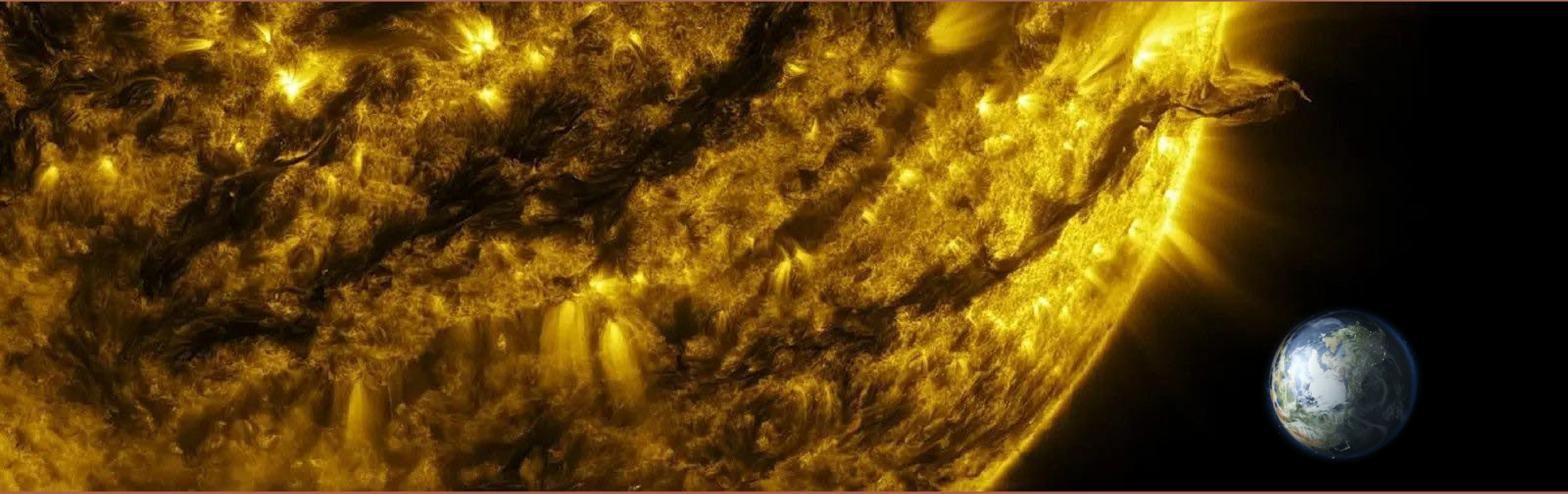
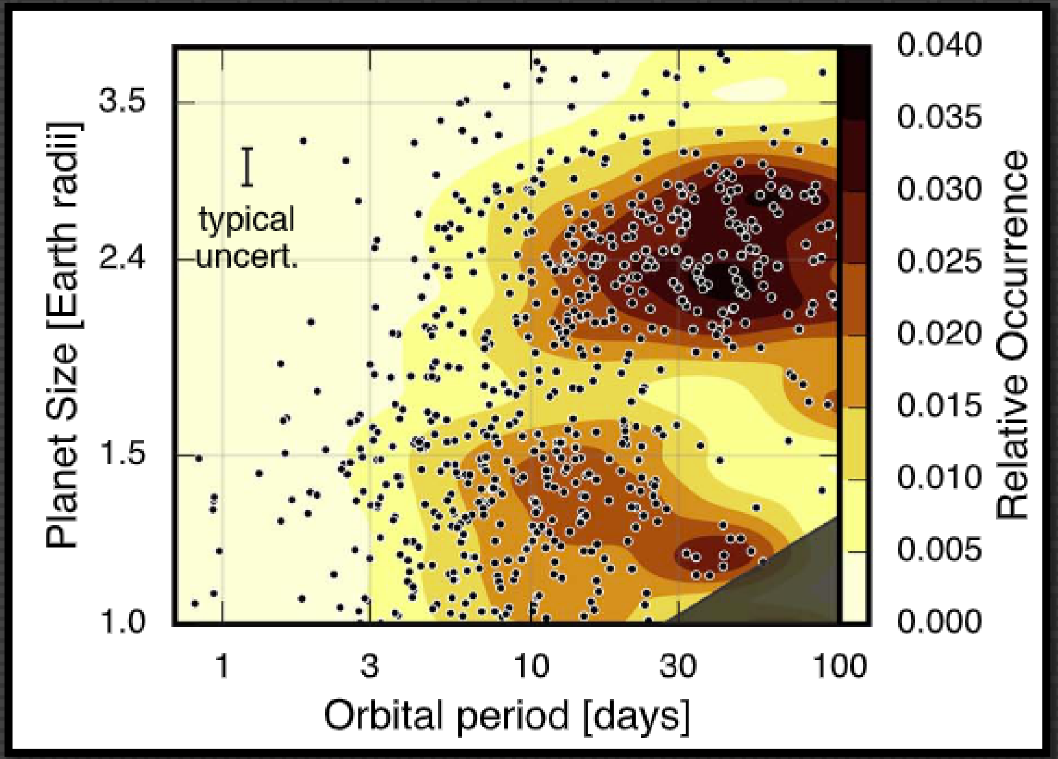


Image credit: NASA

STAR-PLANET INTERACTION AND SMALL PLANET DEMOGRAPHICS

Eve J. Lee
(UC San Diego)

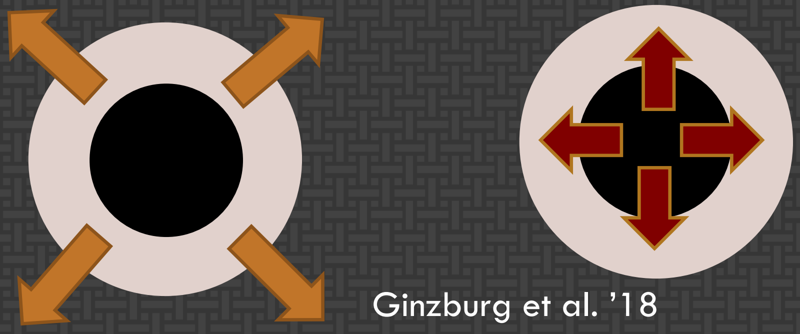
Rocky vs. gas-enveloped planets



Fulton & Petigura (2018)

See also van Eylen et al. (2018), Hsu et al. (2019)

Post-formation mass loss

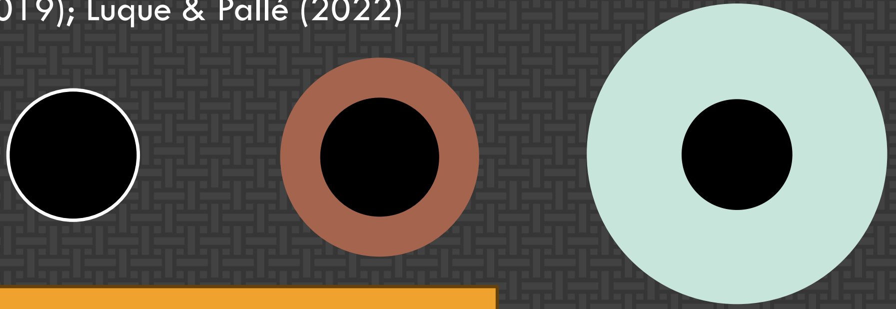


Owen & Wu ‘13, ‘17

Ginzburg et al. ’18
Gupta & Schlichting ‘20

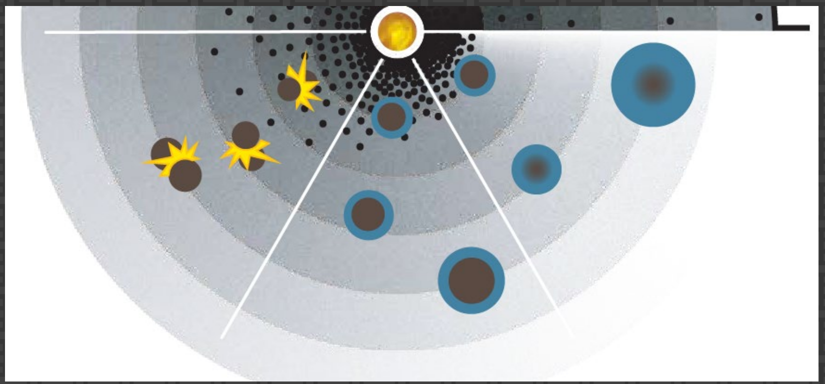
Rocky vs. waterworlds

Zeng et al. (2019); Luque & Pallé (2022)

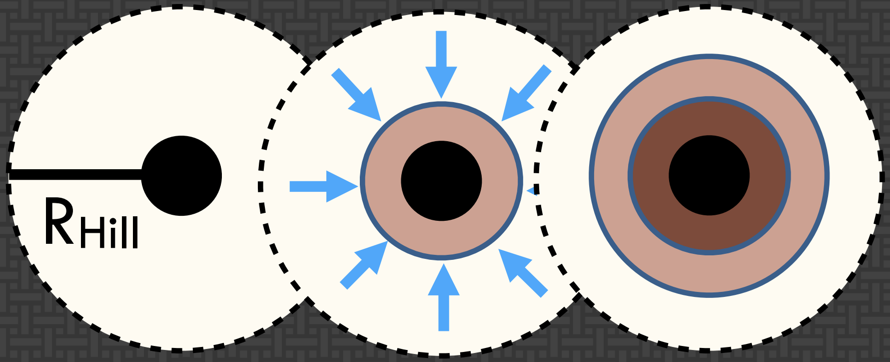


Late-time (gas-poor) formation

EJL & Connors ‘21
EJL, Karalis & Thorngren ‘22

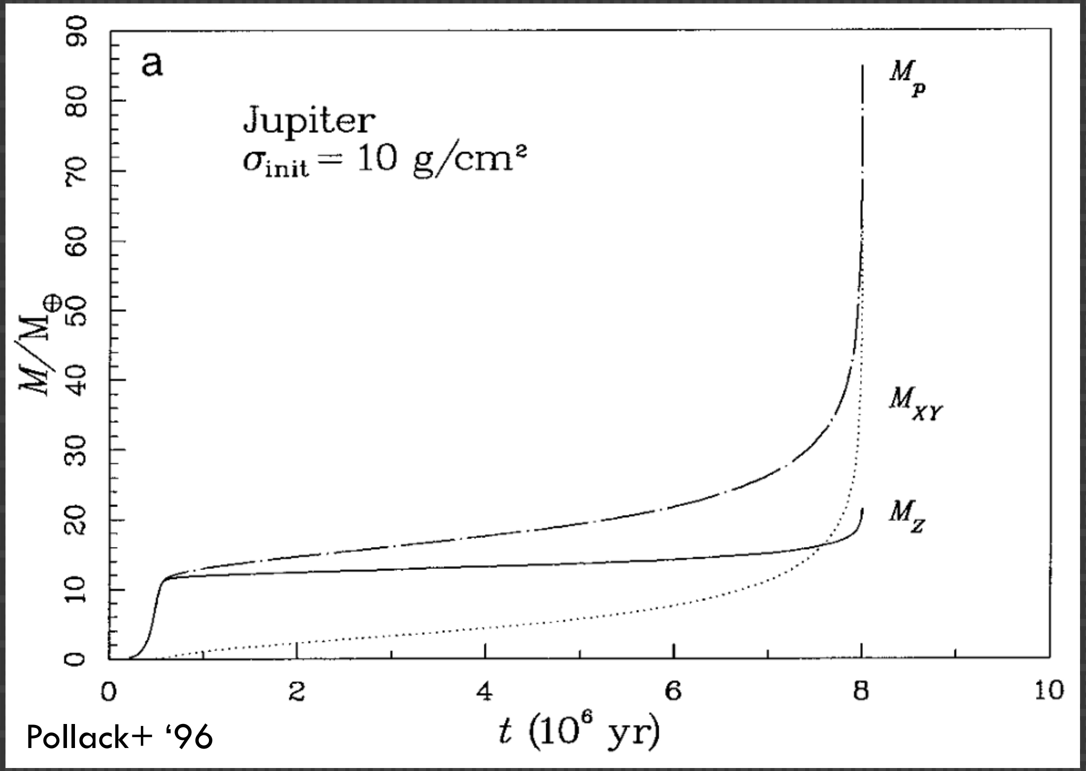


Late-time (gas-poor) formation

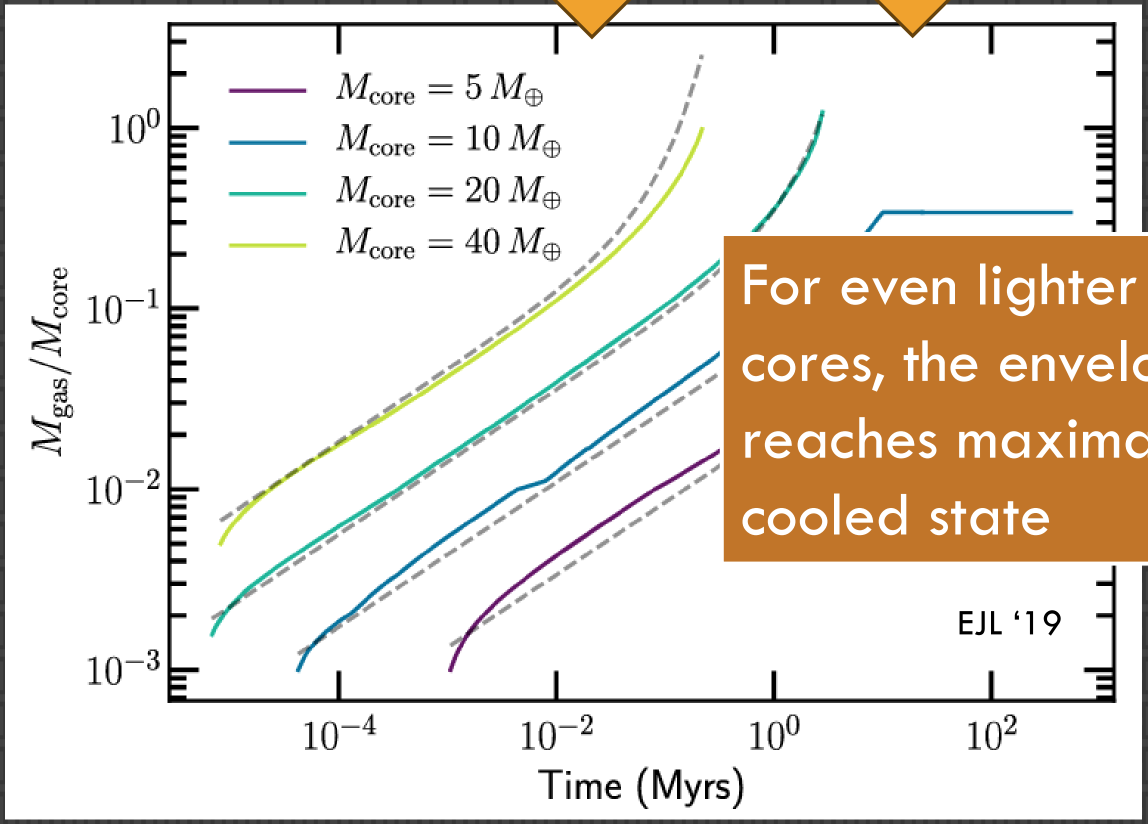


Gas atop massive cores cool & contract faster

Gas atop lighter cores cool & contrast more slowly

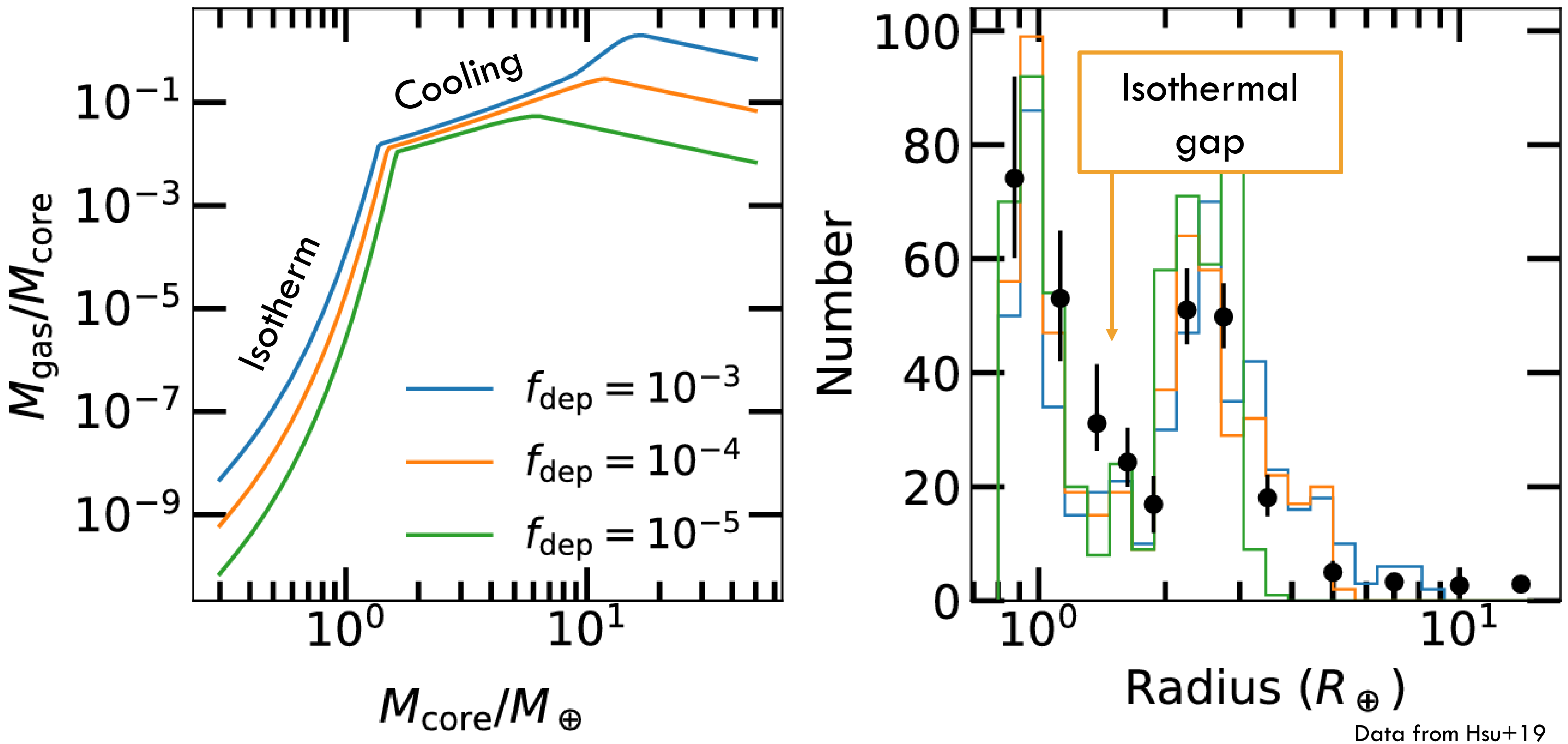


Pollack+ '96



For even lighter cores, the envelope reaches maximally cooled state

EJL '19



Data from Hsu+19

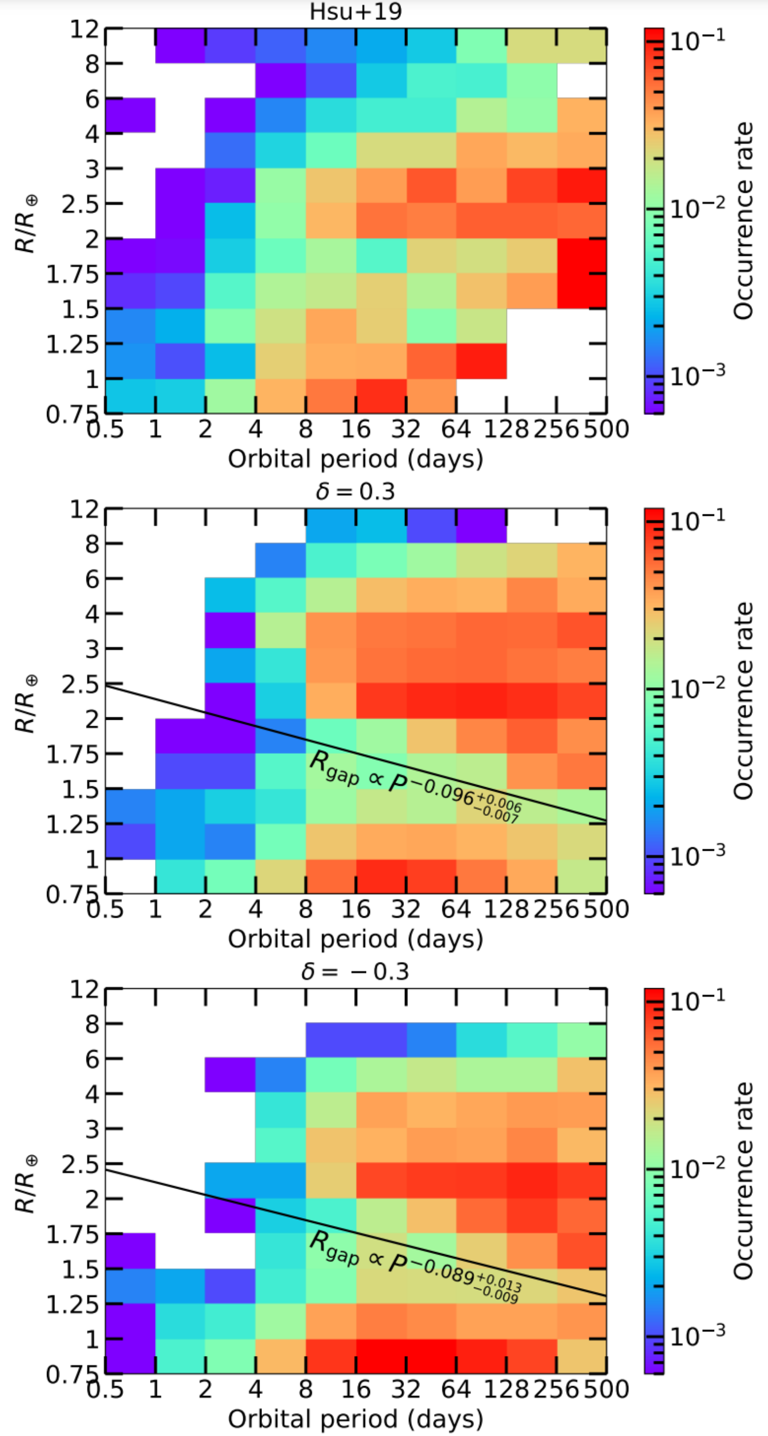
Lee & Connors (2021)
Lee, Karalis, & Thorngren (2022)

Formation alone can carve out the radius gap

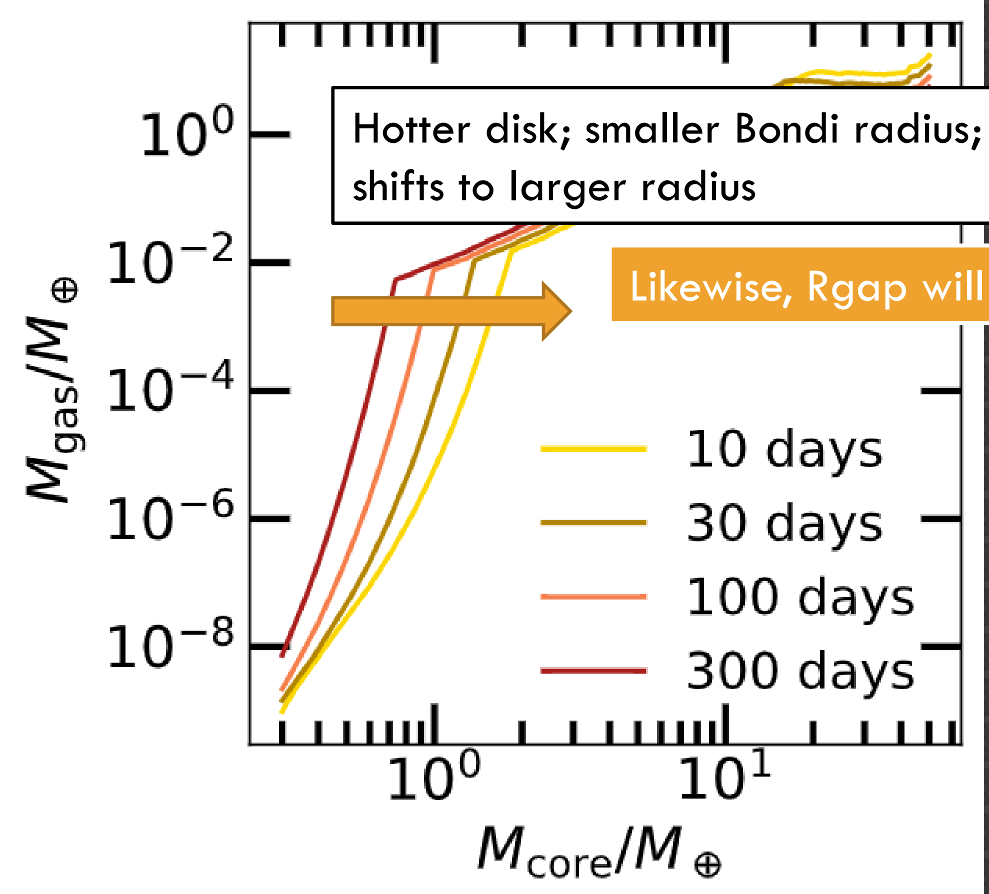
Observation

Top-heavy

Bottom-heavy



EJL, Karalis & Thorngren (2022)



Hotter disk; smaller Bondi radius; gap shifts to larger radius

Likewise, Rgap will rise for hotter stars

$$R_{gap} \propto P^{-0.10^{+0.02}_{-0.03}}$$

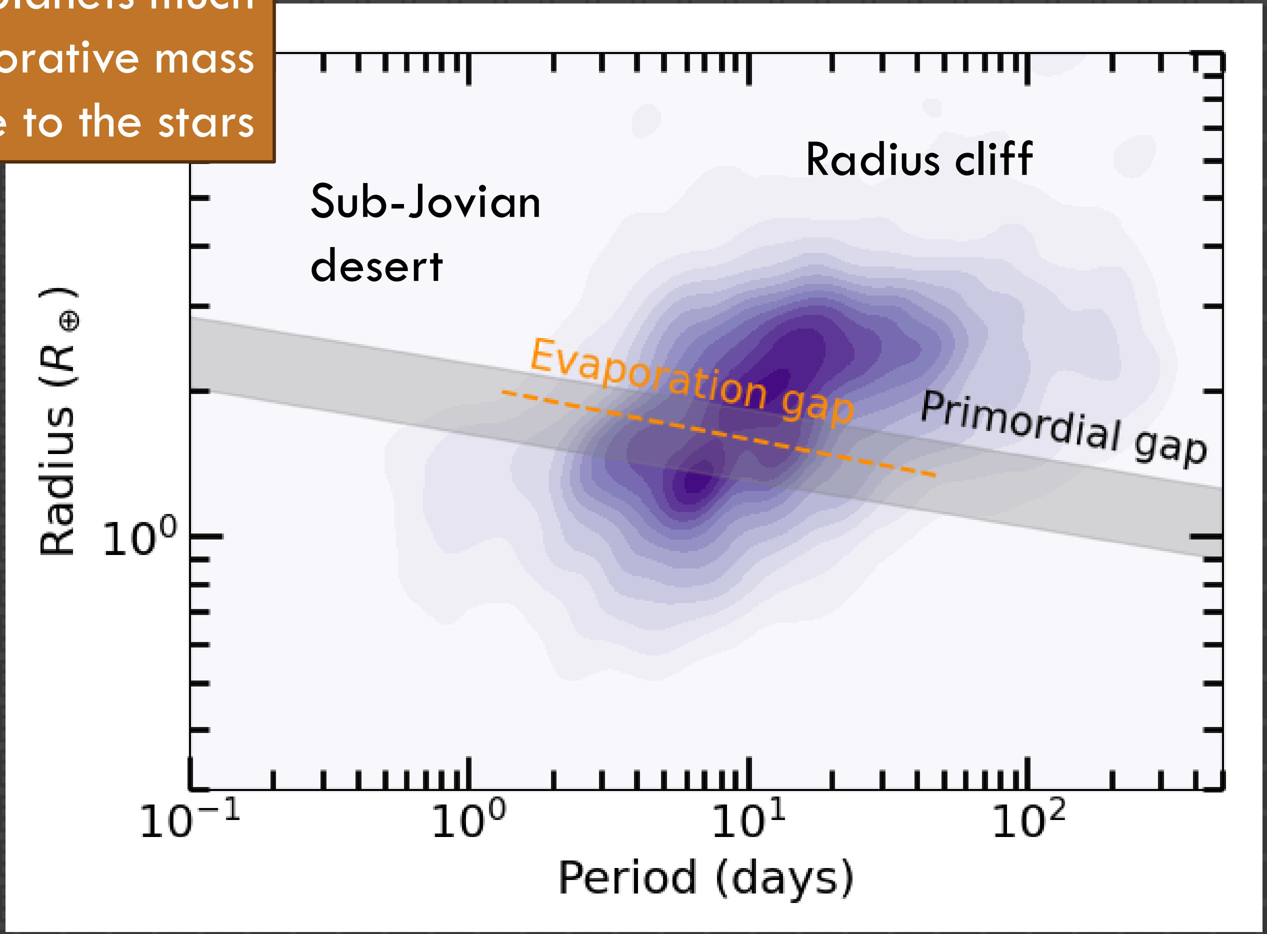
Ho & Van Eylen '23, Ho+ '24

To probe formation, need to go beyond ~30-100 days

The Edges and Deserts in Exoplanet Demographics

Saturns and smaller planets much more susceptible to evaporative mass loss, especially close to the stars

Owen & Lai '18,
Hallatt & EJL '22,
Thorngren, EJL & Lopez '23



EJL & Owen '25 (contour: raw data from NASA Exoplanet Archive)

The Maximum Mass of Rocky Planets

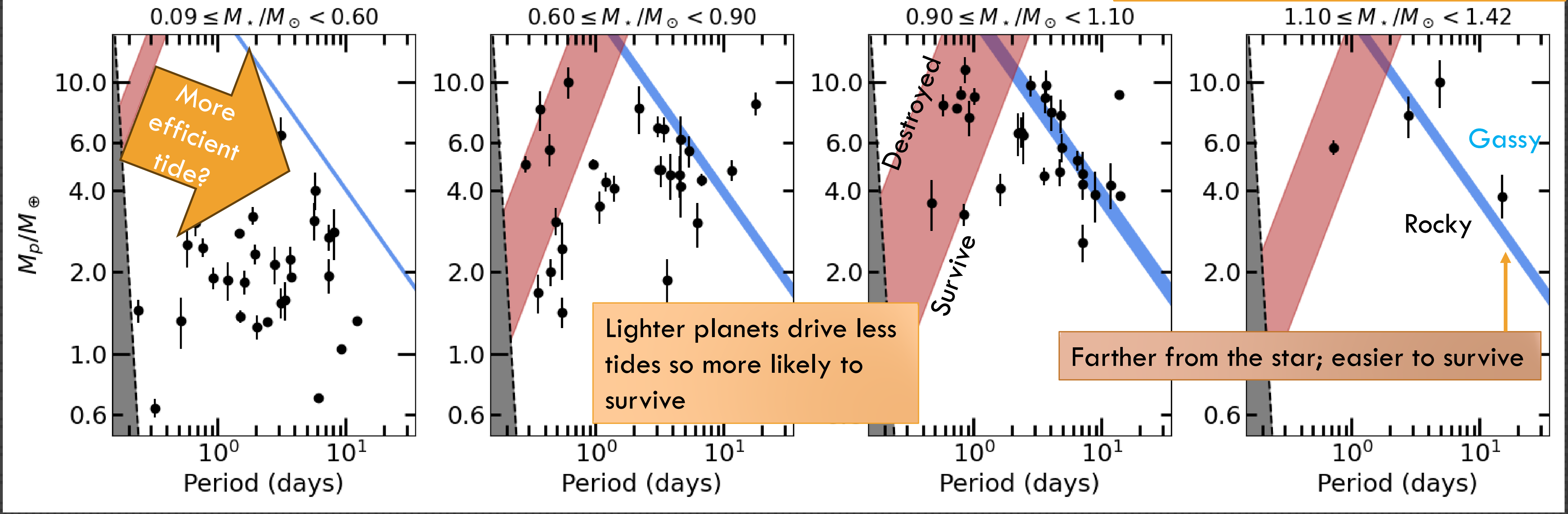
~10 Mearth for a wide range of stellar masses (Parc et al. '24)

Critical core mass for runaway? Not always 10 Mearth (see V. Savignac's talk)

Increases with Mstar

$$\frac{G M_p \dot{M}_{gas}}{R_p} = \frac{\eta}{4} L_{XUV} \left(\frac{R_p}{a_p}\right)^2$$

At same P, also increases with Mstar



More efficient tide?

Lighter planets drive less tides so more likely to survive

Farther from the star; easier to survive

EJL & Owen '25 data from NASA Exoplanet Archive; <2 Rearth; precise mass measurement

$$\dot{a} = -\frac{9}{2} a^{-11/2} G^{1/2} \frac{M_p}{M_*^{1/2}} \frac{R_*^5}{Q'_*}$$

The Edges and Deserts in Exoplanet Demographics

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Owen & Lai ‘18,
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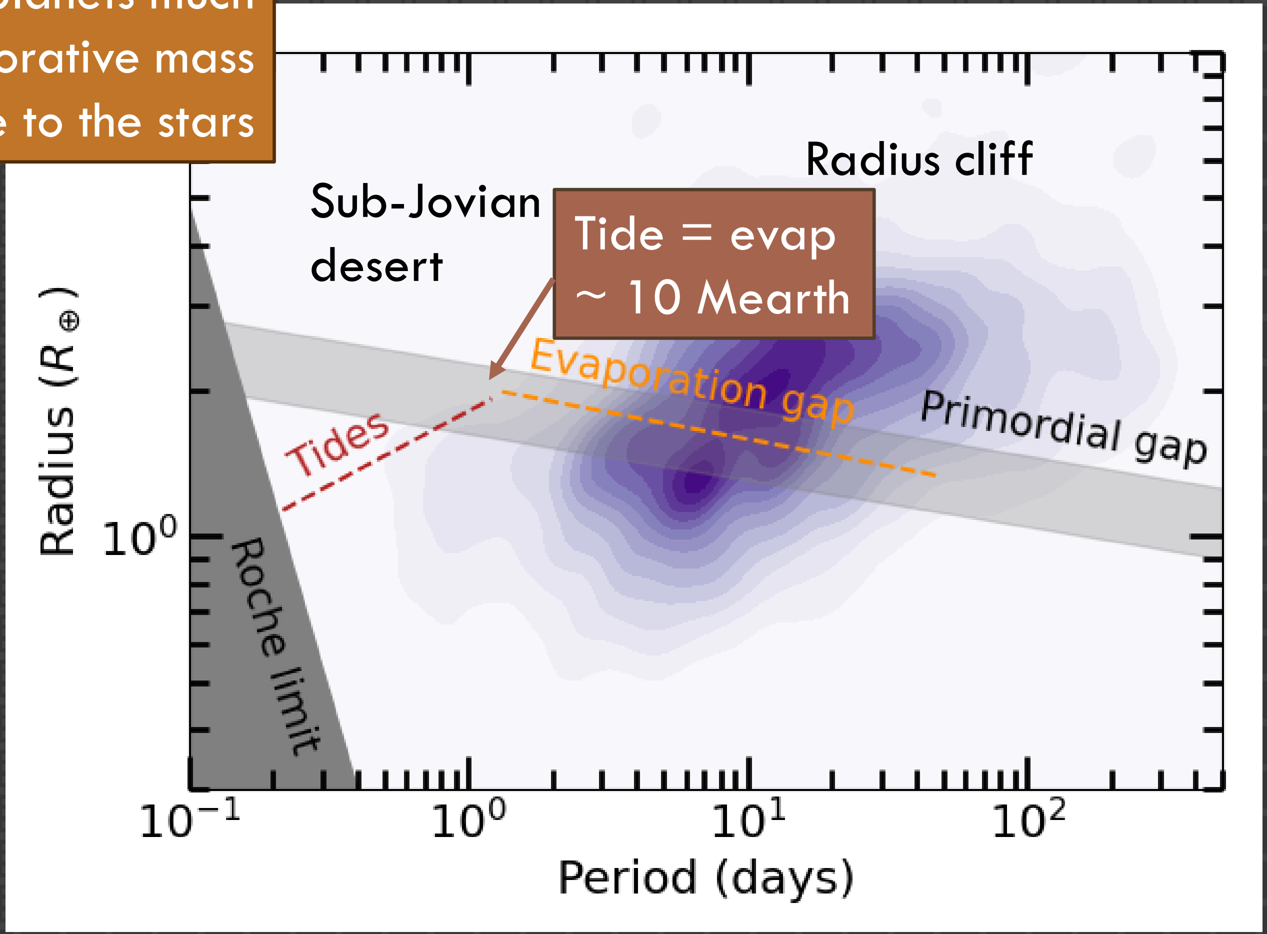
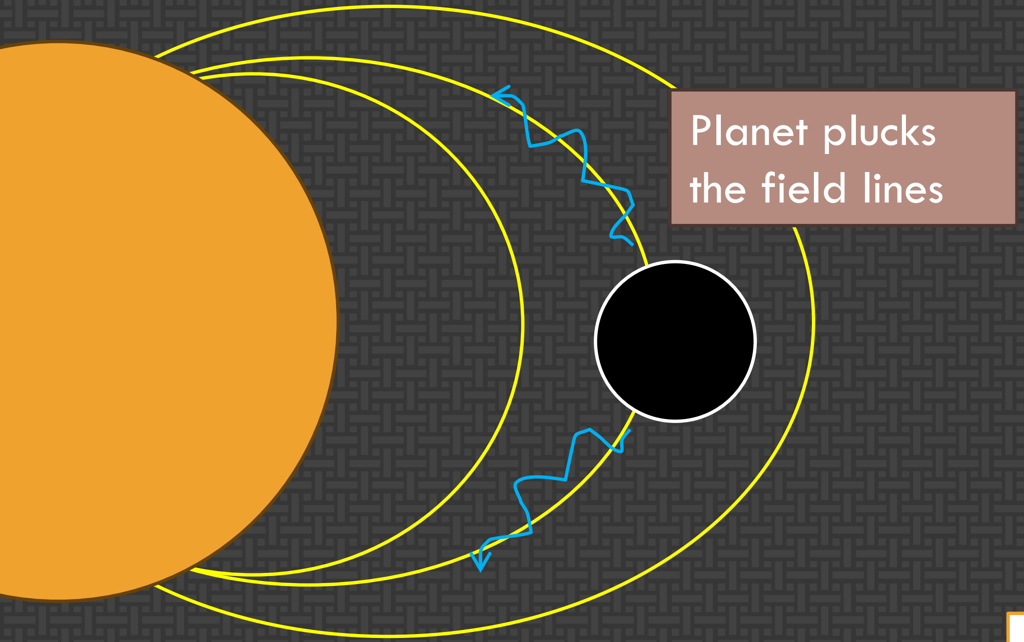


Tide = evap
~ 10 Mearth

EJL & Owen ’25 (contour: raw data from NASA Exoplanet Archive)

Physics of Magnetic Drag


Planet plucks the field lines

$$\nabla \times E = -\frac{1}{c}\frac{\partial B}{\partial t}$$

Induced E-field drives potential difference across the planet driving current

This is a circuit with the planet and the star as resistors! And this resistance causes heating

Cross-sectional area of radiator

Degree of twist in the field

$$P \sim \frac{32}{3\pi}\pi R_p^2 v_A \left(\frac{v_k}{v_A}\right)^2 \frac{B^2(a)}{8\pi} s$$

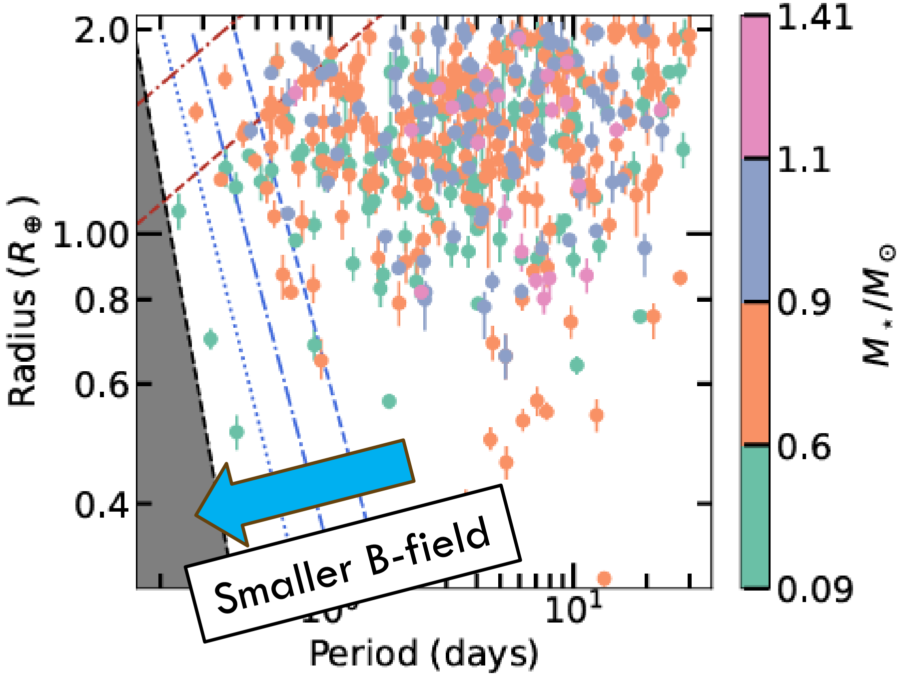
Speed of wave propagation

Magnetic energy density

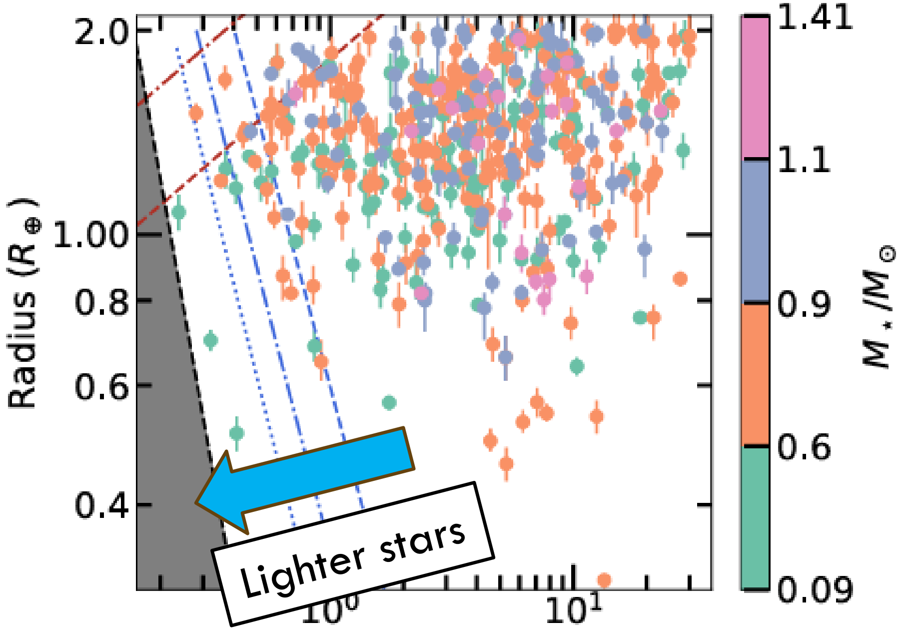
Loss of energy = orbital decay

Magnetic drag dominates over tides for sub-Earth USPs!

Cleaner probe of star-planet magnetic interaction



Smaller B-field

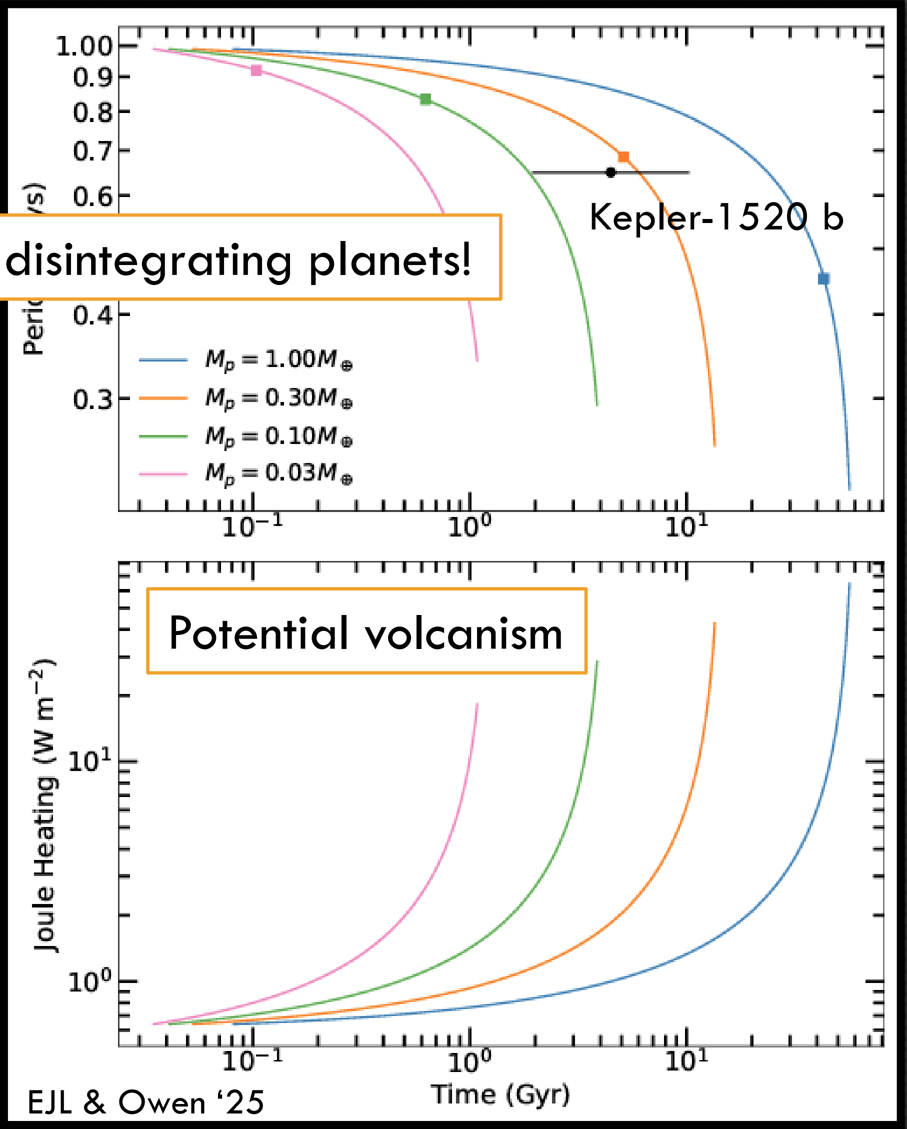


Lighter stars

EJL & Owen '25

$$B(a) = B_* \left(\frac{R_*}{a}\right)^3$$

Lighter stars are smaller so decays more at the same location



Could be progenitors of disintegrating planets!

Potential volcanism

EJL & Owen '25

The Edges and Deserts in Exoplanet Demographics

Simulation movie

Saturns and smaller planets much more susceptible to evaporative mass loss, especially close to the stars

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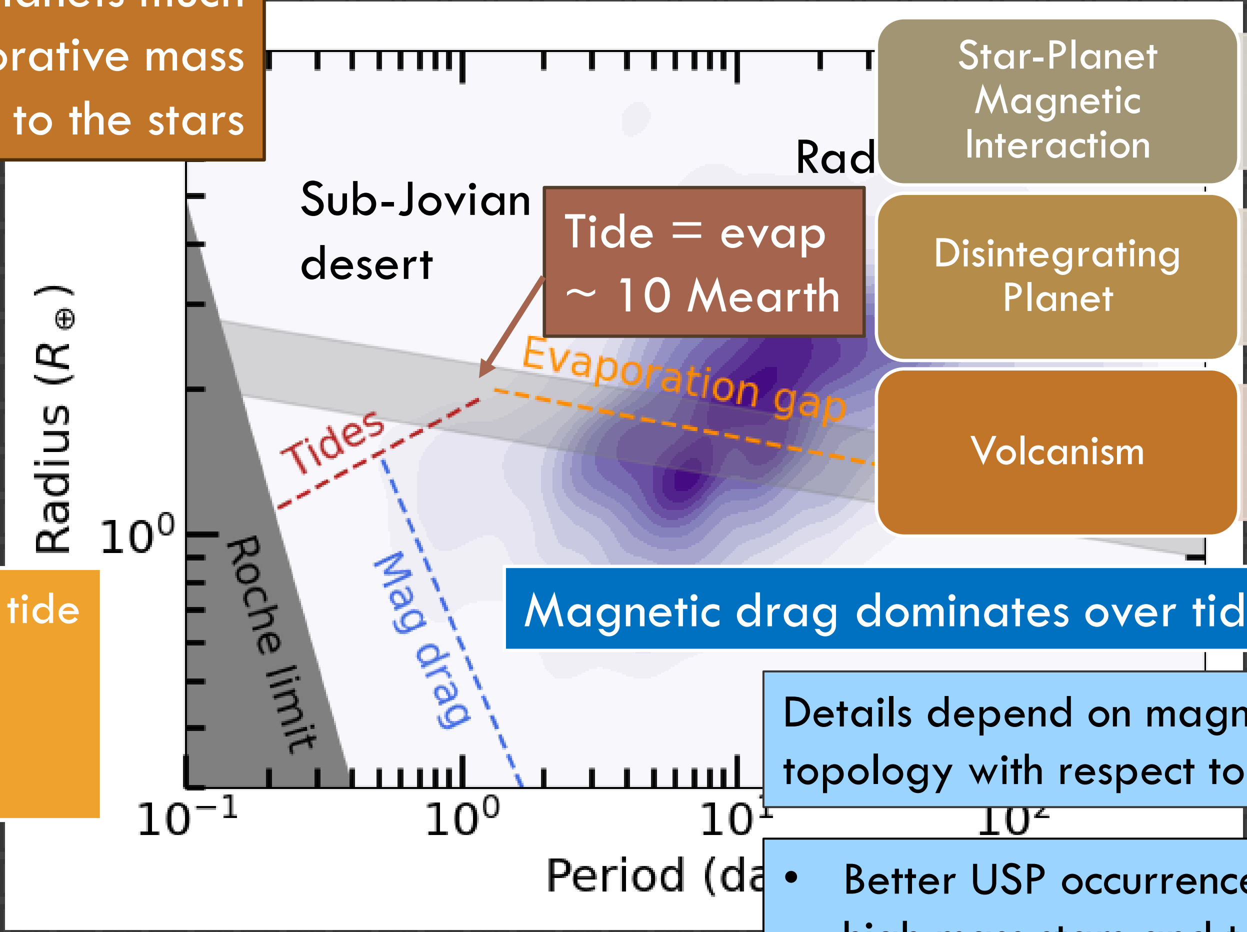


Tide = evap
~ 10 Mearth

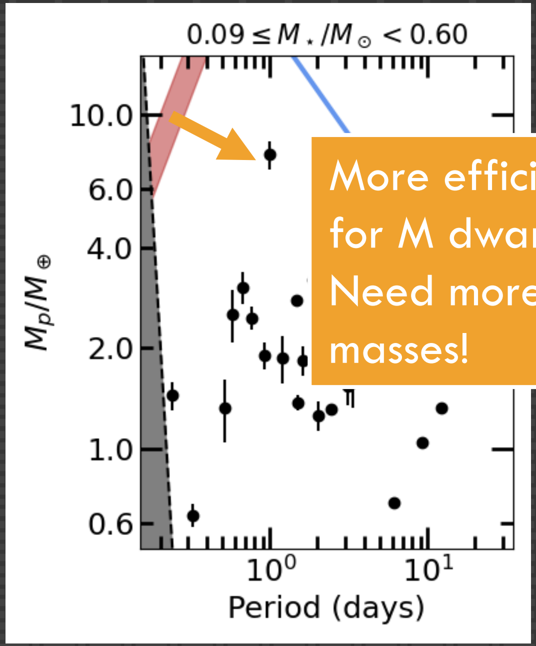
EJL & Owen ’25 (contour: raw data from NASA Exo

Star-Planet Magnetic Interaction	• Modulation in stellar activity signature?
Disintegrating Planet	• USP occurrence rate <Rearth • Need better conductivity profile
Volcanism	• Atmospheric signature? • Phase curve to probe nightside?

Magnetic drag dominates over tides for sub-Earth USPs!

Details depend on magnetic field evolution and topology with respect to stellar mass

- Better USP occurrence rate towards low and high mass stars and towards sub-Earth
- Better probe of stellar magnetic fields



More efficient tide for M dwarfs? Need more masses!