A Study of the Radius Cliff

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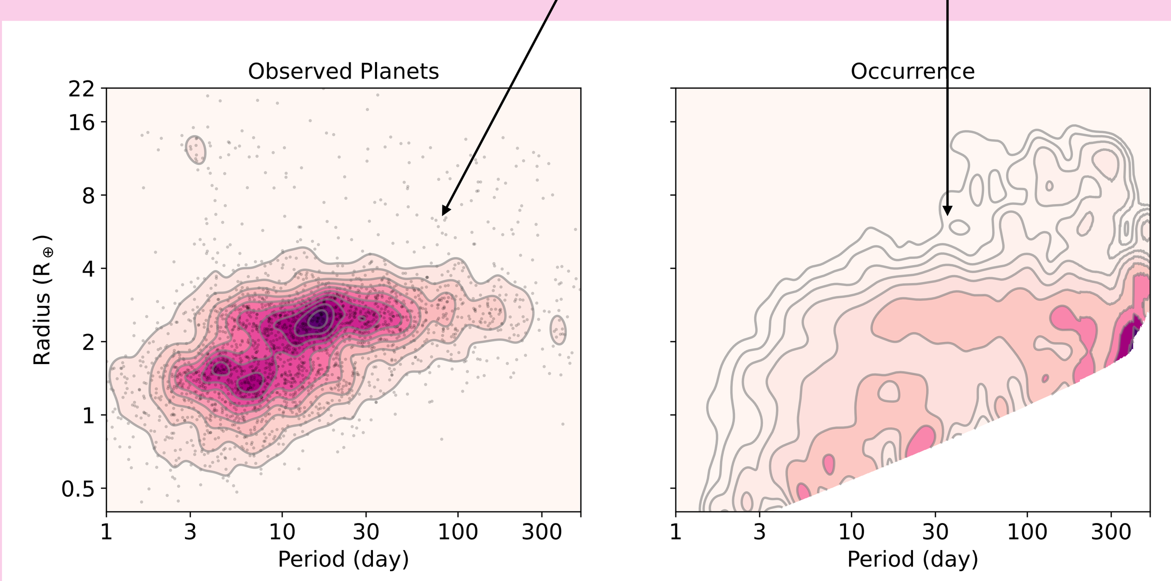
The Radius Cliff is the horizontal drop off in planet occurrence, ranging from 3-4 Re.

It is apparent in both the observed and in the intrinsic population

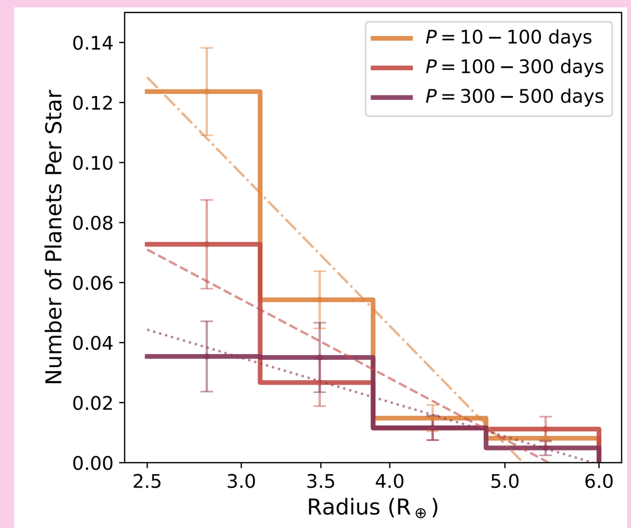


With the method of Dattilo et al. (2023), we measure occurrence of Kepler FGK stars, using the DR25 planet catalog.

We include reliability measurements for each planet, pipeline and vetting completeness for our stellar sample, and stellar parameters derived from Gaia DR2 to compute occurrence with a kernel density estimator.

For this study, we focus on occurrence from 10–500 days and 2.5–6 Re.

By measuring the cliff slope across different orbital period bins, we can get a 2D measure of the cliff shape.

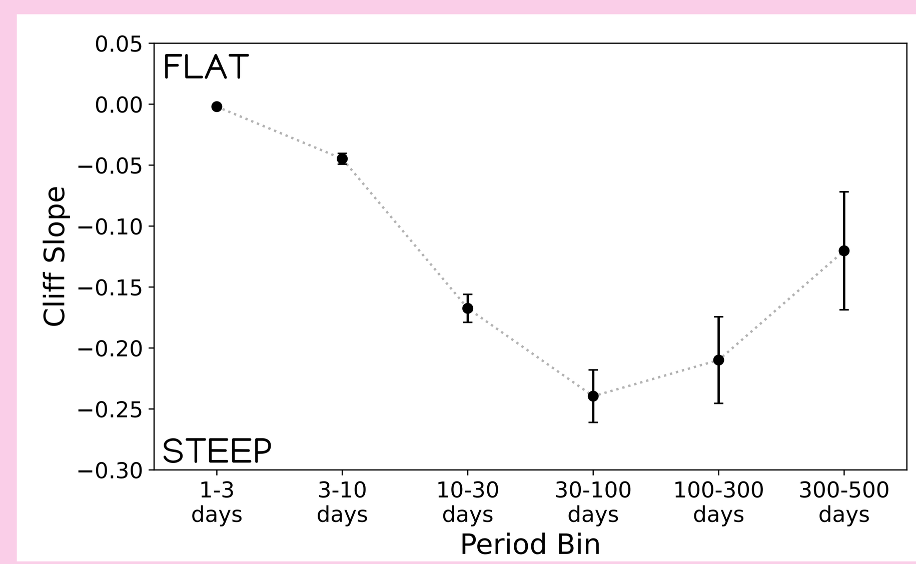


Left: the radius distribution for different period bins. We fit each radius distribution with a line to find the slope of the radius cliff.

Below, we compare the slope measured for each period bin to measure the shape of the radius cliff.

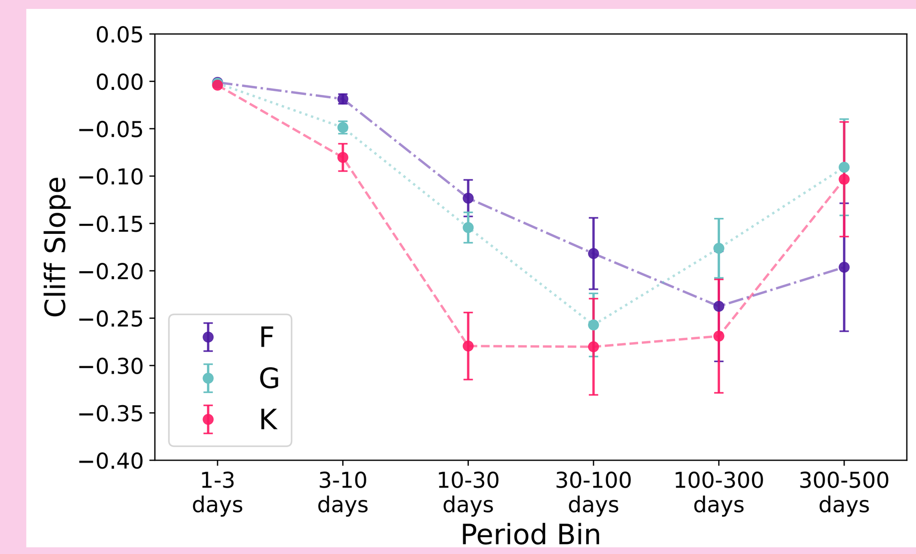
Right: each point is the slope of the cliff for each period bin.

The steepest part of the cliff is past the edge of the Neptune desert, at 30–100 days.



While the Neptune desert shapes the cliff at short orbital periods, the cliff becomes progressively more flat at long orbital period.

The cliff is not flat across period or insolation!



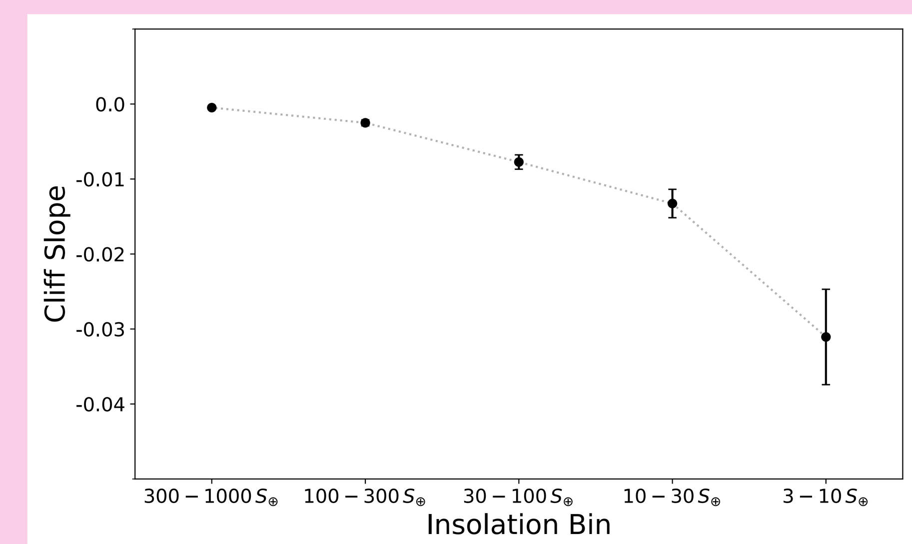
Left: we split the previous figure into 3 stellar type bins based on T_{eff}.

The shape of the cliff differs across stellar type: the steepest slope is at shorter periods for cooler stars.

We also compute occurrence as a function of insolation-radius space.

Right: FGK cliff slope as a function of insolation bins (rather than period bins, as above)

The cliff remains relatively flat until low insolation.



The cliff shape is more flat in insolation than in period, indicating that the shape of the radius cliff is dependent on integrated flux.

So what are some possible causes of the cliff shape?

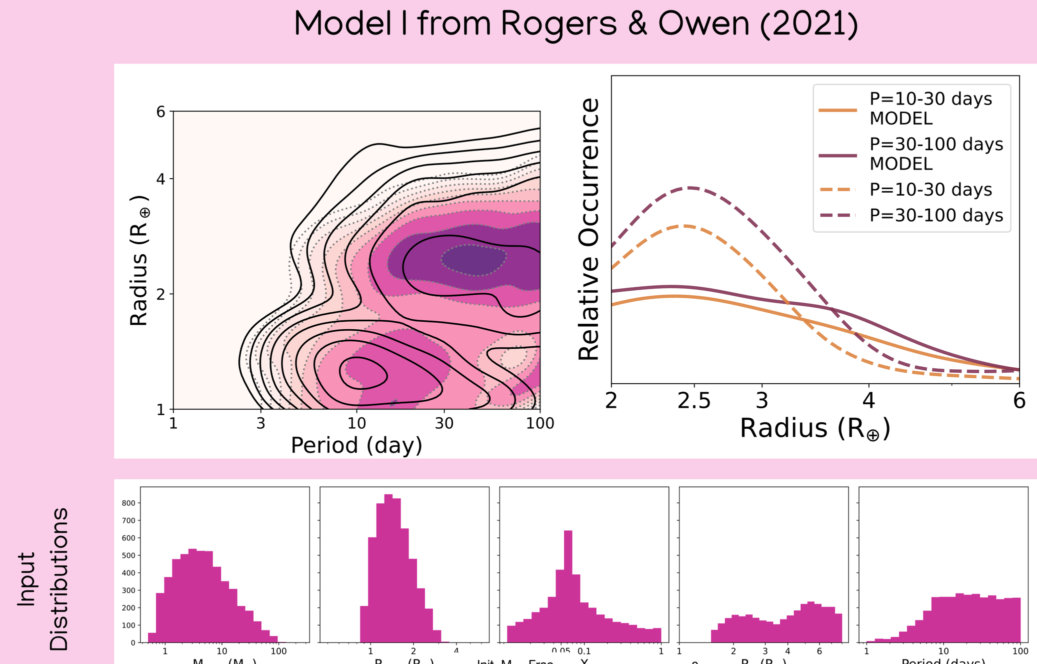
- Weakening atmospheric mass loss processes
  - These processes shape the bottom edge of the Neptune desert
- Chemical processes in the sub-Neptune core/atmosphere boundary
  - The fugacity crisis limits the size of the envelope (Kite et al. 2019)
- Formation or migration limits

Current models of the radius valley do not replicate the cliff shape:

We evolve a population of 5,000 planets (with varying characteristics) for 3 Gyr of atmospheric mass loss* based on current theoretical models of the radius valley.

Photoevaporation

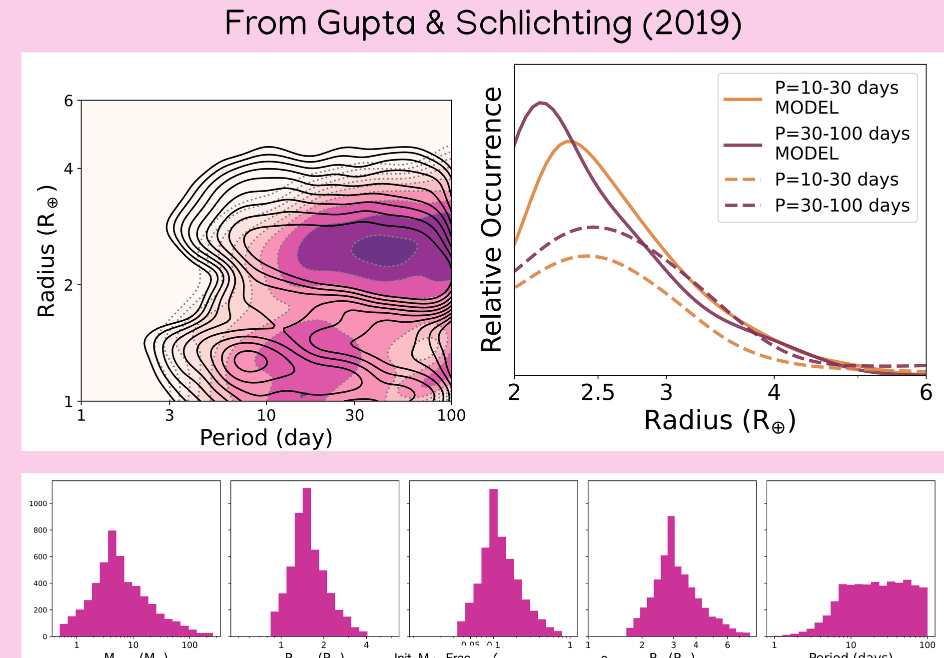
Model I from Rogers & Owen (2021)



The peak of the distribution is the super-Earths, not the sub-Neptunes, but is highly dependent on the initial core mass distribution.

Core-Powered Mass Loss

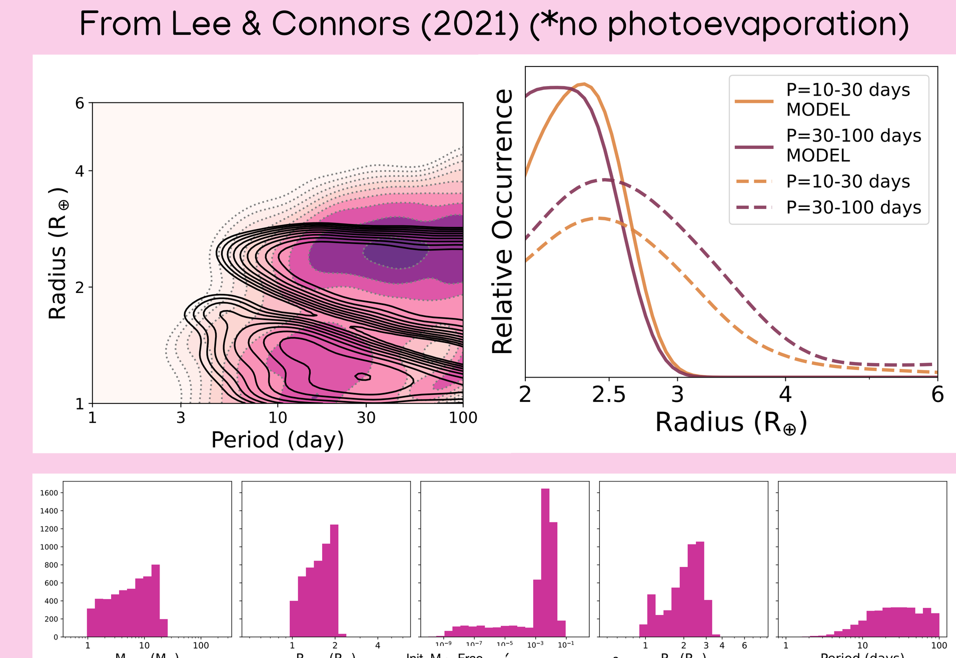
From Gupta & Schlichting (2019)



The peak of the distribution is also the super-Earths, but the slope of the radius cliff is a much better match than the other models.

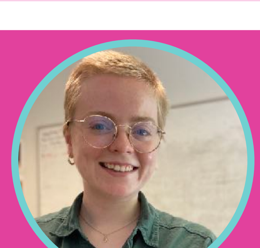
Formation

From Lee & Connors (2021) (*no photoevaporation)



The initial atmospheres are determined as a function of maximum isothermal mass based on the core mass. The sub-Neptunes do not gain enough atmospheric mass in this model to reproduce the larger planets.

While the radius cliff may be a by-product of atmospheric mass loss, it is not likely to be produced by the same parameters that produce the radius valley.



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Citations:

Dattilo et al. (2023); in review ○ Berger et al. (2020) ○ Bryson et al. (2021) ○ Rogers & Owen (2021) ○ Gupta & Schlichting (2019) ○ Lee & Connors (2021) ○ Kite et al. (2019) ○ Burke & Catanzarite (2017)

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