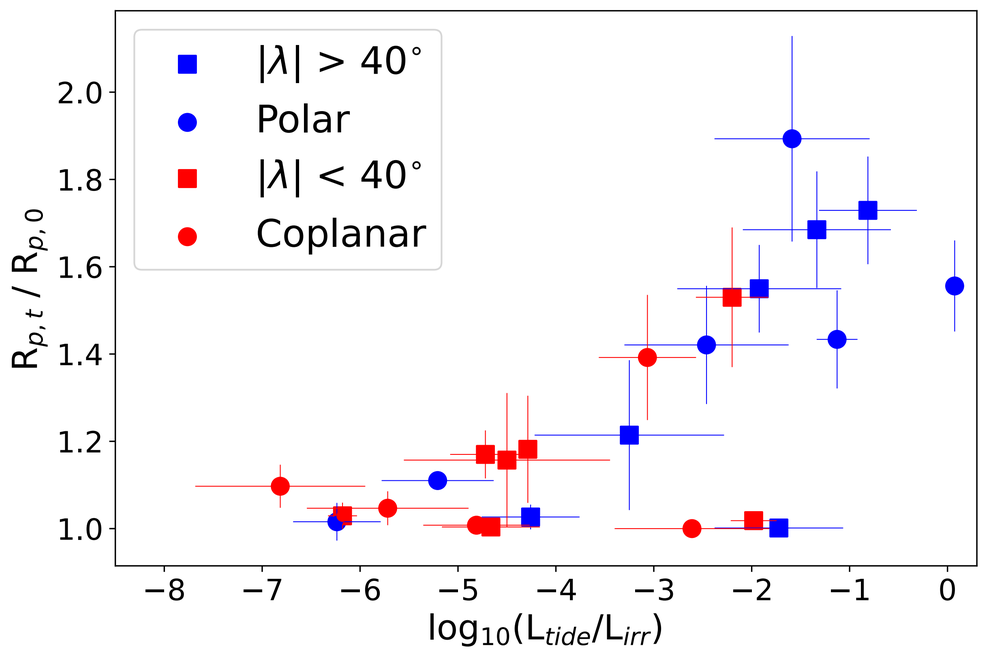


3. Results: Planets with highly oblique orbits show more tidal heating and inflation

Here we show constraints on f_{env} and the planet's tidal quality factor for two examples: (i) WASP-107 b has a highly misaligned and moderately eccentric orbit, and after including tidal heating in the structure models, we find that it is significantly tidally inflated. (ii) TOI-1136 has a coplanar and less eccentric orbit and shows less tidal inflation as f_{env} does not really change whether tides are included in the model or not.



4. Population Analysis: Misaligned vs. Aligned Planets



We model 24 observed planets and demonstrate with 90% confidence that misaligned planets experience more tidal dissipation and hence radius inflation than the aligned ones.

We verify our results with statistical tools and find it to be marginally significant. However, we need **more 3D obliquity measurements!**

References:

Albrecht et al. (2021)
Dai et al. (2023)
Millholland (2019)
Millholland et al. (2020)
Petigura et al. (2020)
Rubenzahl et al. (2021)

Key Takeaways:

1. Tidally induced atmospheric inflation plays a significant role in the structures of many misaligned Neptune-sized planets
2. The misaligned population appears more inflated than the aligned population!
3. Tidally induced radius inflation could also non-negligibly impact the dynamic evolution of a planet. We show this using a case study of WASP 107 b