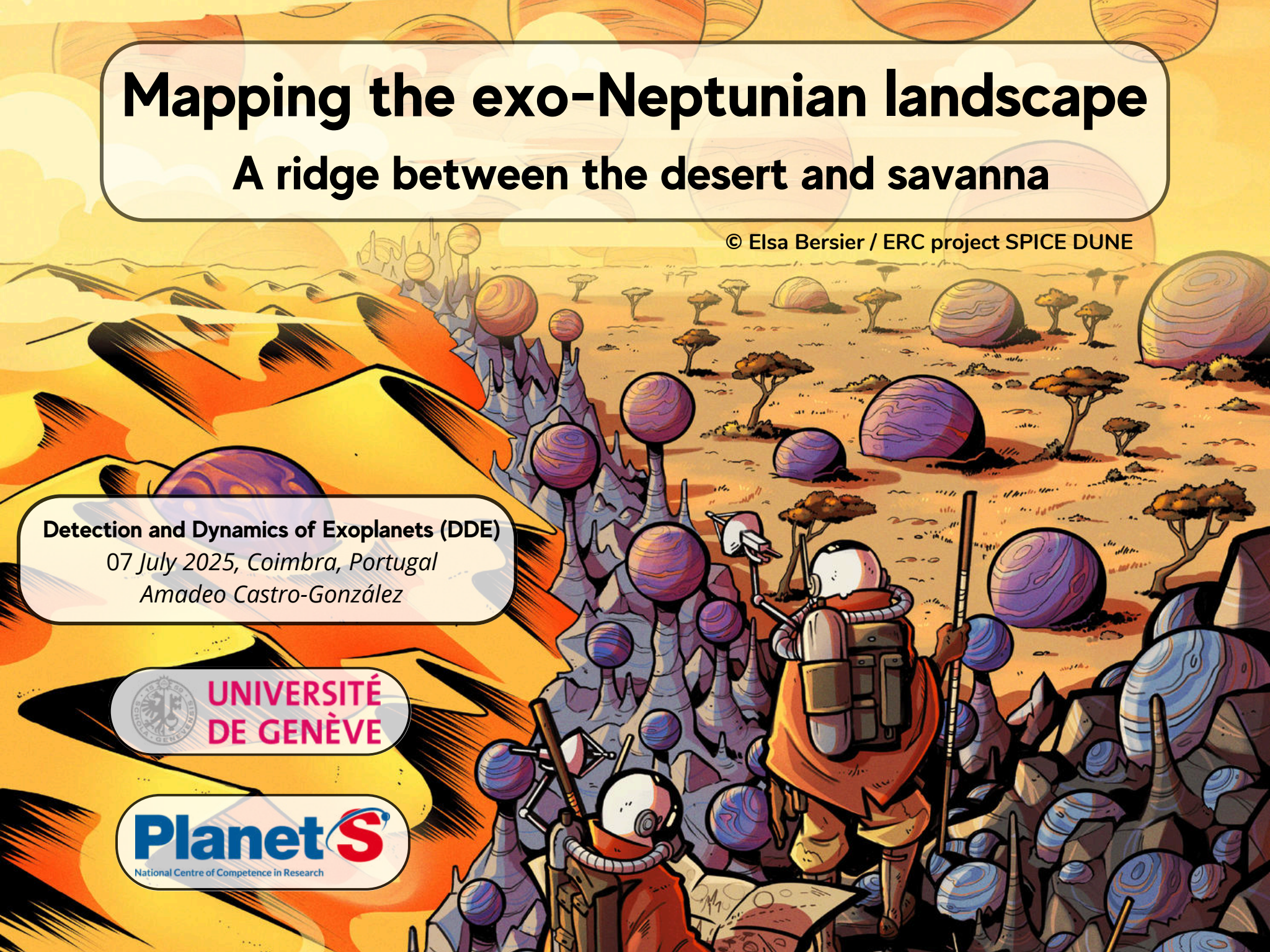
Mapping the exo-Neptunian landscape

A ridge between the desert and savanna



Detection and Dynamics of Exoplanets (DDE)
07 July 2025, Coimbra, Portugal
Amadeo Castro-González

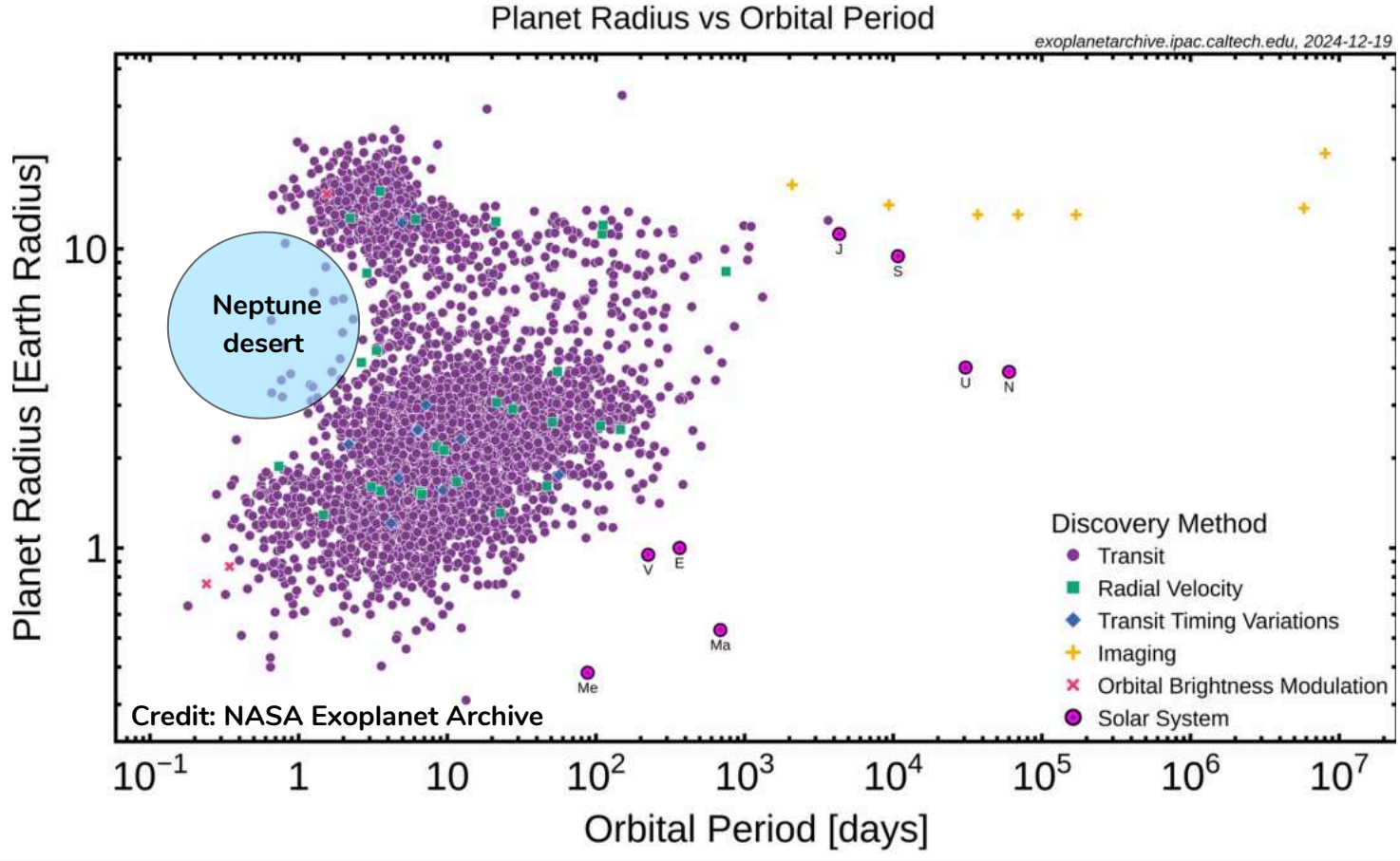
UNIVERSITÉ DE GENÈVE

PlanetS
National Centre of Competence in Research

Context

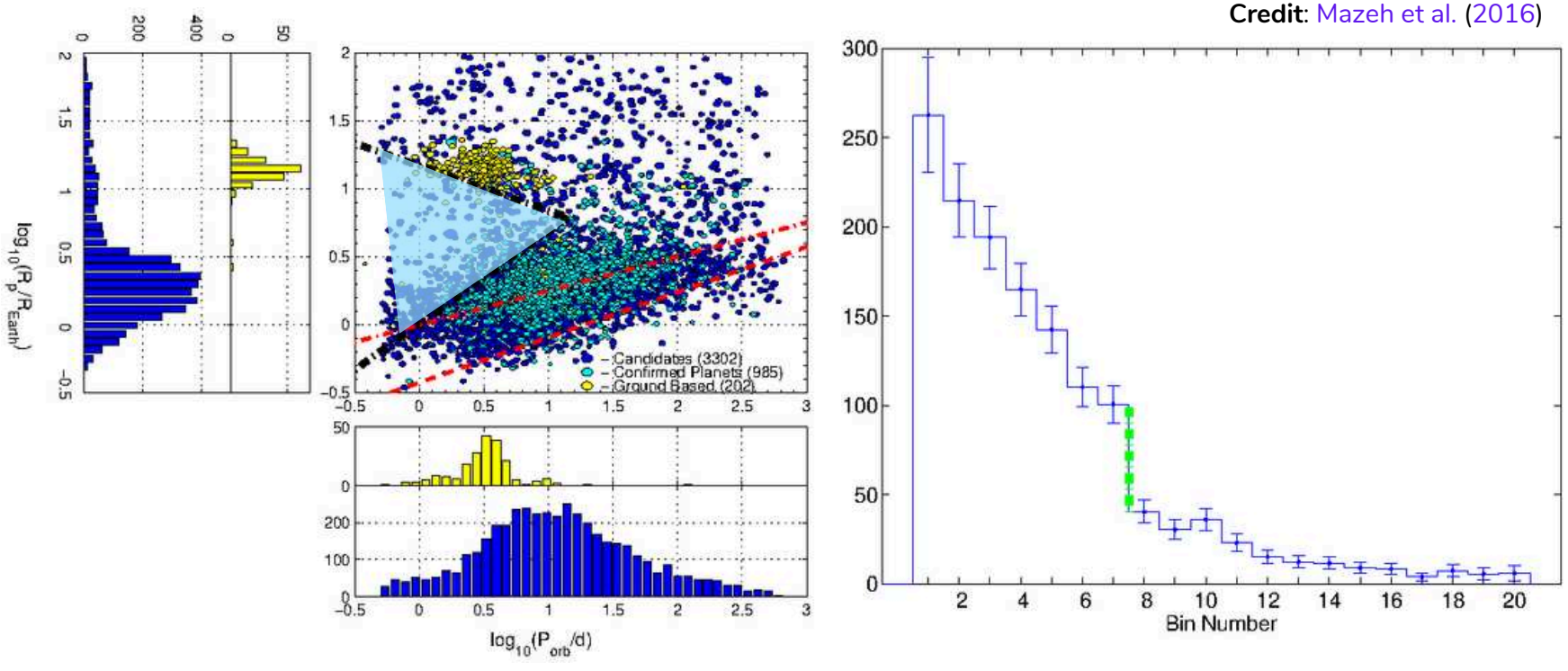
Context

The hot **Neptune desert** refers to the closest orbits of Neptunian planets, where **very few detections are found** (e.g. Szabó & Kiss 2011).



Context

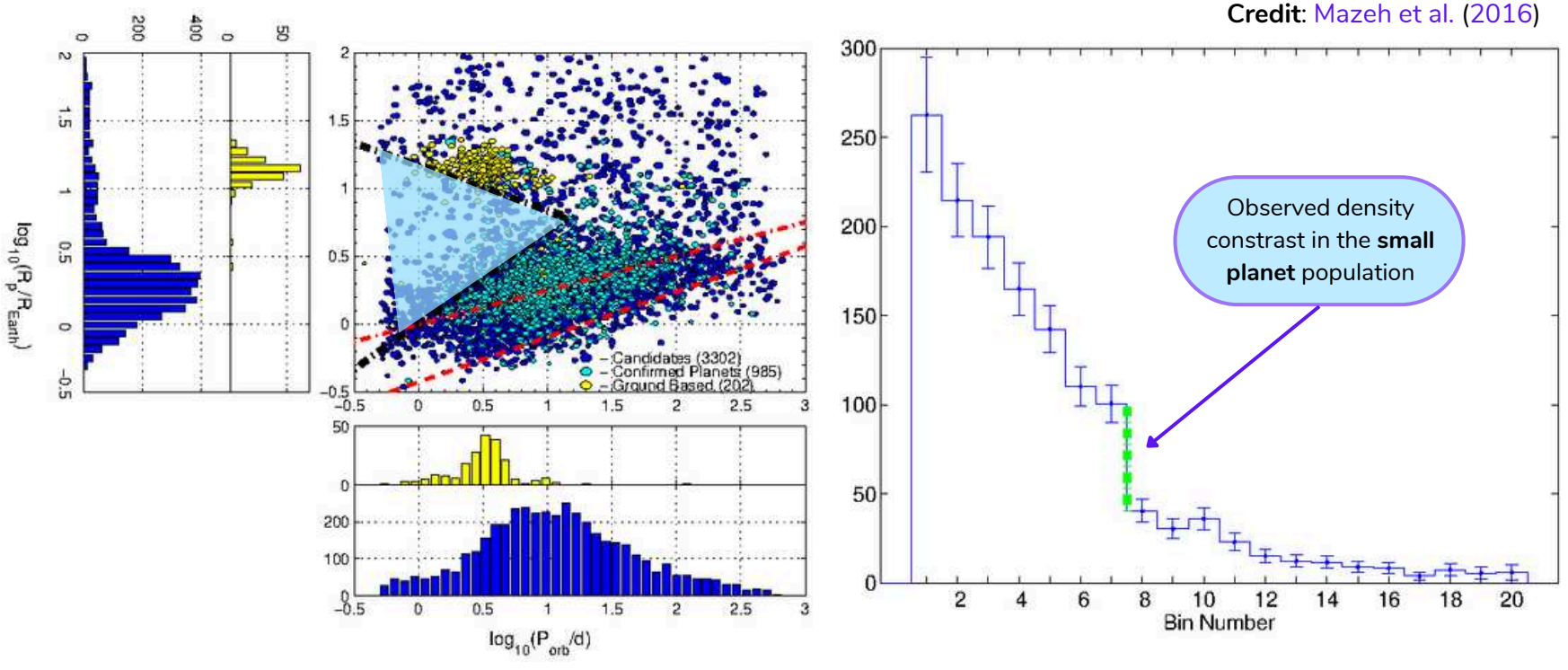
Its **boundaries** were first delineated by Mazeh et al. (2016). The authors used confirmed and candidate planets and assumed a **triangular shape** determined by **planet density constrasts** in the **hot Jupiter** and **small planet** population.



Credit: Mazeh et al. (2016)

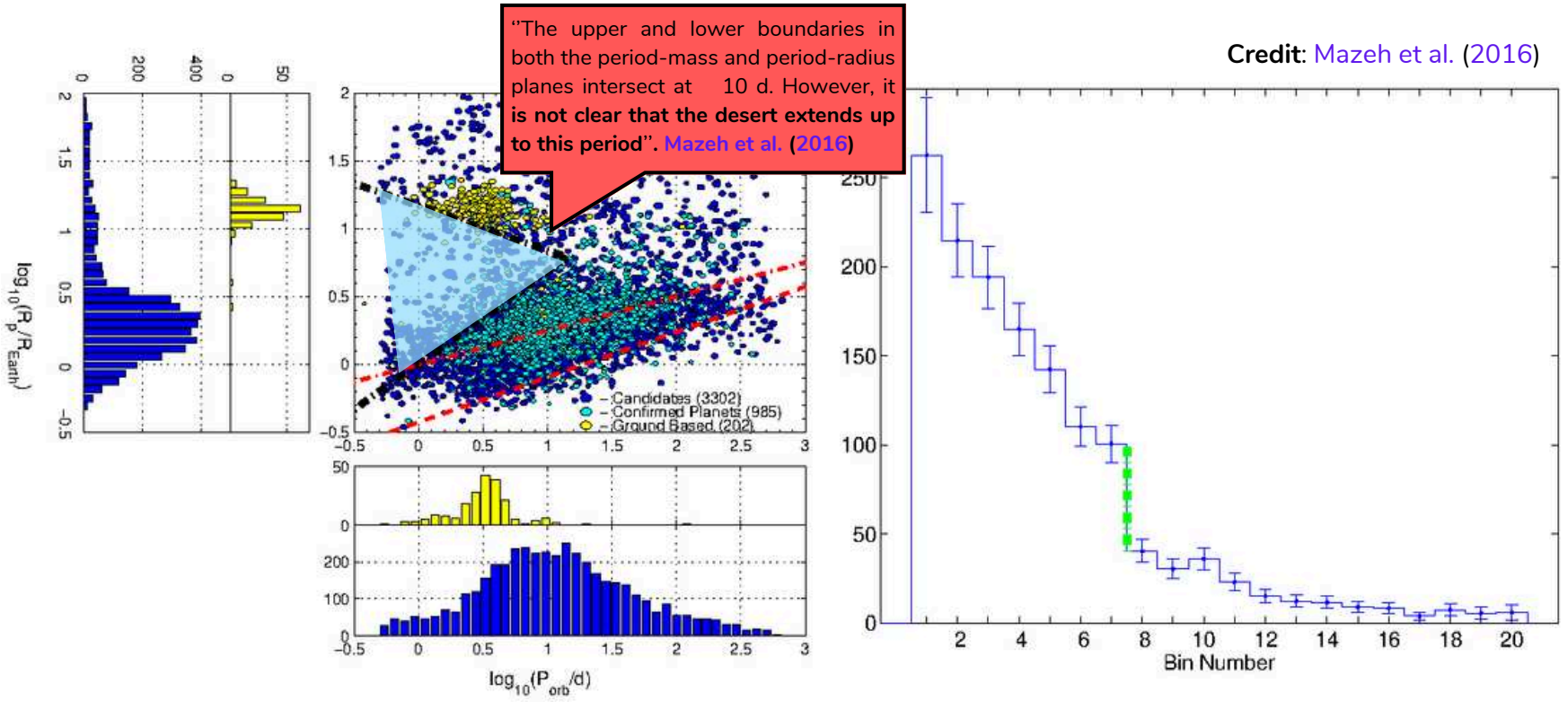
Context

Its **boundaries** were first delineated by Mazeh et al. (2016). The authors used confirmed and candidate planets and assumed a **triangular shape** determined by **planet density constrasts** in the **hot Jupiter** and **small planet** population.



Context

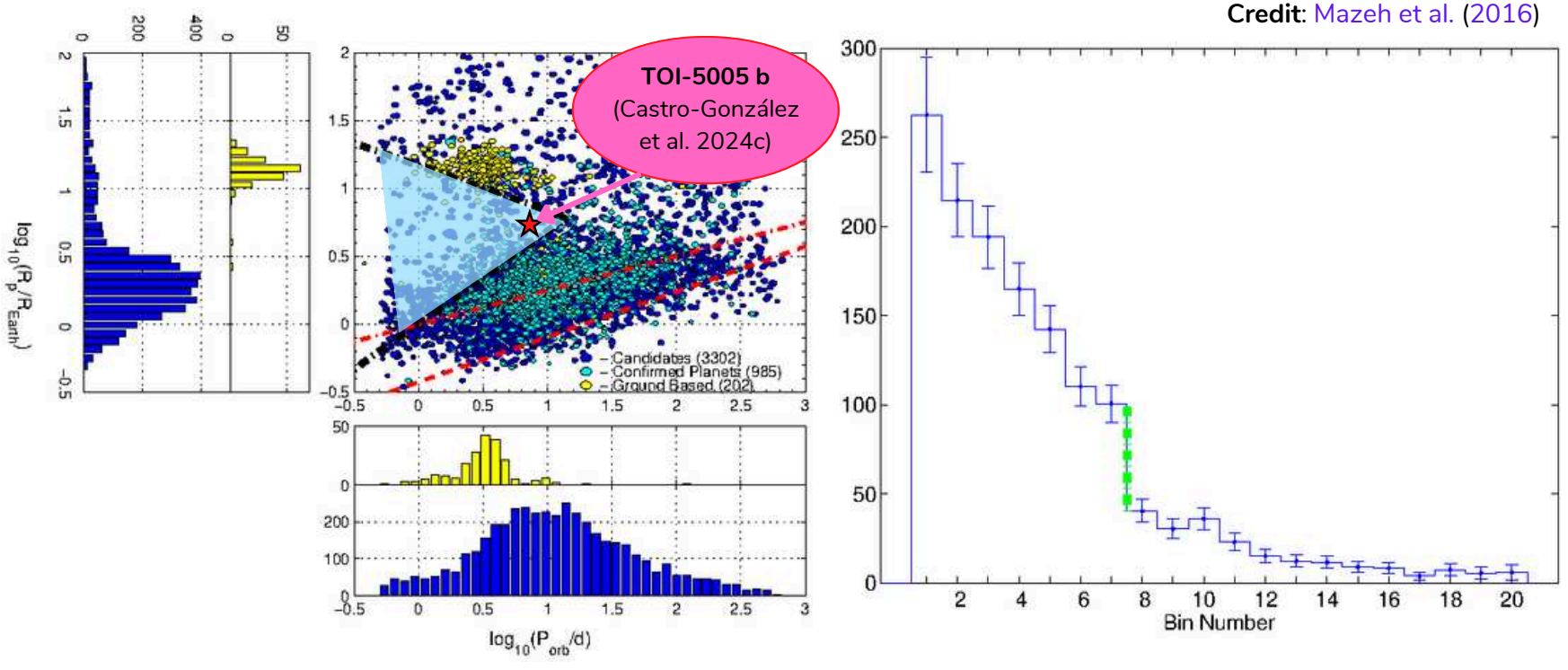
Its **boundaries** were first delineated by Mazeh et al. (2016). The authors used confirmed and candidate planets and assumed a **triangular shape** determined by **planet density constrasts** in the **hot Jupiter** and **small planet** population.



Credit: Mazeh et al. (2016)

Context

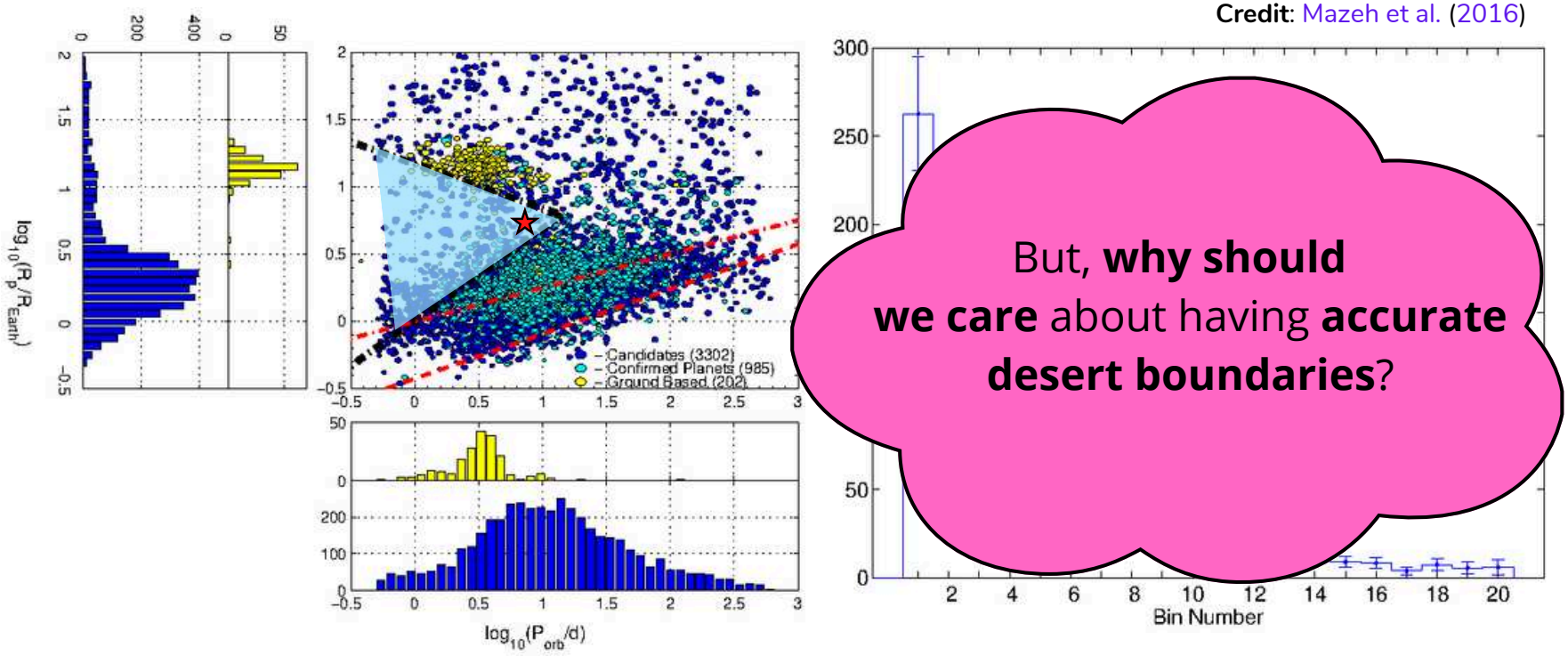
Its **boundaries** were first delineated by Mazeh et al. (2016). The authors used confirmed and candidate planets and assumed a **triangular shape** determined by **planet density constrasts** in the **hot Jupiter** and **small planet** population.



Credit: Mazeh et al. (2016)

Context

Its **boundaries** were first delineated by Mazeh et al. (2016). The authors used confirmed and candidate planets and assumed a **triangular shape** determined by **planet density constrasts** in the **hot Jupiter** and **small planet** population.



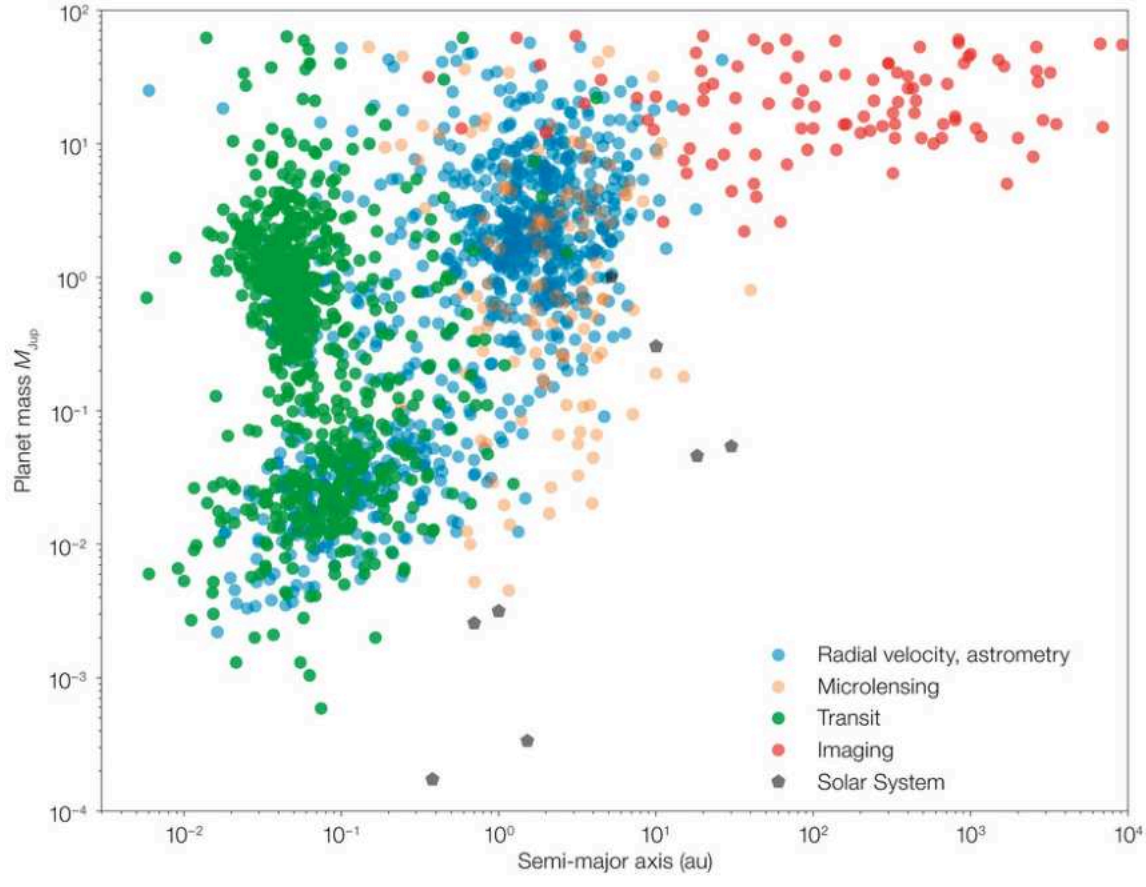
Credit: Mazeh et al. (2016)

But, **why should we care** about having **accurate desert boundaries**?

Context

What **we think** about the desert ....

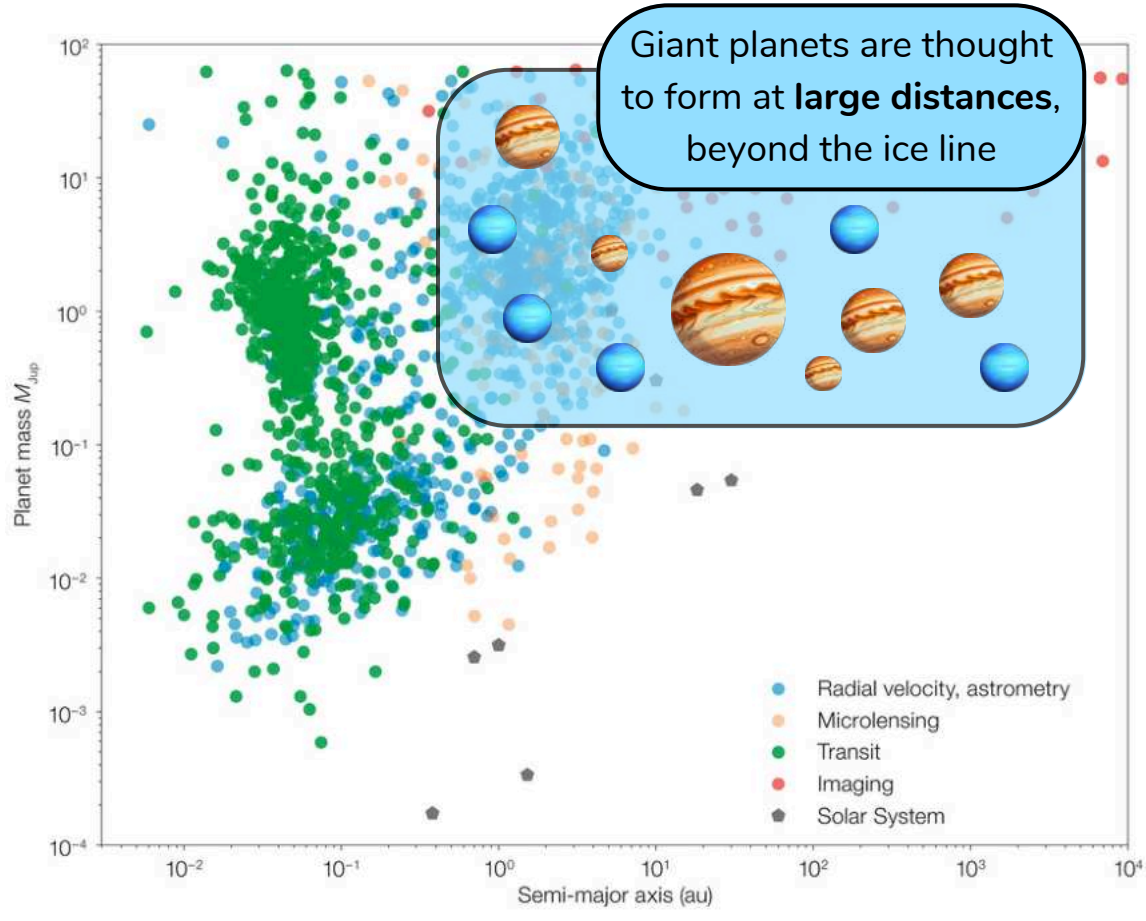
- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



Context

What **we think** about the desert ....

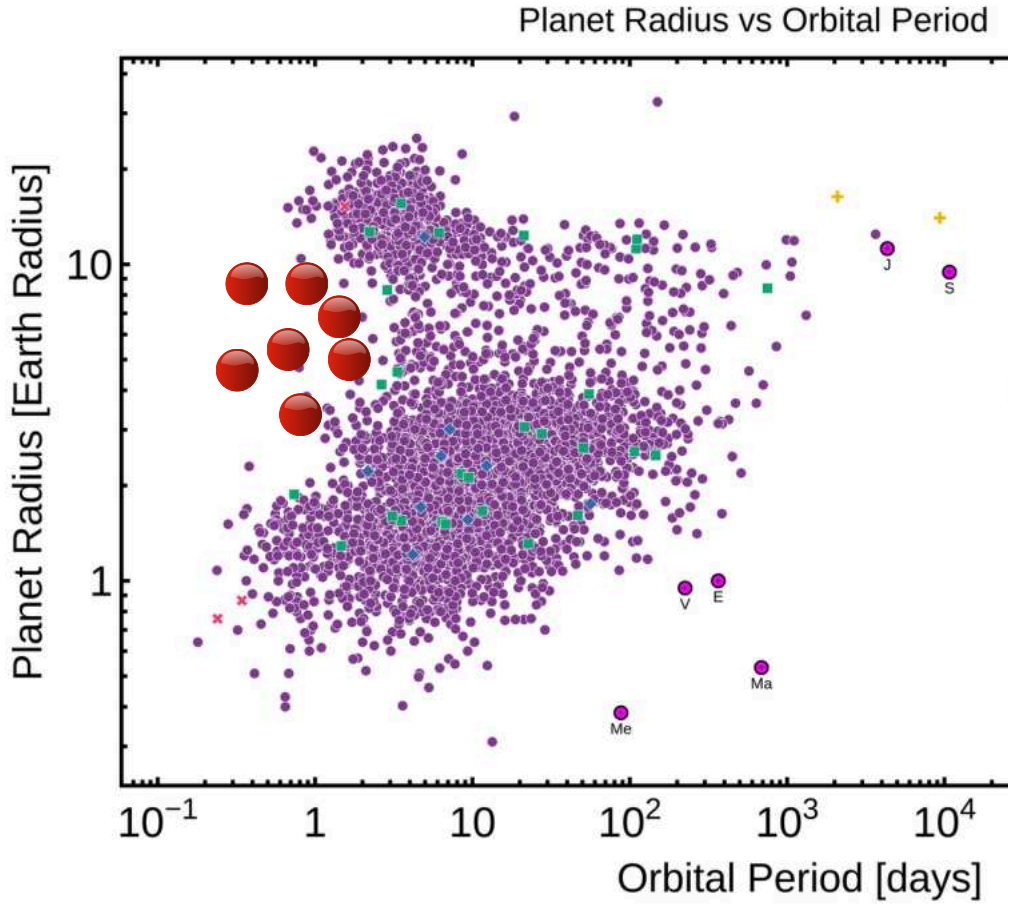
- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



Context

What **we think** about the desert ....

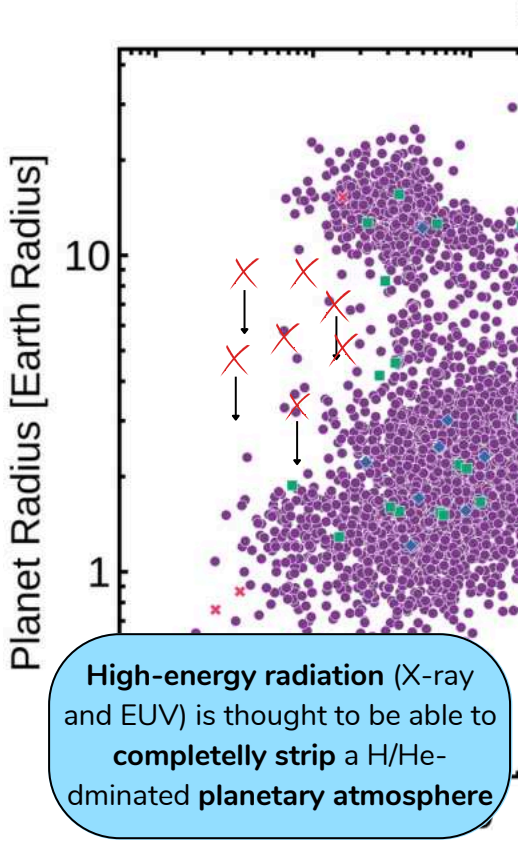
- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



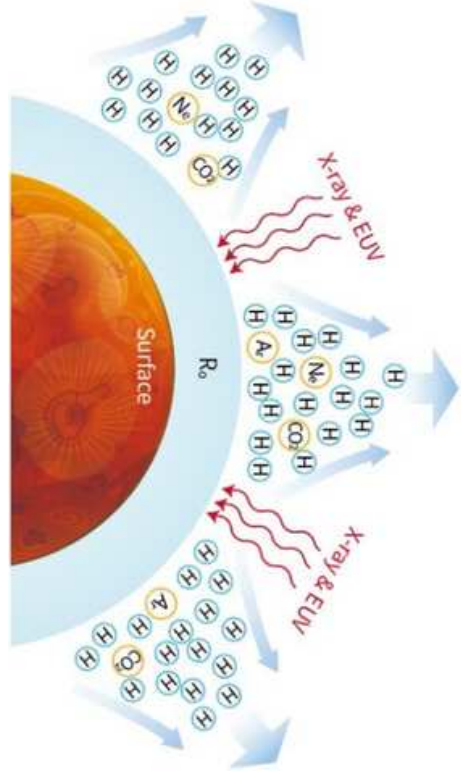
Context

What **we think** about the desert ....

- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



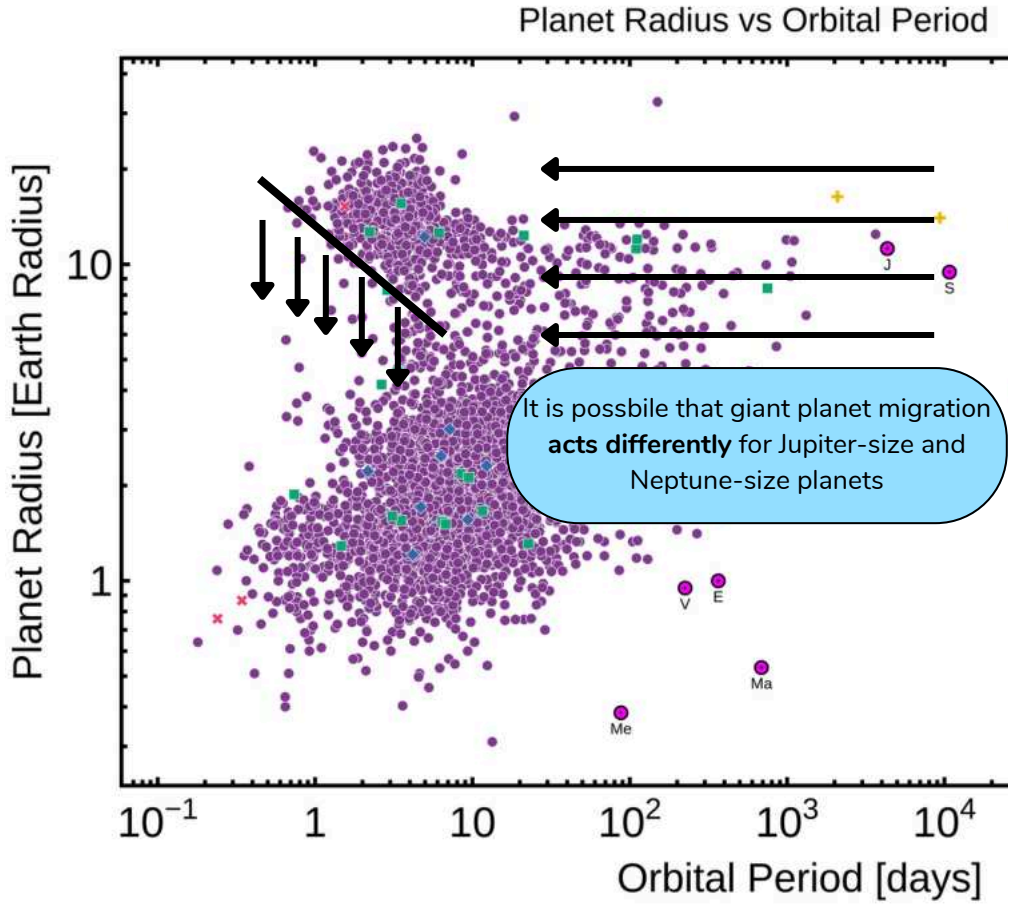
High-energy radiation (X-ray and EUV) is thought to be able to **completelly strip** a H/He-dminated **planetary atmosphere**



Context

What **we think** about the desert ....

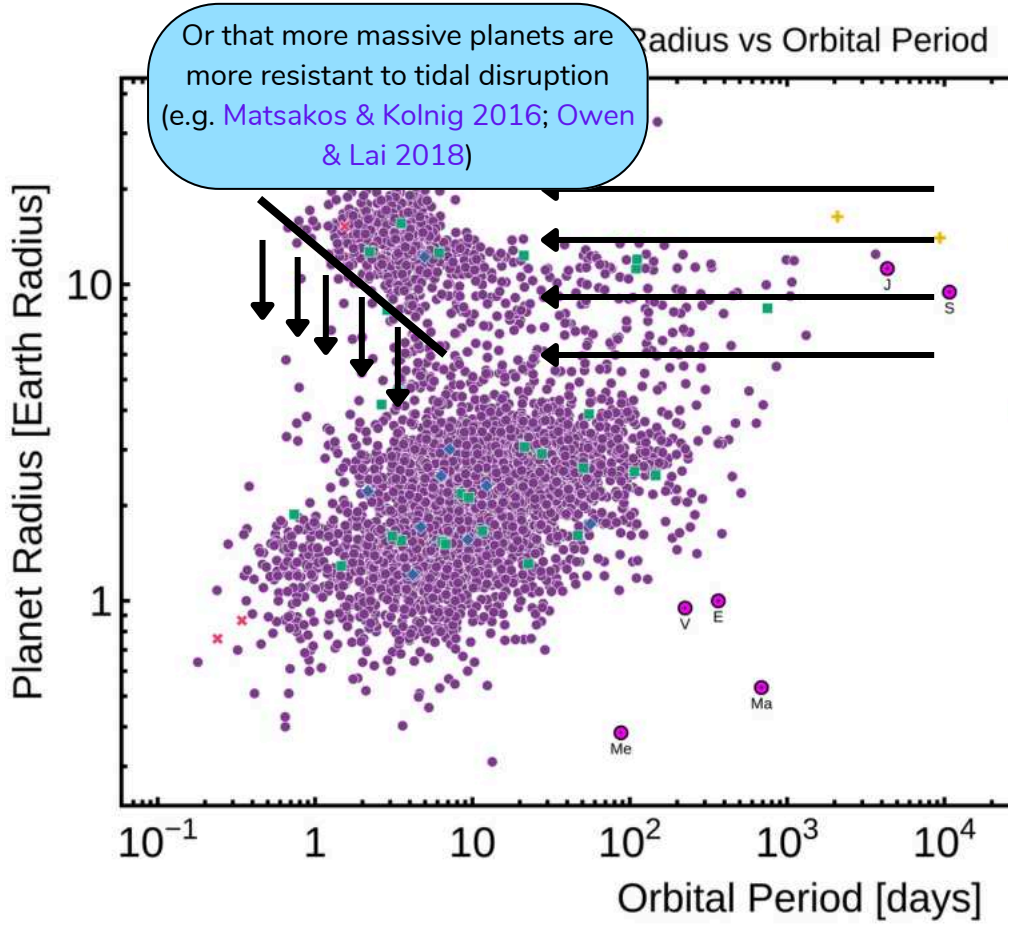
- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



Context

What **we think** about the desert ....

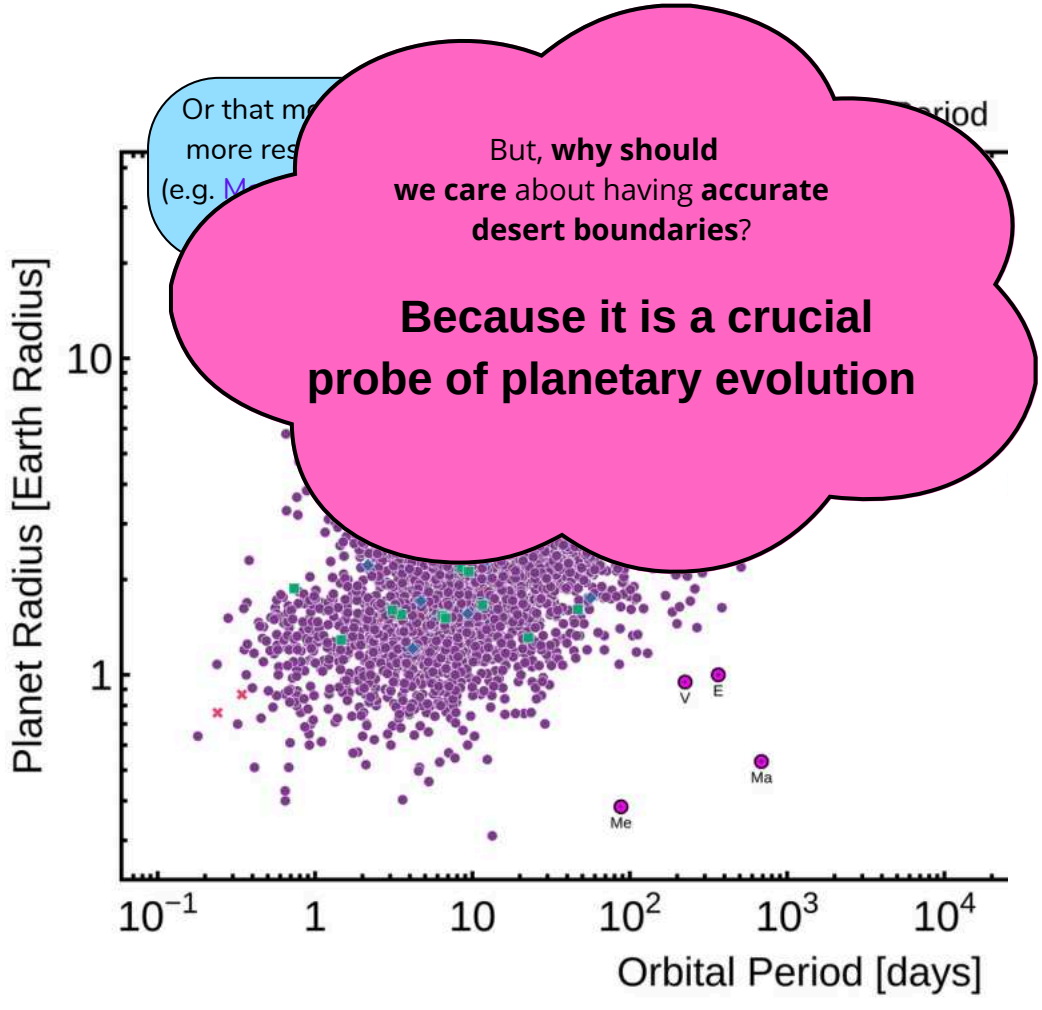
- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



Context

What **we think** about the desert ....

- It is **not** a **direct outcome** of **planet formation**
- It can be partially shaped by **atmospheric erosion**
- It can be partially shaped by **migration processes**



Mapping the exo-Neptunian landscape

Mapping the exo-Neptunian landscape

Our three premises

- Population-based
- Self-consistent
- With no assumptions on its shape

Mapping the exo-Neptunian landscape

Our three premises

- Population-based
- Self-consistent
- With no assumptions on its shape

Mapping the exo-Neptunian landscape

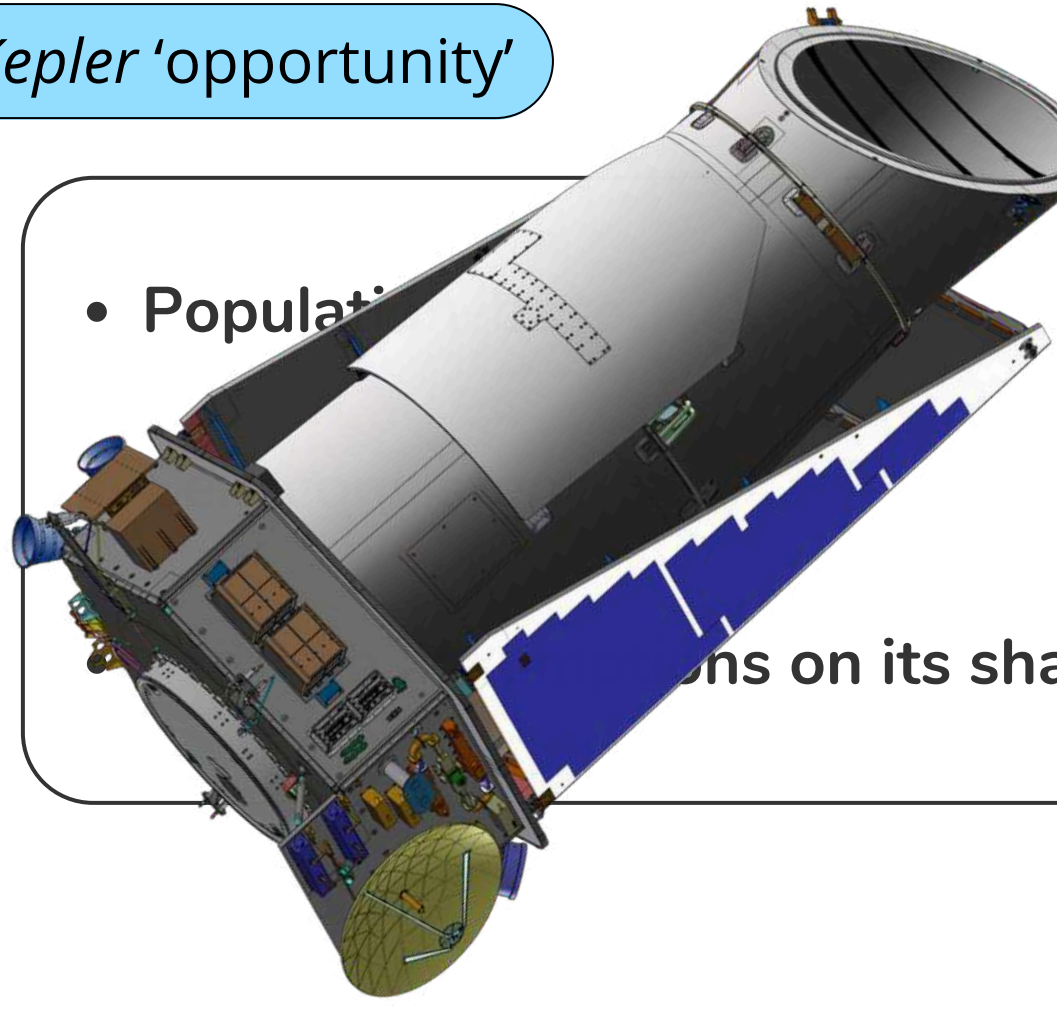
Our three premises

- Population-based
- Self-consistent
- With no assumptions on its shape

Mapping the exo-Neptunian landscape

Our three premises

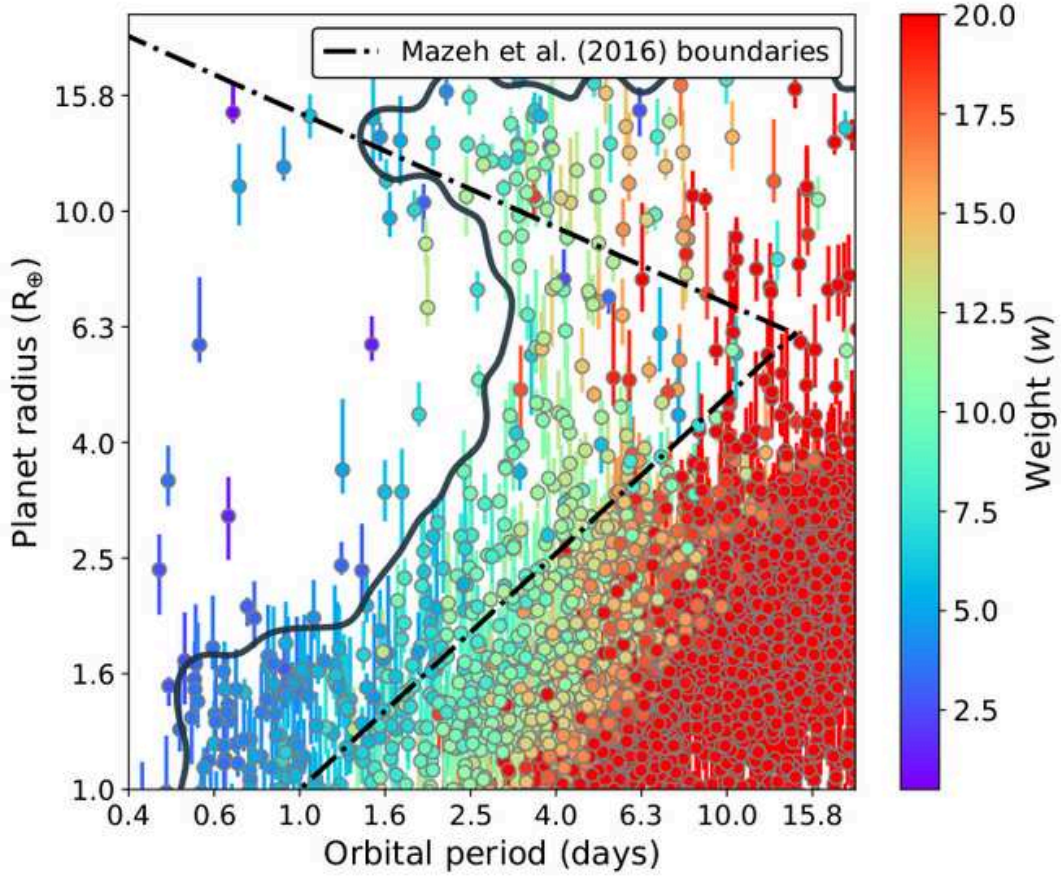
The *Kepler* 'opportunity'



- Populati
- ons on its shape

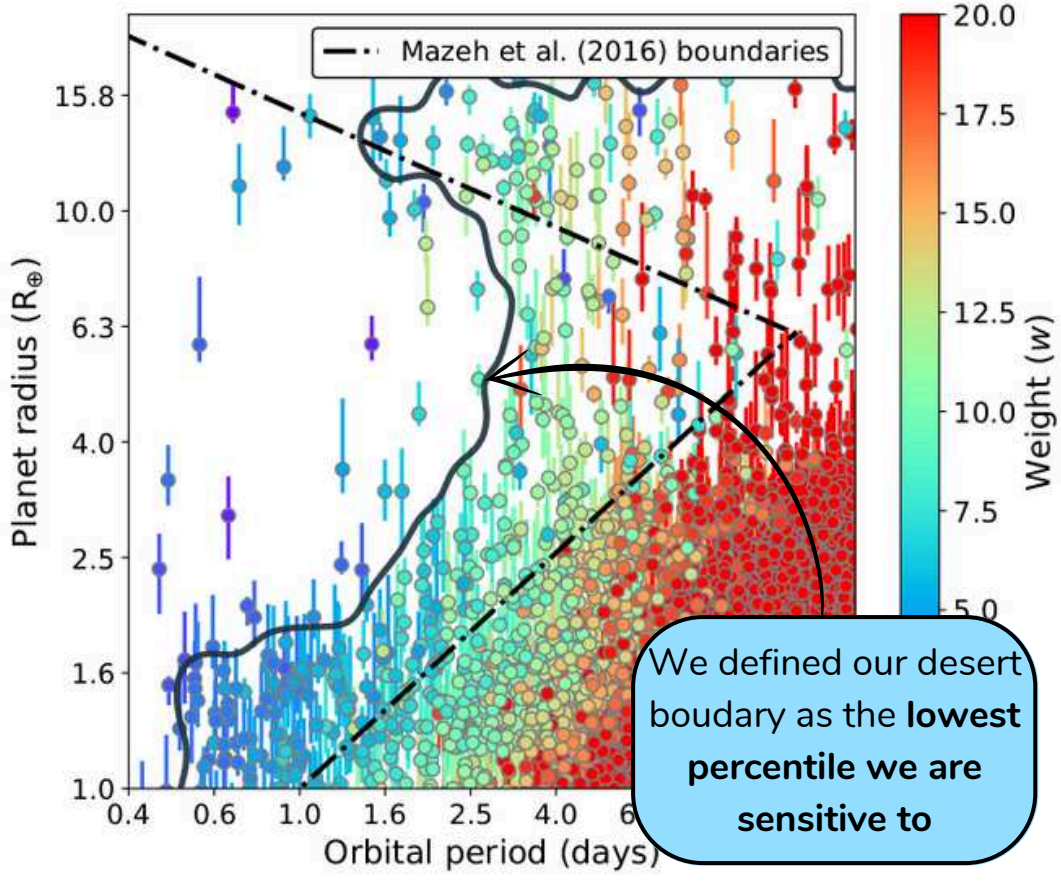
Mapping the exo-Neptunian landscape

Delineating the desert boundaries



Mapping the exo-Neptunian landscape

Delineating the desert boundaries

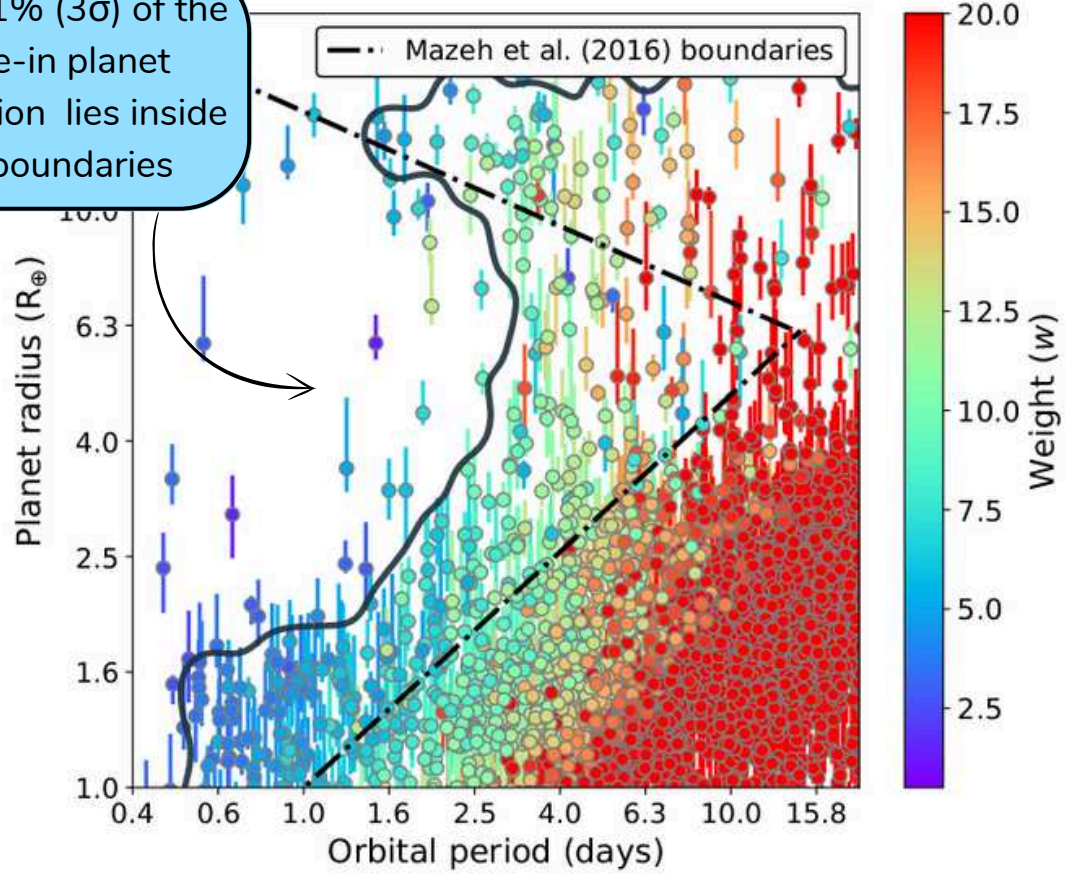


We defined our desert boudary as the **lowest percentile we are sensitive to**

Mapping the exo-Neptunian landscape

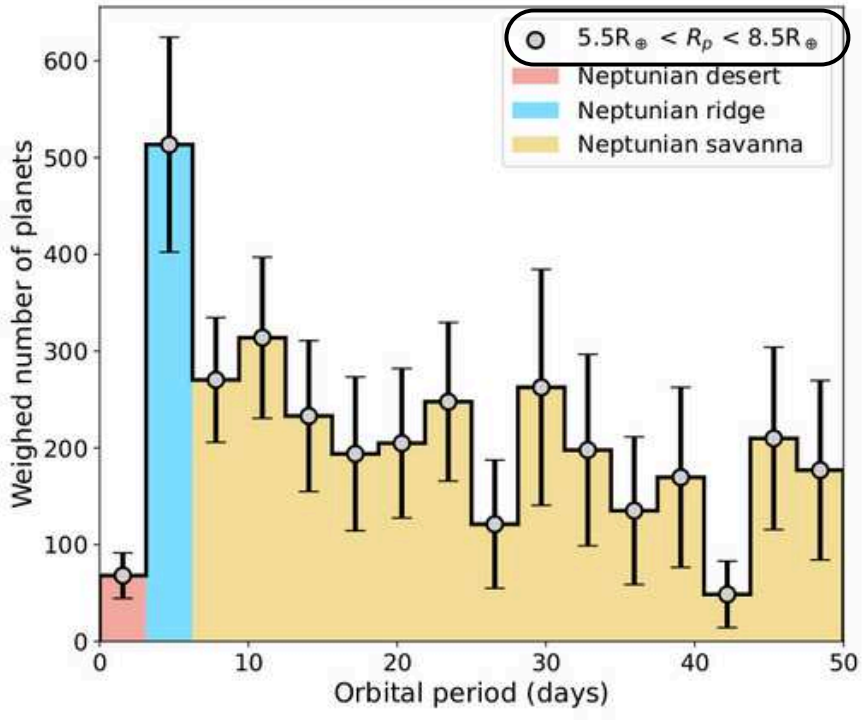
Delineating the desert boundaries

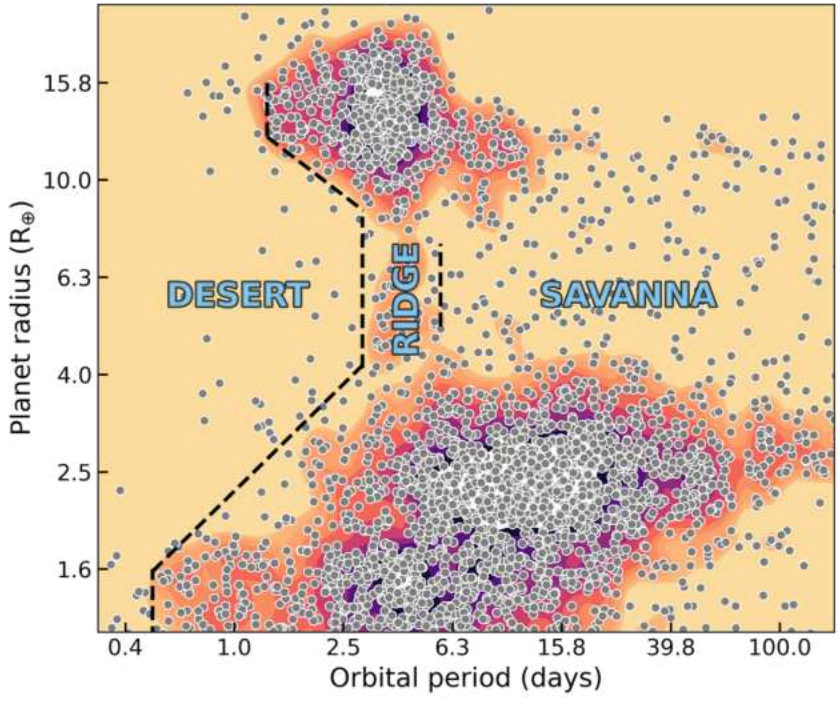
Only 0.1% (3σ) of the close-in planet population lies inside our boundaries



Mapping the exo-Neptunian landscape

Exploring the transition between the desert and savanna

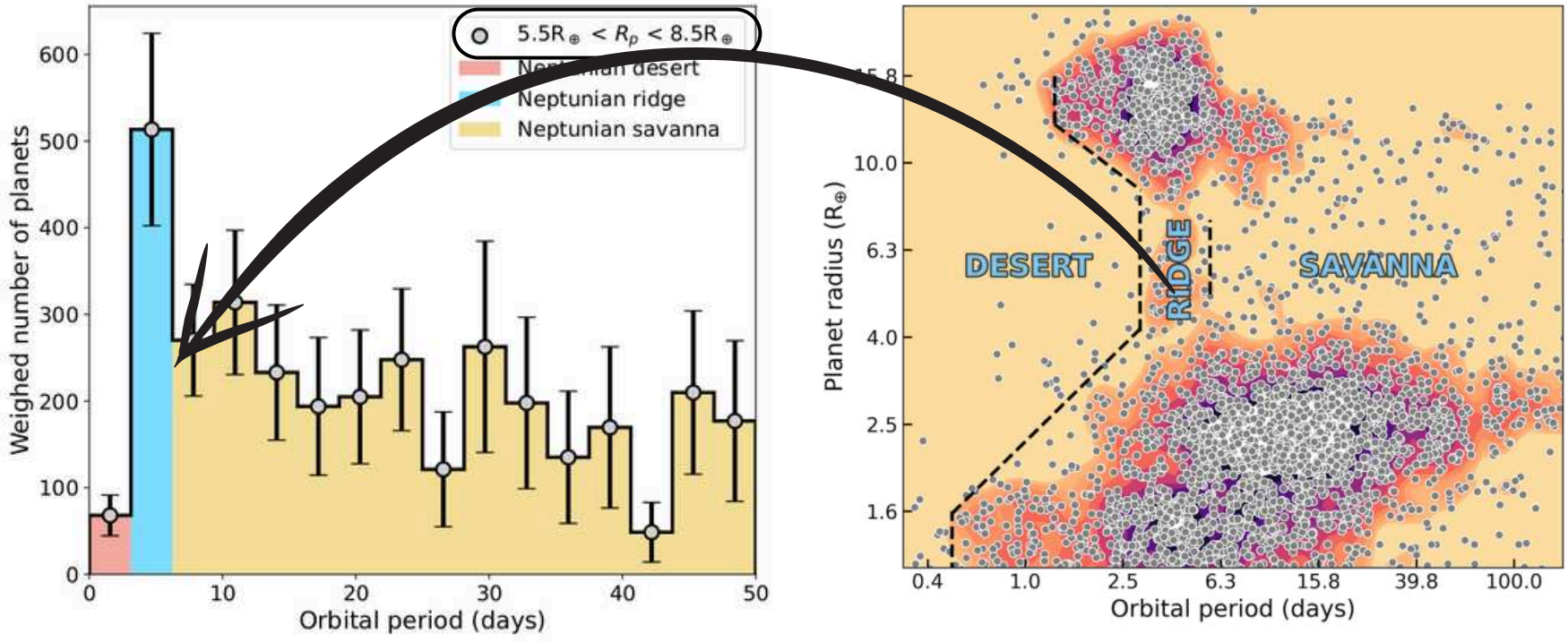




We identify an **over-density of planets** in the period range **~3.2-5.7 days**, particular to the Neptunian domain (i.e. ~$5.5R_\oplus$-$8.5R_\oplus$), which we refer to as the **Neptunian ridge**

Mapping the exo-Neptunian landscape

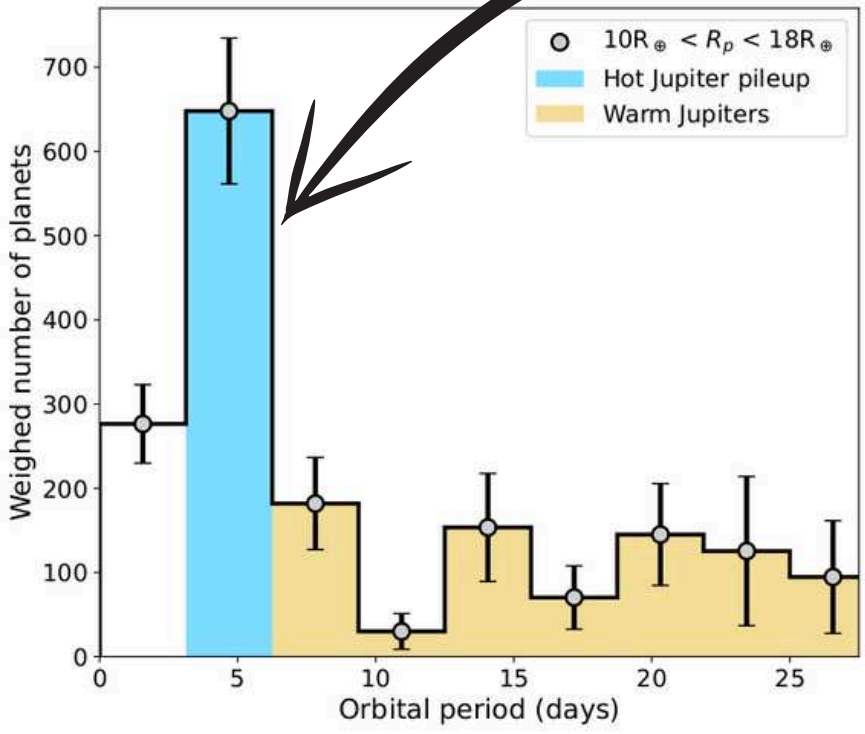
Exploring the transition between the desert and savanna

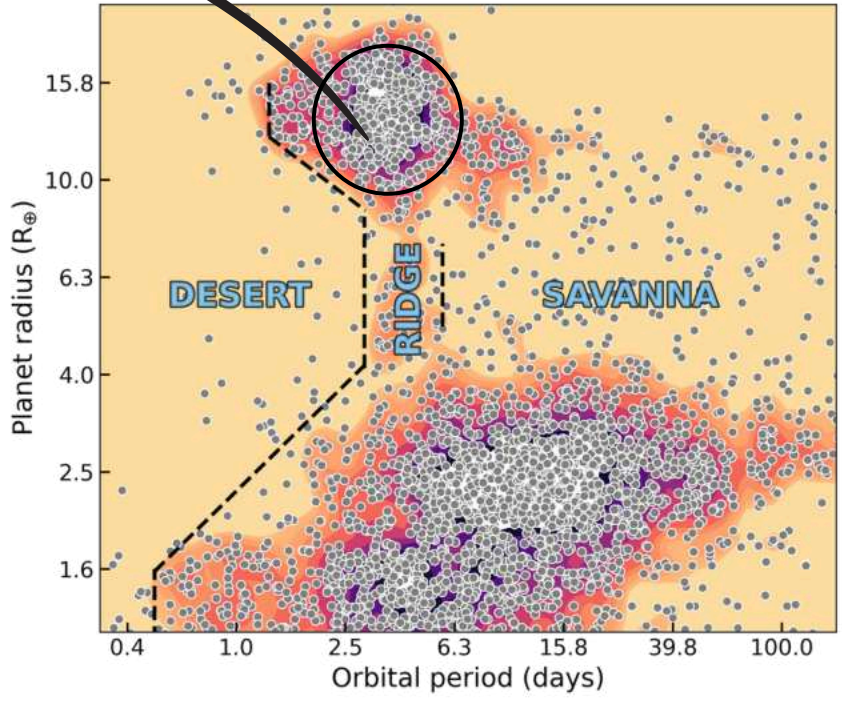


We identify an **over-density of planets** in the period range **~3.2-5.7 days**, particular to the Neptunian domain (i.e. ~5.5$R_\oplus$-8.5$R_\oplus$), which we refer to as the **Neptunian ridge**

Mapping the exo-Neptunian landscape

Exploring the transition between the desert and savanna





Notably, the period range of the ridge **perfectly matches the period range of the hot Jupiter pileup** (3-6 days; Cumming et al. 1999; Udry et al. 2003), suggesting that **similar evolutionary processes might be acting in both populations**

Mapping the exo-Neptunian landscape

Other ridge-related results (**before** the ridge)

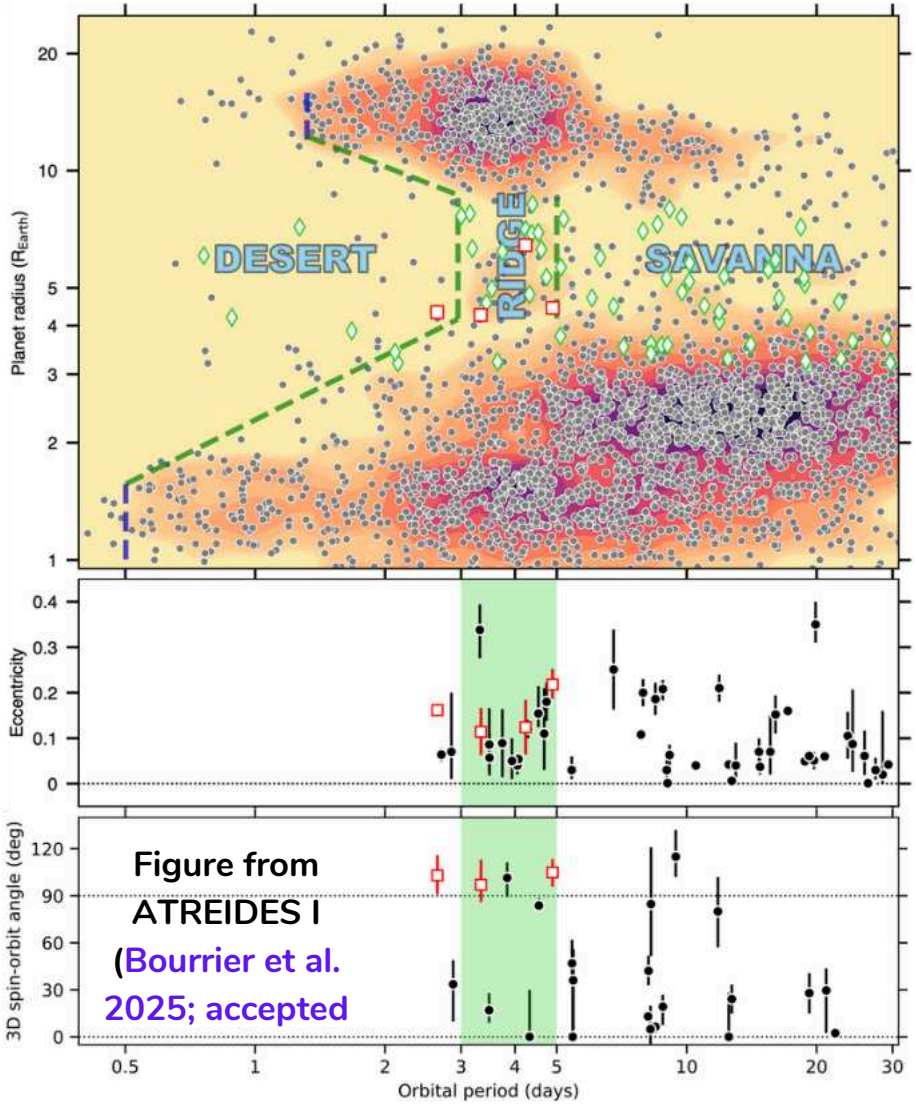


Figure from ATREIDES I (Bourrier et al. 2025; accepted

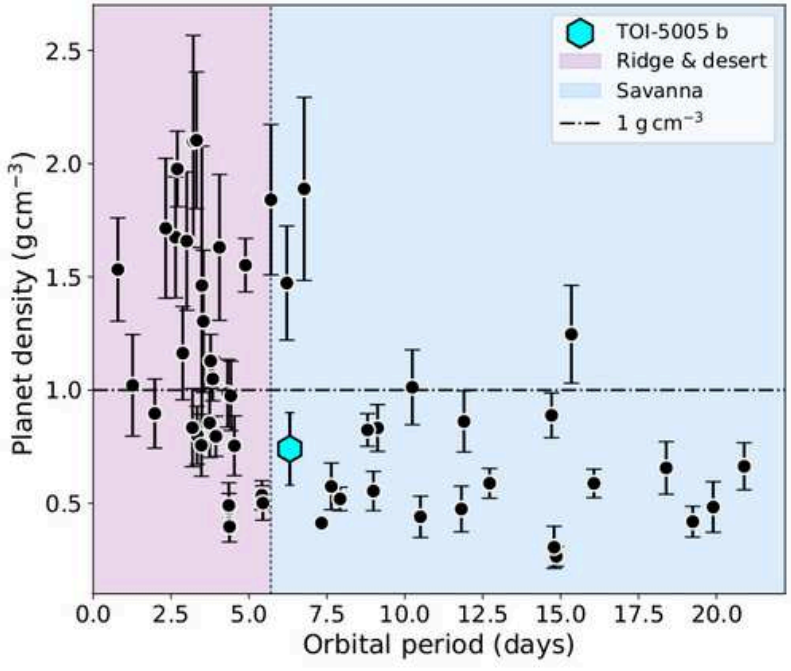
Planets in the ridge present **small but non-zero eccentricities** (Correia et al. 2020)

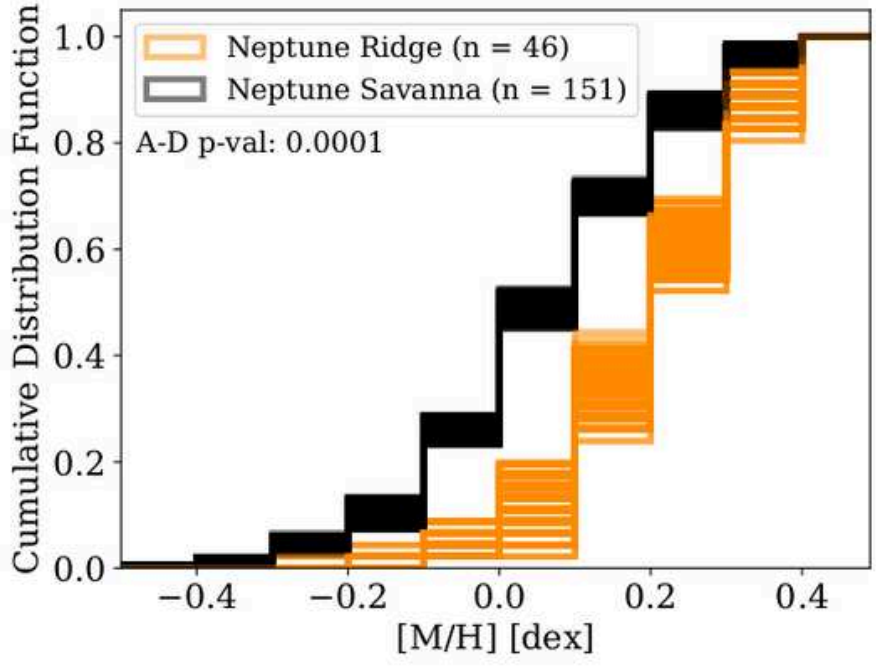
Ridge planets present **misaligned orbits more frequently** (Bourrier et al. 2023)

These two tentative features suggest that **high-eccentricity tidal migration (HEM) might be preferentially bringing Neptunes towards the ridge**

Mapping the exo-Neptunian landscape

Other ridge-related results (**after** the ridge)





Planets in the ridge typically show **larger densities** than in the savanna (Castro-González et al. 2024c)

Ridge planets are hosted by stars with **higher metallicities** than savanna's (Vissapragada et al. 2025)

Conclusions

- We determined accurate, population-based boundaries for the Neptunian desert in the period-radius plane
- We identified an overdensity of Neptunian planets with orbital periods between ~3 and ~6 days, which we call the Neptunian ridge
- The Neptunian ridge suggests a common path in the evolution of the closest giant planets, from Neptune to Jupiter sizes (HEM, ...?)
- The HEM hypotesis will be studied with an obliquity census of close-in Neptunes (ATREIDES; Bourrier et al. 2025)