



**UNIVERSITY
OF WARWICK**



UNVEILING THE NATURE OF CLOSE-IN NEPTUNE PLANETS: Insights from a Homogeneous Planetary Sample

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Monday 6th July 2025

THE NEPTUNE LANDSCAPE

DESERT:

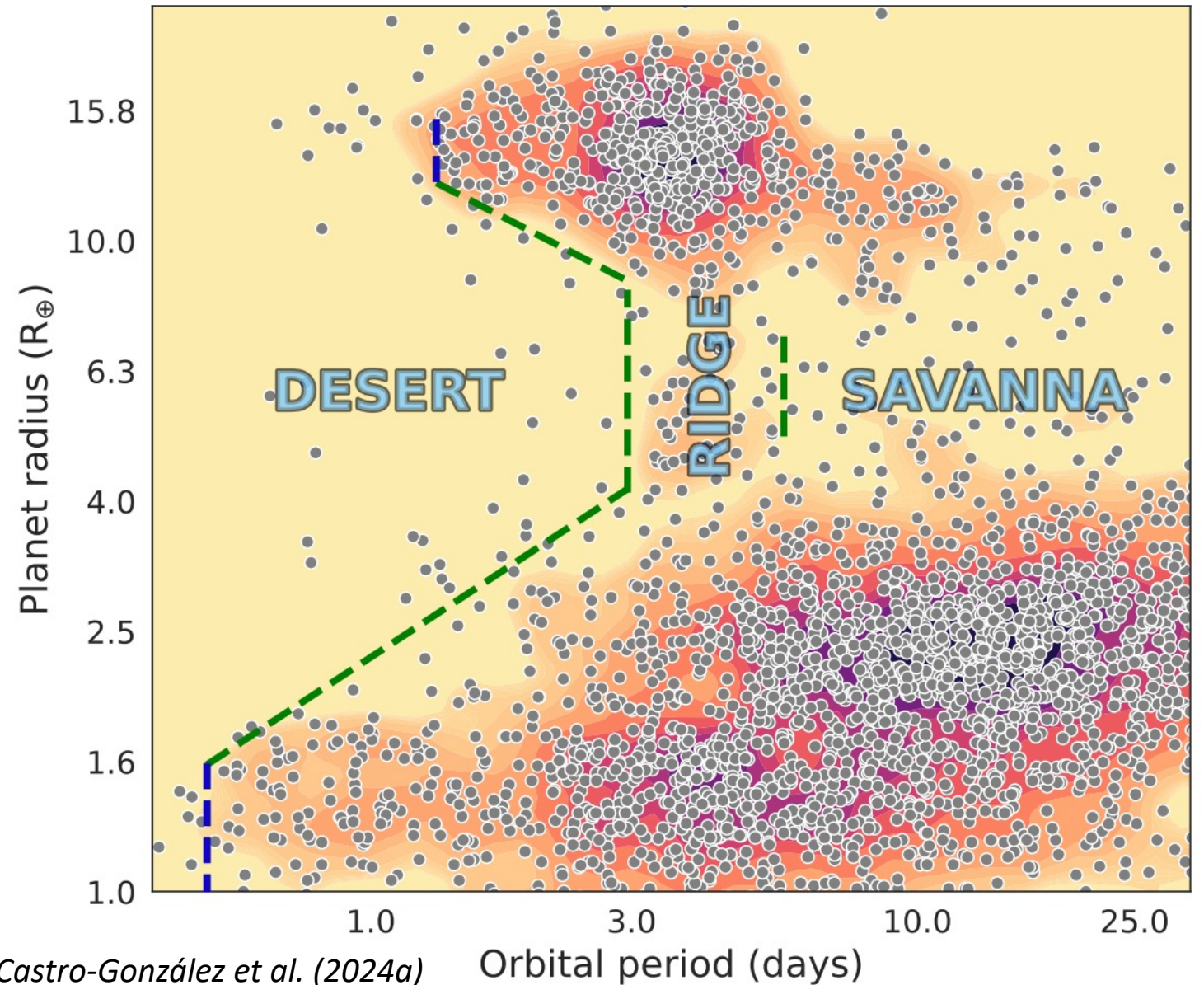
Significant dearth of Neptune-sized planets with $P_{\text{orb}} < 3.2$ days

RIDGE:

Over density of intermediate planets with P_{orb} between 3.2 and 5.7 days (see Castro-González et al. 2024a)

SAVANNA:

A milder deficit of Neptune-size planets at longer periods (see Bourrier et al. 2023)



OUR SAMPLE

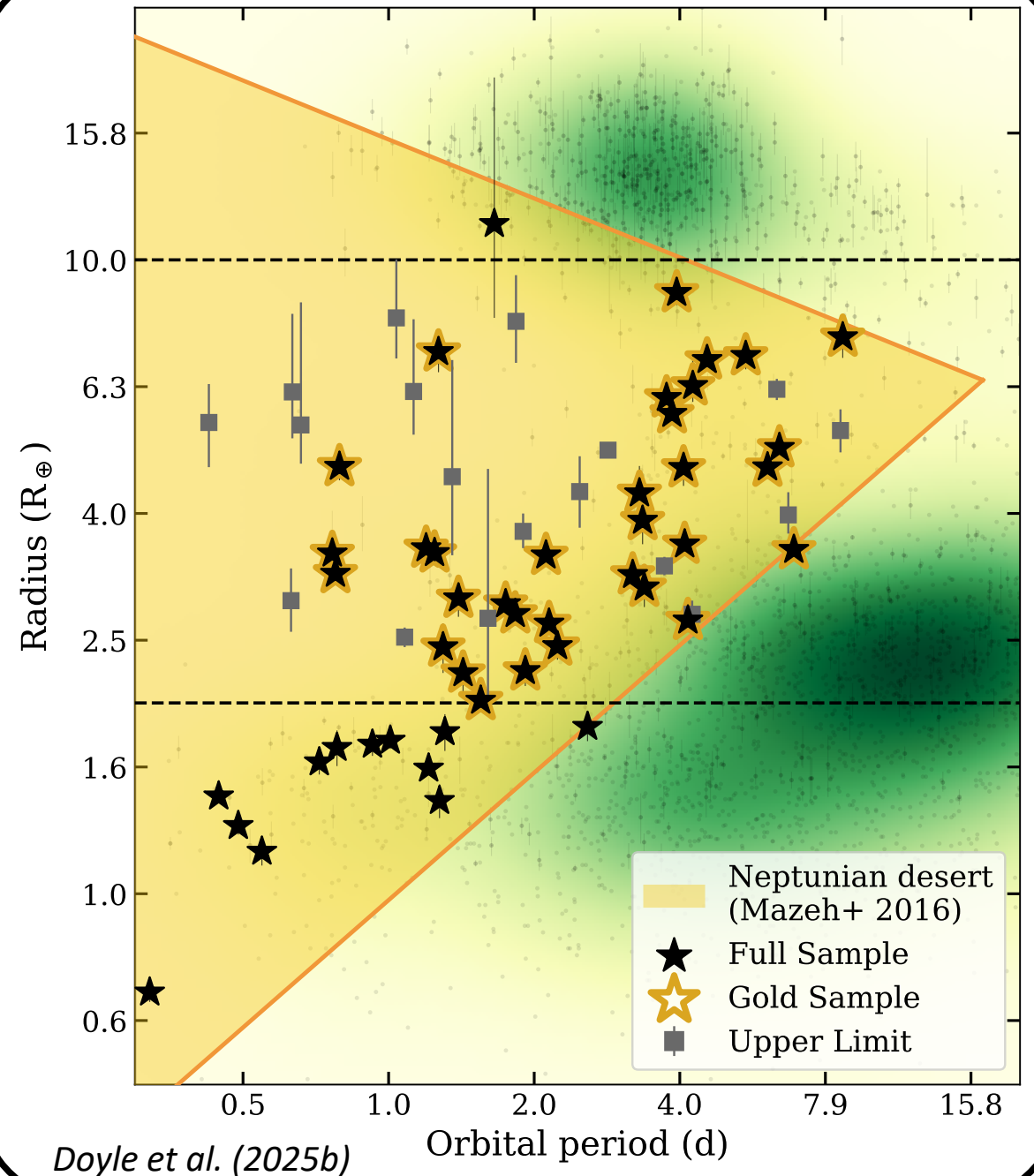
- Began with full sample of all known TOIs cutting on the magnitude, stellar radius and effective temperature.
- Used merit ranking for all known Neptune targets (based on work by Ares Osborn) taking visual magnitude and location within the Neptune desert.

Full Neptune desert sample of 64 targets:

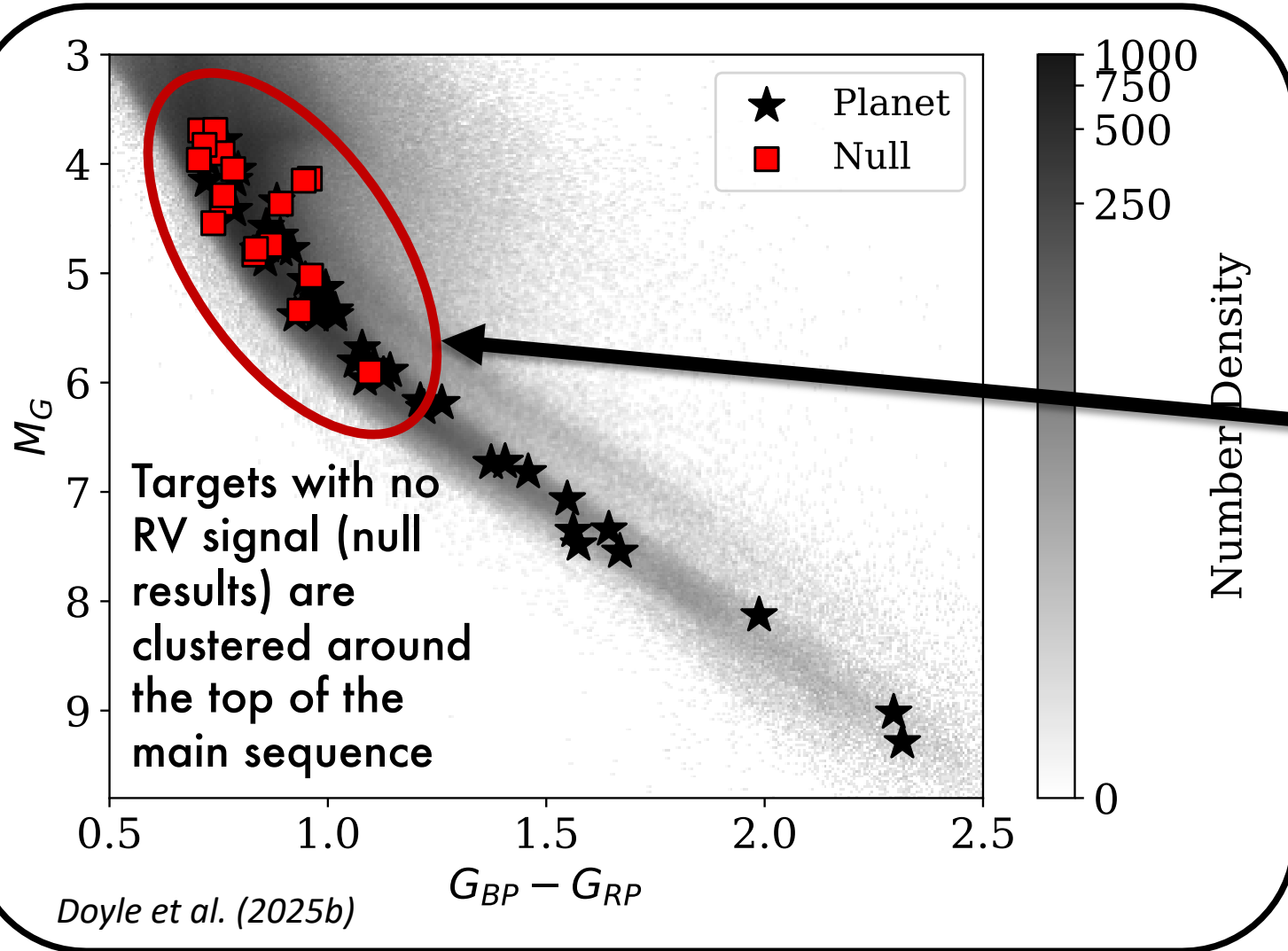
- 46 confirmed planets
- 18 null detections

Gold Neptune desert sample of 33 targets.

- With planetary radii between 2 and 10 R_{\oplus}



WHAT CAN GAIA TELL US?



Based off our study in Doyle et al. (2024) which cross matched SPOC FFI targets with Gaia.

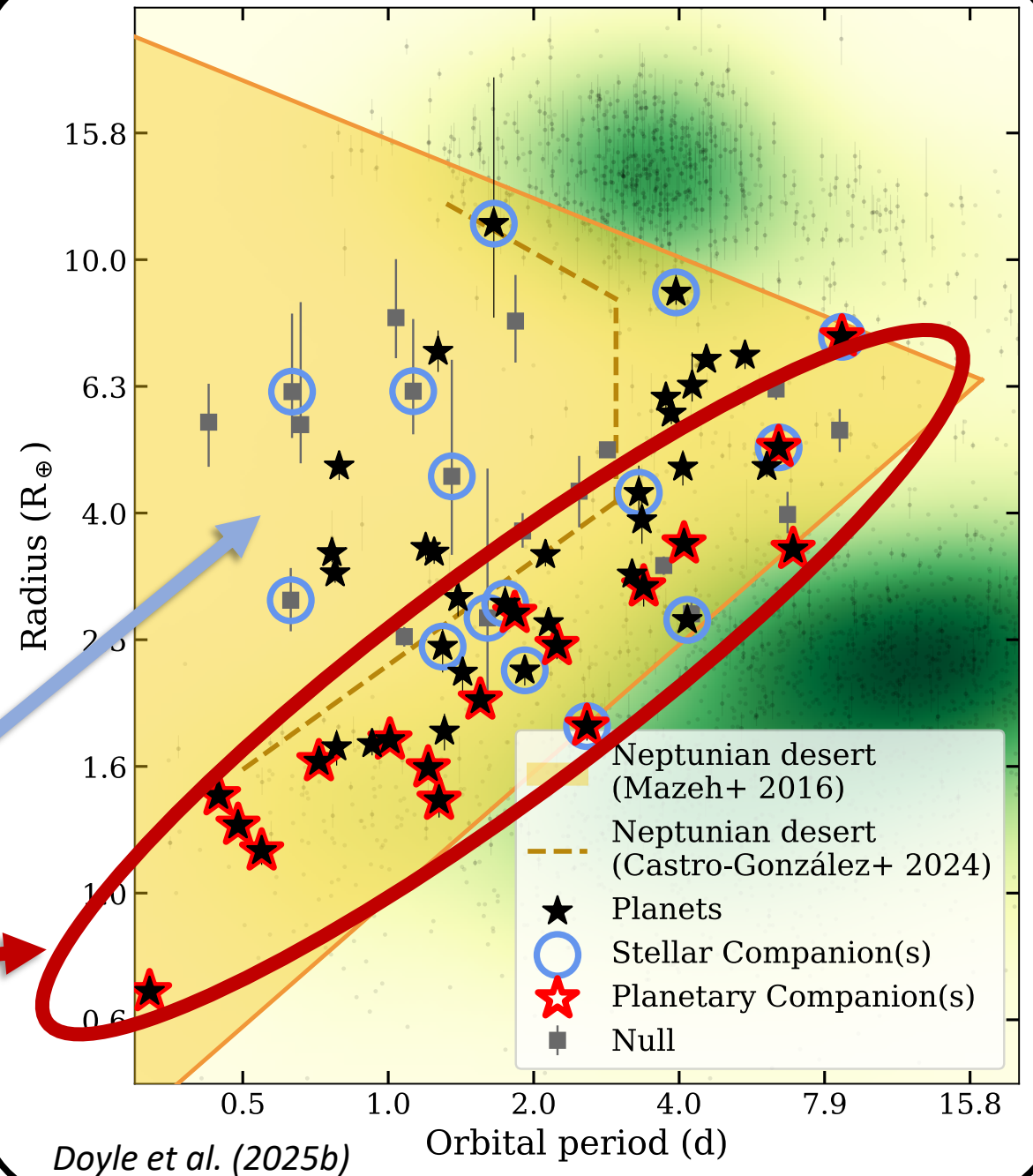
Higher chances of being false positives?

late-A and F spectral Types have increased chances of being members of binary systems (Tian et al. 2018) or even triple systems (Offner et al. 2023)

STELLAR MULTIPLICITY & MULTIPLE PLANETARY SYSTEMS

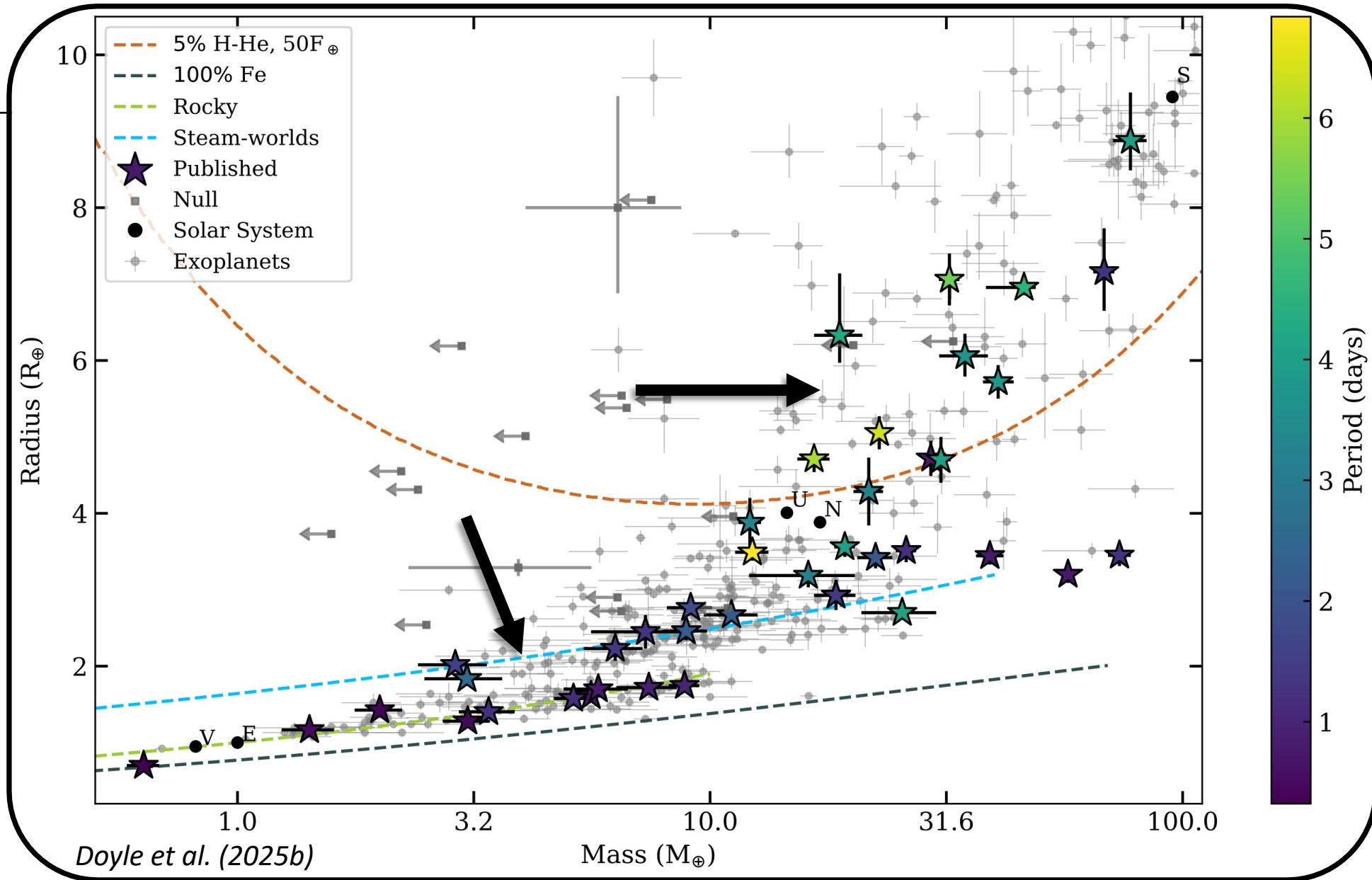
What implications can stellar or planetary multiplicity have for the formation and evolution of Neptune desert planets?

- 15 (23%) have stellar companions with separations > 100 AU.
- 17 (26%) are members of a multi-planet system.
- 3 targets have both stellar and planetary companions.



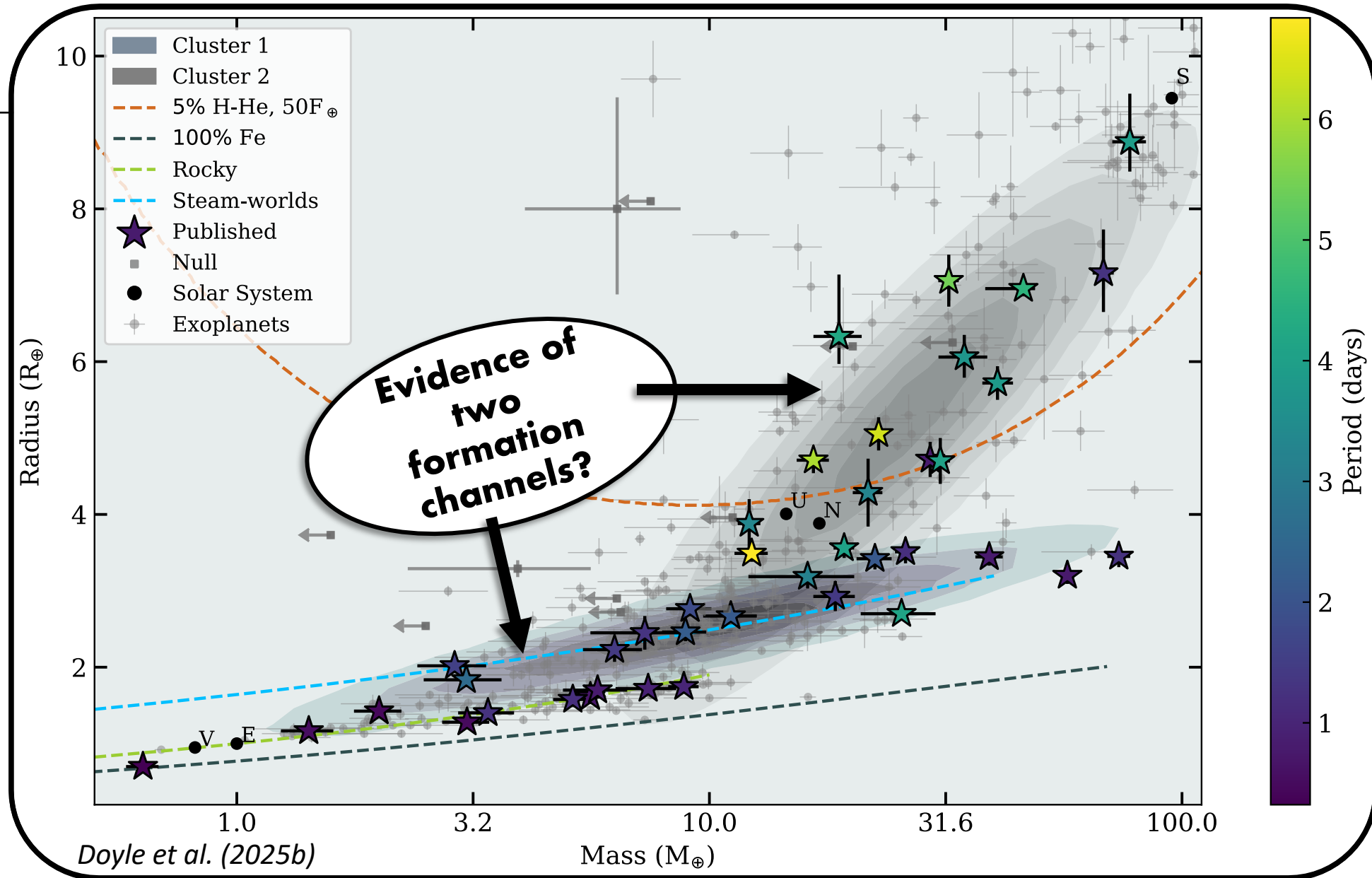
DENSITY

Visually, can see clusters of short period planets around the Earth-like and water lines. Longer period planets sit above water and H-He lines.

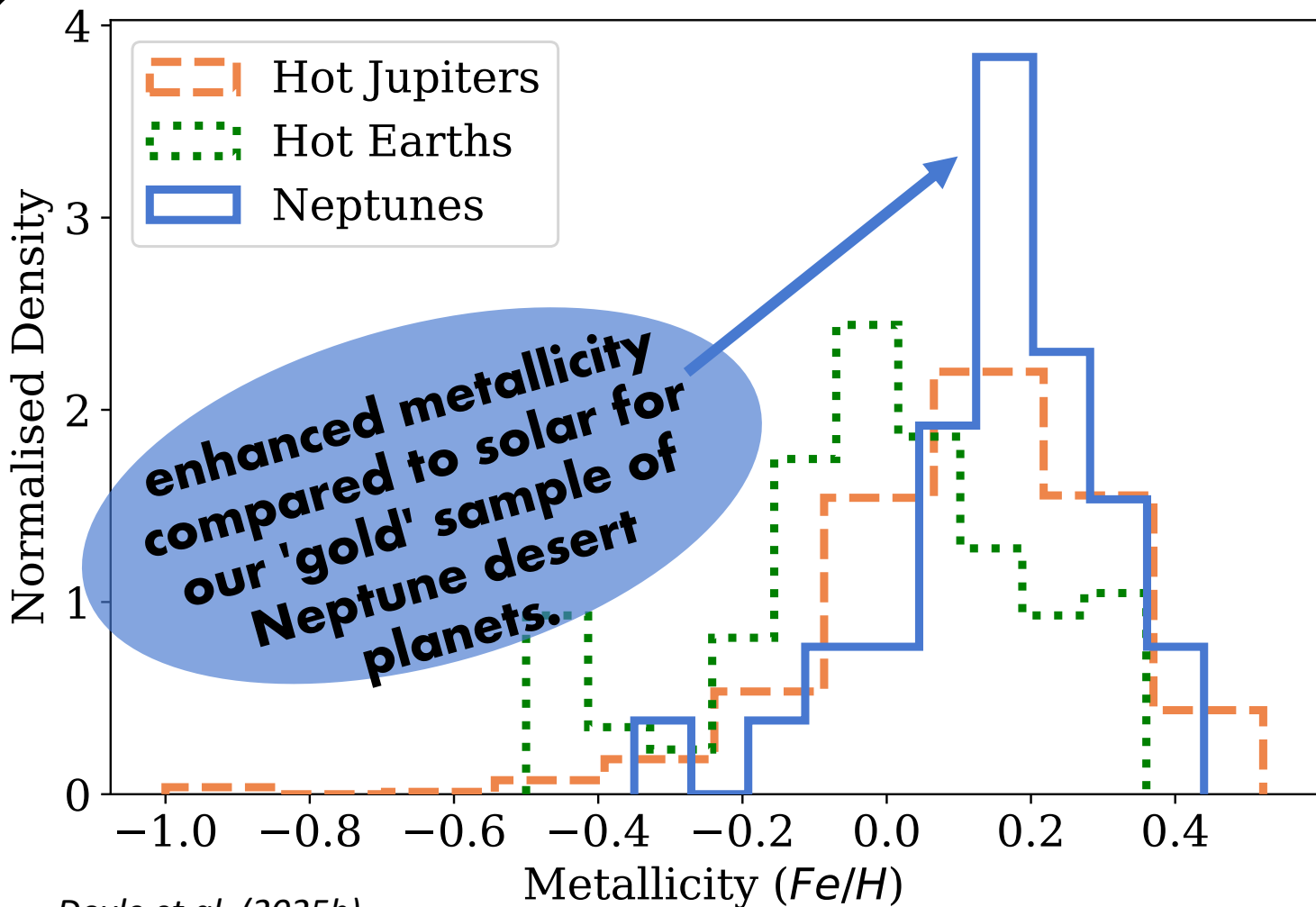


DENSITY

Used a 2-component Gaussian Mixture Model (see Pedregosa et al. 2011) on mass, radius and orbital period to separate our full sample into two clusters. These are split at $P_{\text{orb}} \sim 3$ days.



METALLICITY

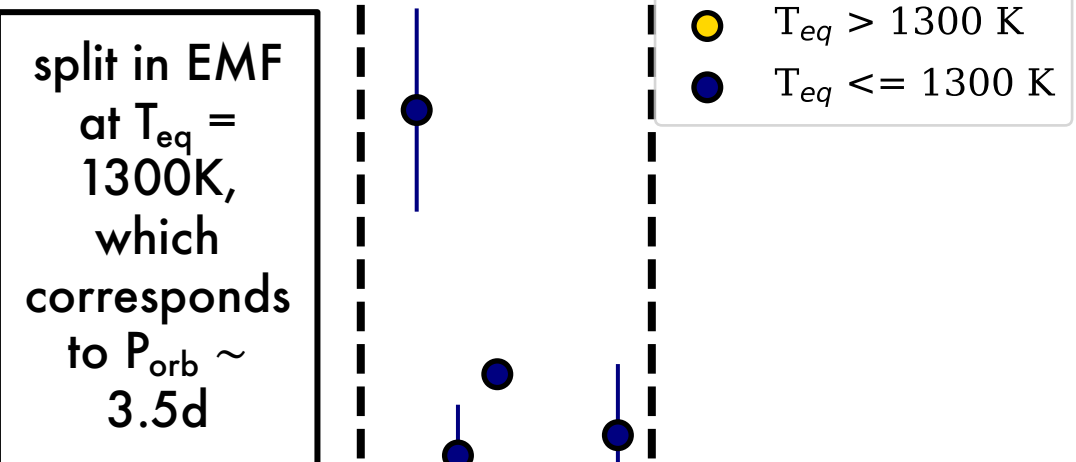
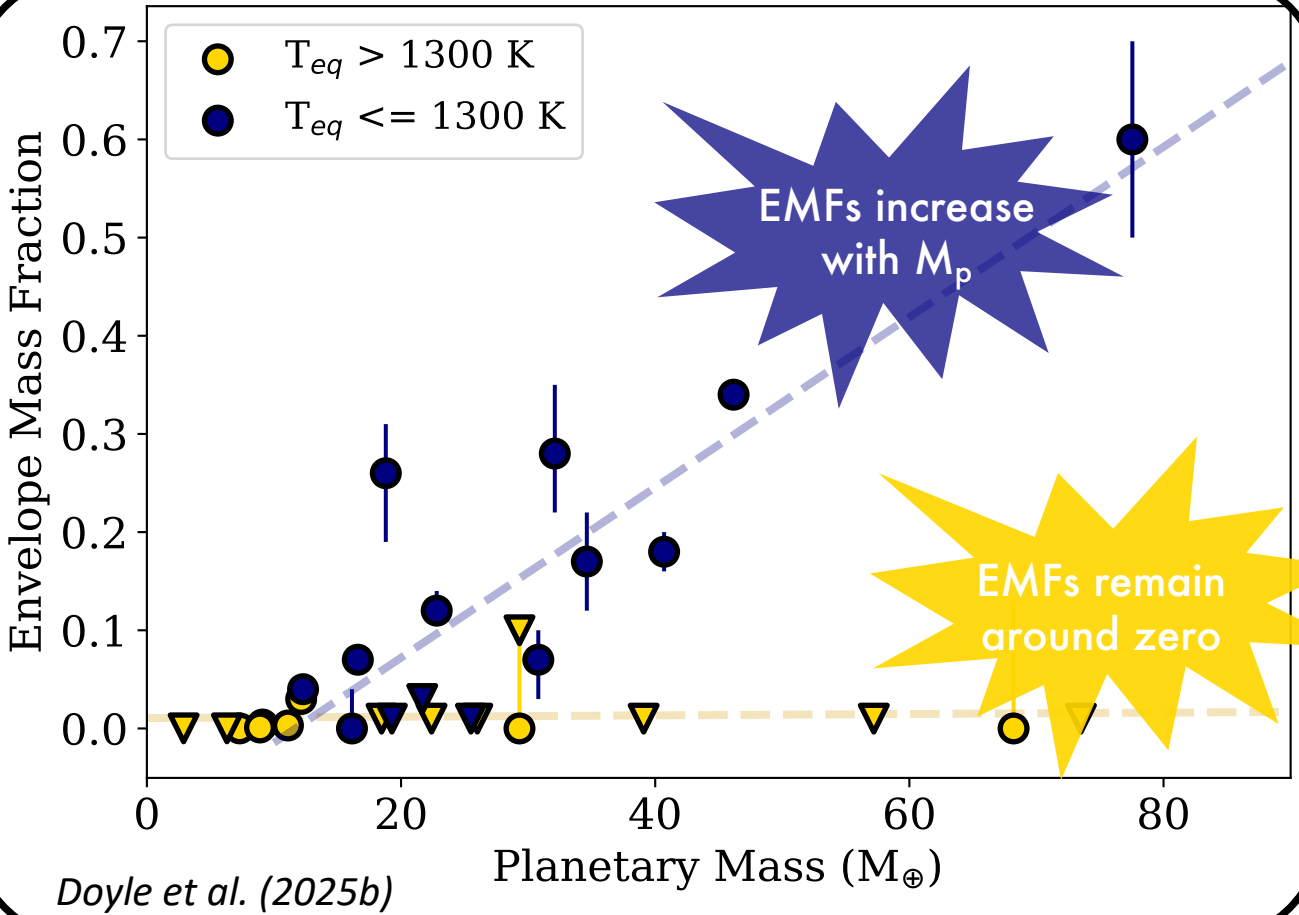


Doyle et al. (2025b)

From this point onwards all analysis on gold sample only!

- Short period gas giants found orbiting more metal-rich stars (e.g. Gonzalez 1997; Santos et al. 2001, 2004)
- USP terrestrial planets have solar-like metallicity distribution (Dai et al. 2021)
- Hot Neptunes occur around metal-rich stars (Dong et al. 2018; Vissapragada & Behrard 2024)

ENVELOPE MASS FRACTIONS (EMF)

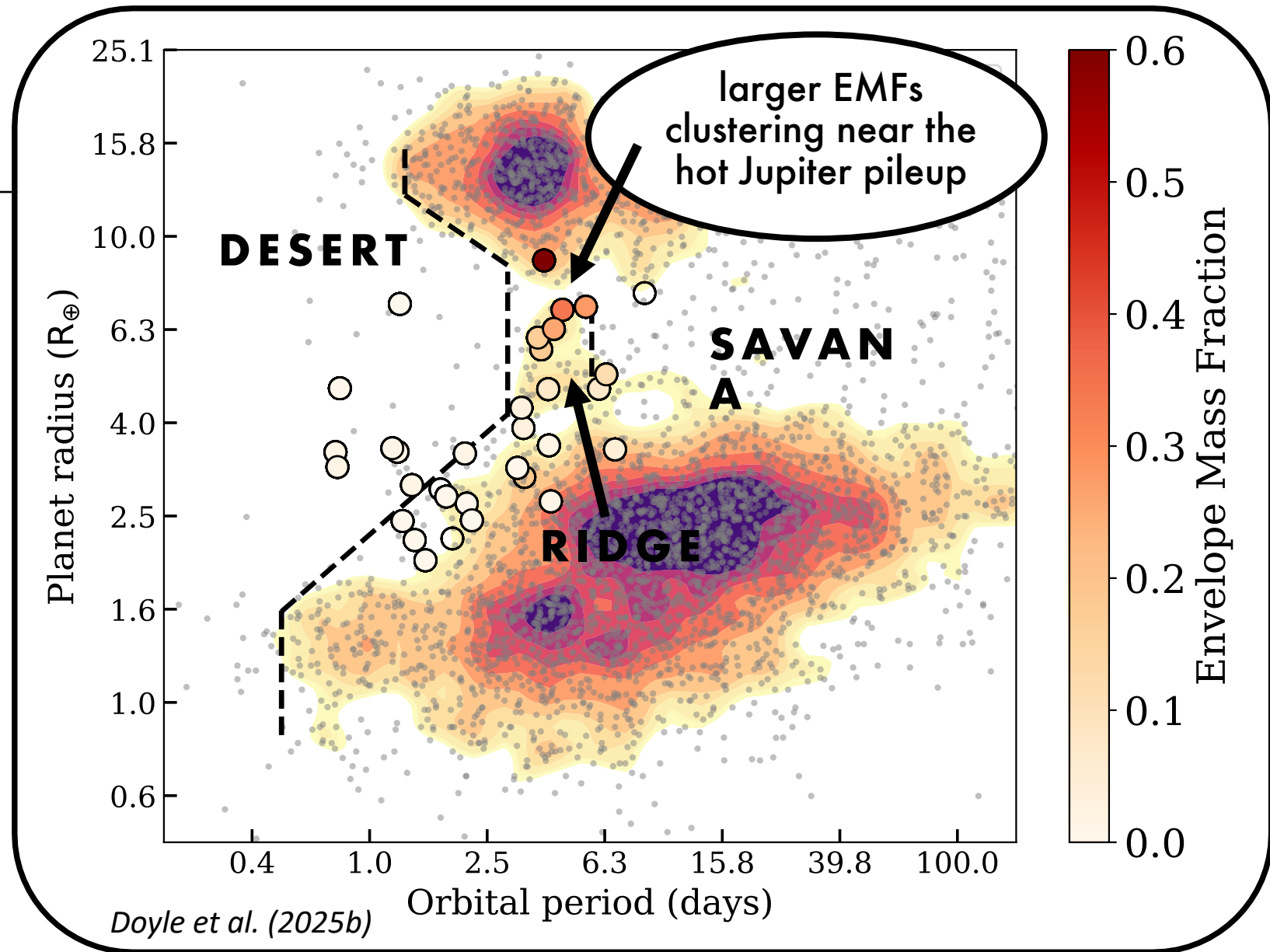


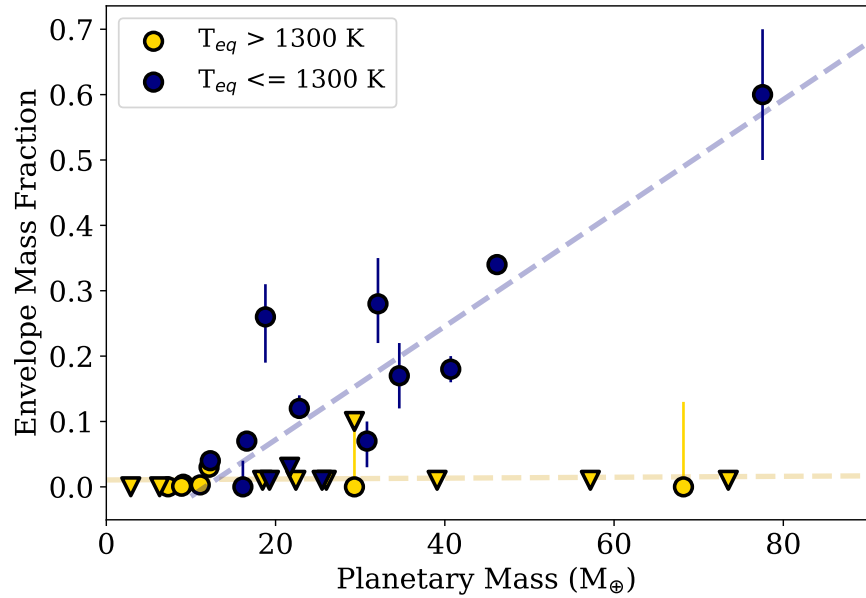
Use GASTLI (Acuña et al. 2021; Acuña et al. 2024) to calculate the EMF for 21 of our 'gold' sample and (Lopez & Fortney 2014) for the remaining 8 targets.

THE NEPTUNE DESERT

At orbits of 3 days, there is a split in the evolution of systems within the desert!

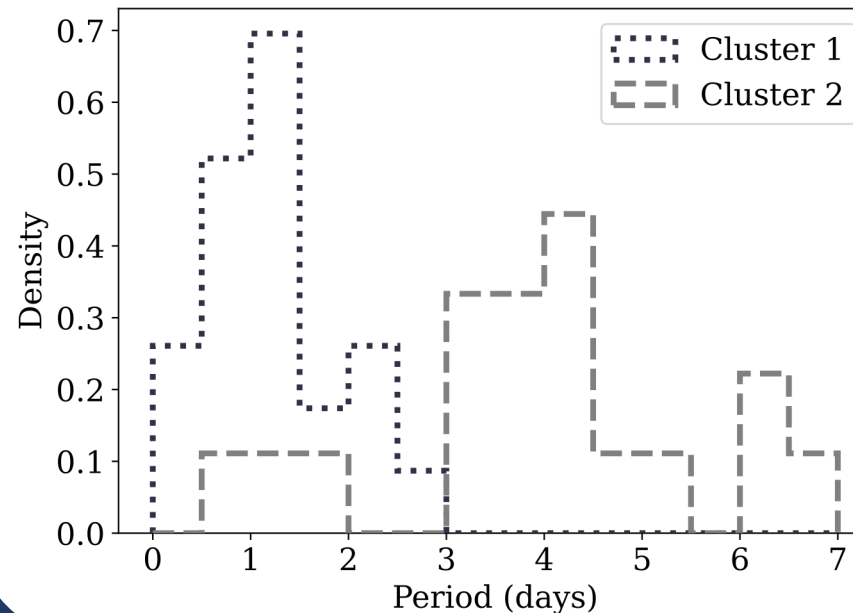
- within the desert, low EMF fraction photoevaporation plays a key role.
- within the ridge, planets have a range of EMF which depends on planetary mass.



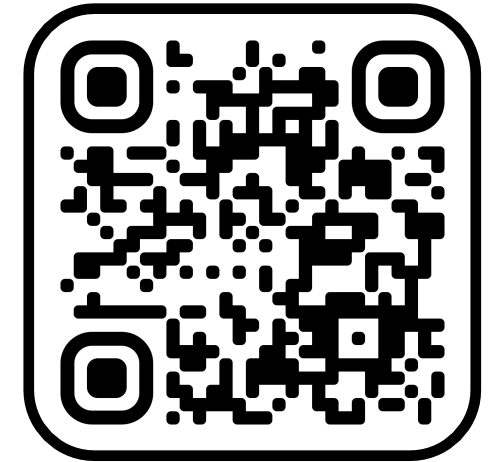


- Planets with $T_{eq} > 1300$ K ($P_{orb} \lesssim 3.5$ days) have very low to zero EMF, suggesting photoevaporation is key in their evolution.
- Planets with $T_{eq} < 1300$ K ($P_{orb} \gtrsim 3.5$ days) have a trend in EMF which increases for higher planetary mass, as predicted for gas giant planets formed via core accretion.

- Two clusters appear in the mass-radius diagram with a split in orbital period at ~ 3 days, similar to our EMF analysis, further suggesting two formation and/or migration mechanisms.



SUMMARY



Read the full paper here!

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