Exoplanets and their dependence on stellar host properties

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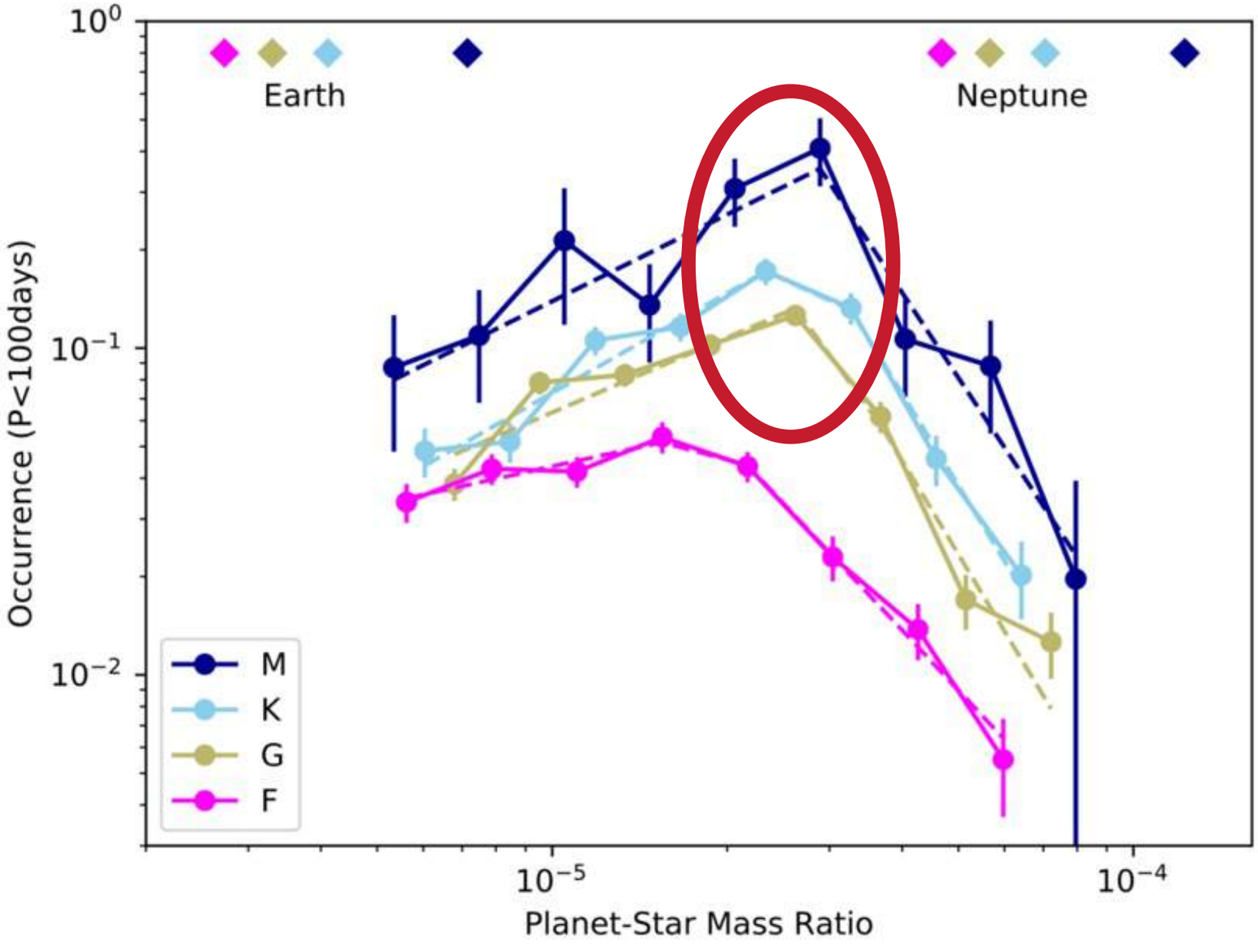
1. **Do planets have a characteristic mass, and does it correlate with the mass of the stellar host?**

2. **How does the occurrence rate of SE and GG populations correlate with stellar properties (mass and metallicity)?**

Planet mass correlates with stellar mass

- Characteristic mass of Super-Earths **increases linearly** with the mass of their stellar hosts.



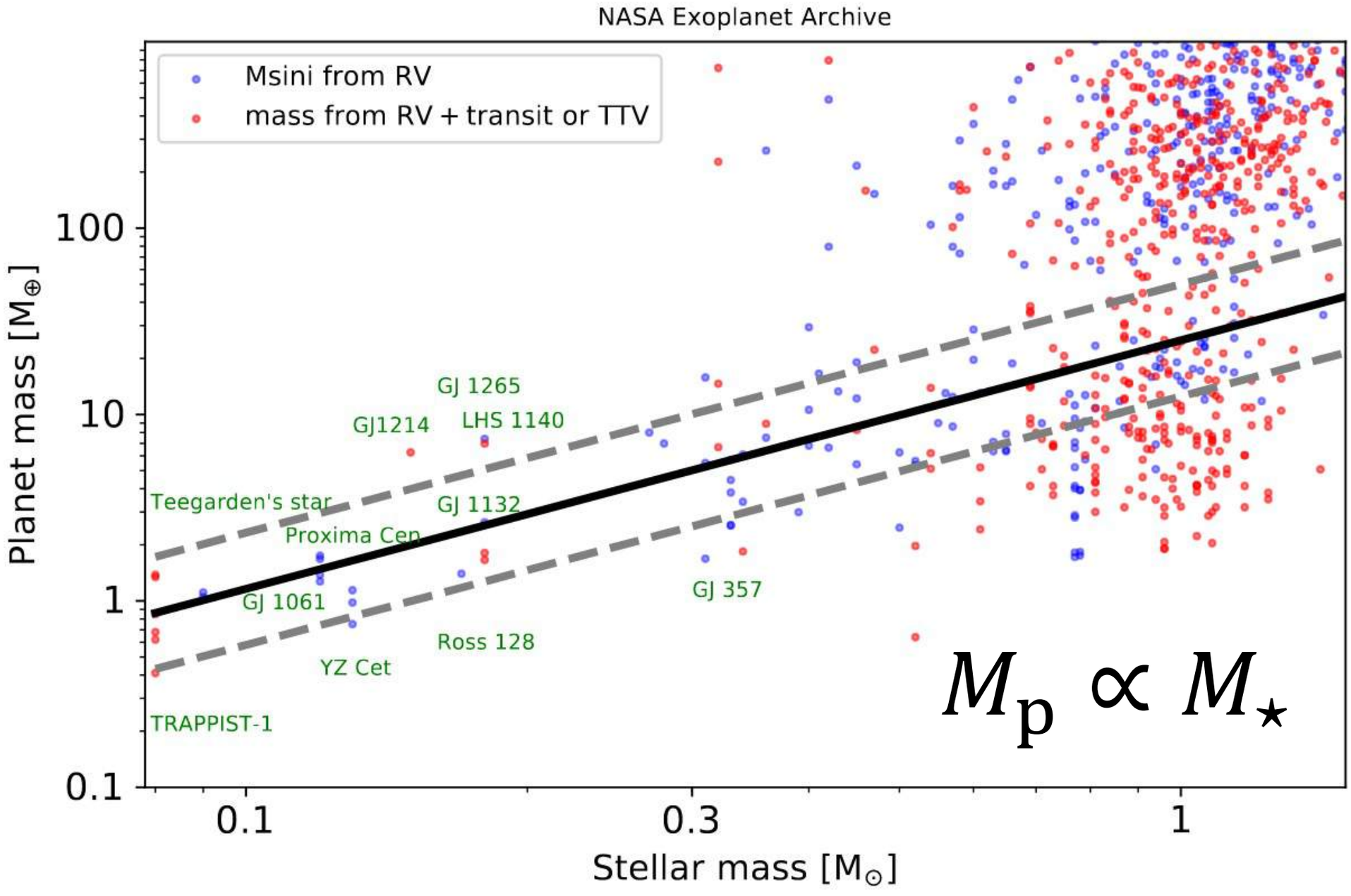
Pascucci+2018, Wu2019

$$M_{\rm p}/M_\star \simeq \text{const}$$

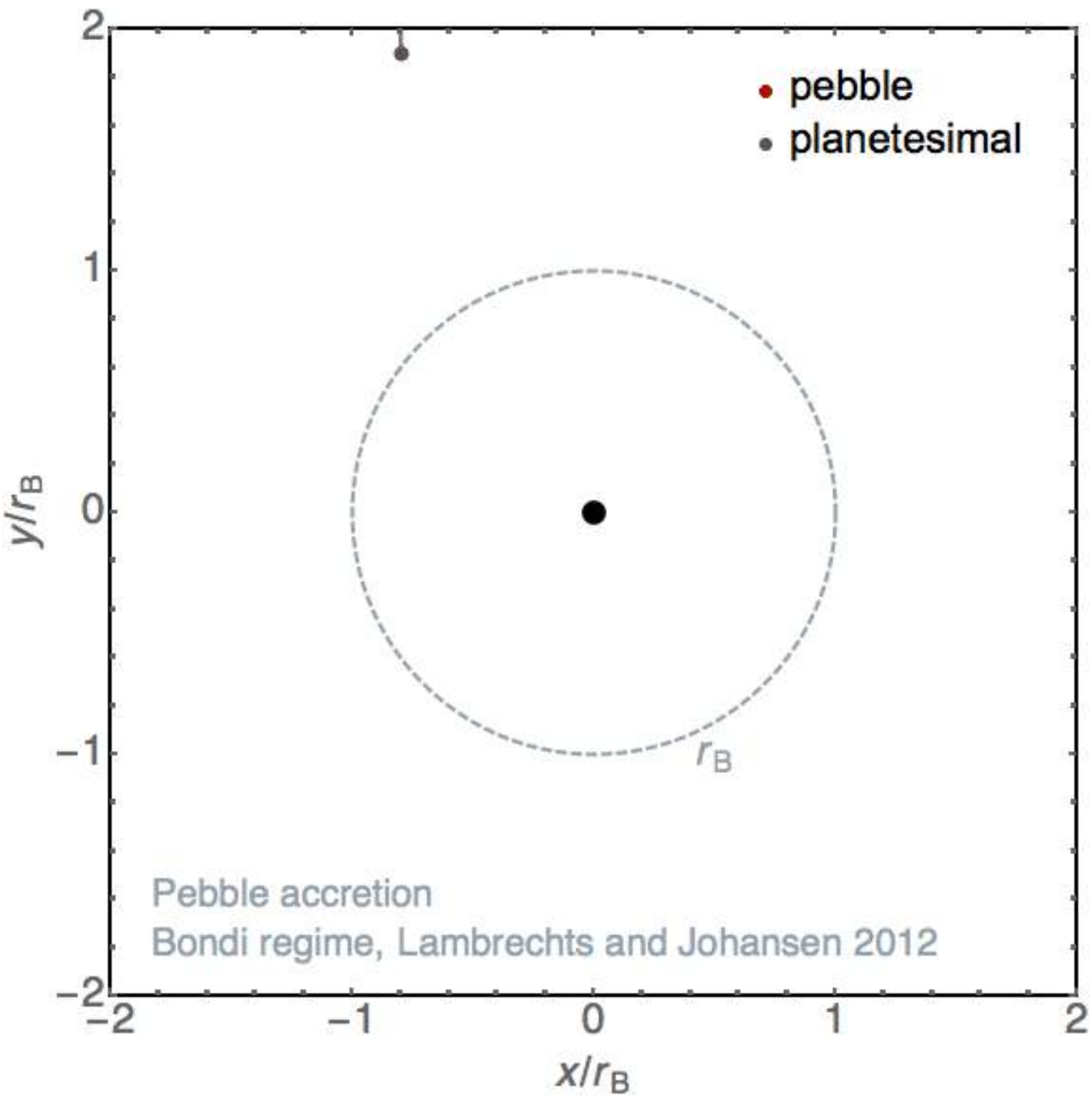
$$\downarrow$$

$$M_{\rm p} \propto M_\star$$

Planet mass correlates with stellar mass



Pebble accretion: from planetesimals to planets



mm-cm size pebbles

gravitational force + **gas drag**

Ormel & Klahr 2010,

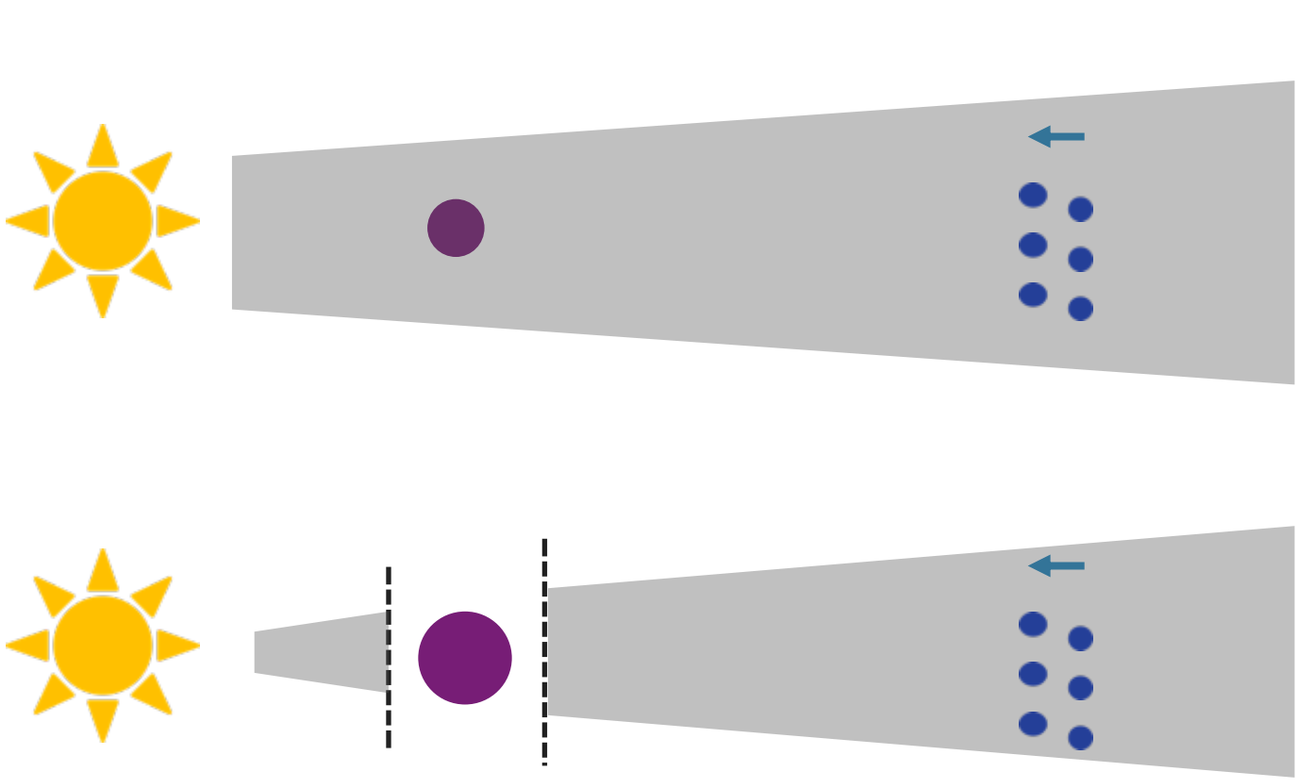
Lambrechts & Johansen2012,2014,

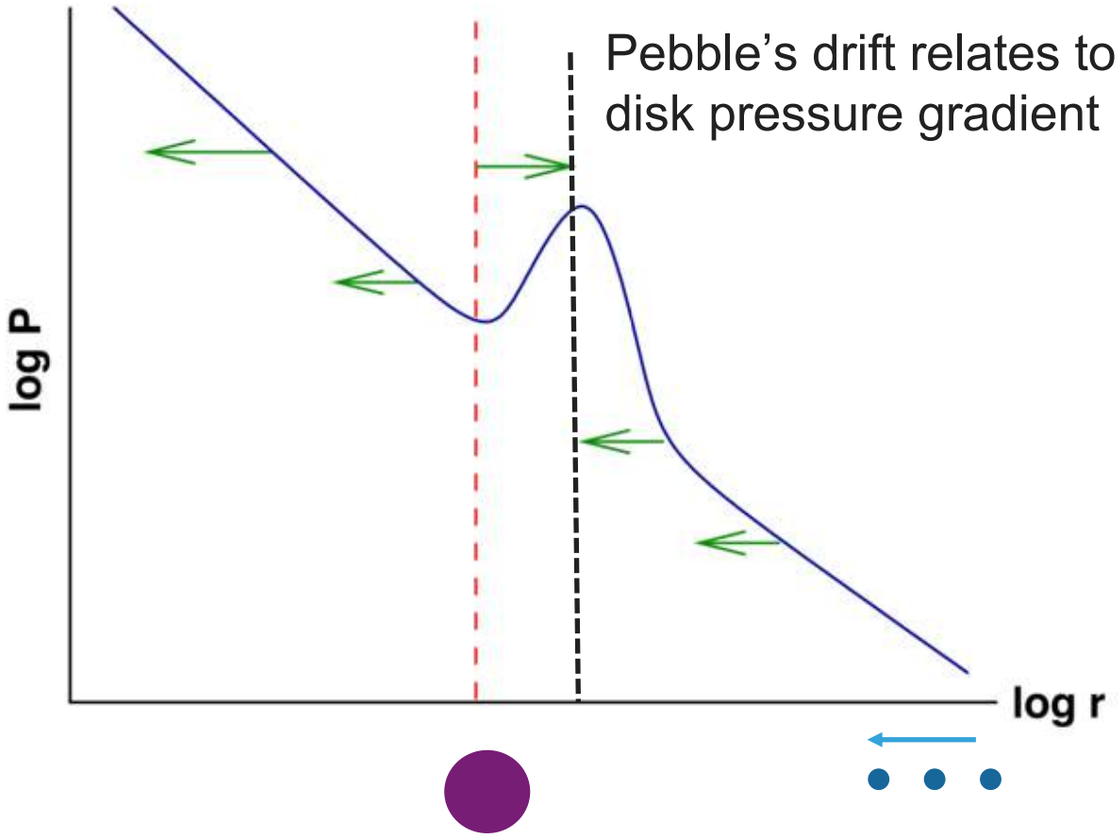
Ida+2016,Ormel & Liu 2018

- large accretion radius $\sim R_{\mathrm{Hill}}$
- massive pebble disk $\sim 100\ M_{\oplus}$

Massive planet stops accreting pebbles

Pebble isolation mass





$$M_{\rm iso} \simeq 20 M_\oplus \left(\frac{h_{\rm gas}}{0.05}\right)^3 \left(\frac{M_\star}{M_\odot}\right)$$

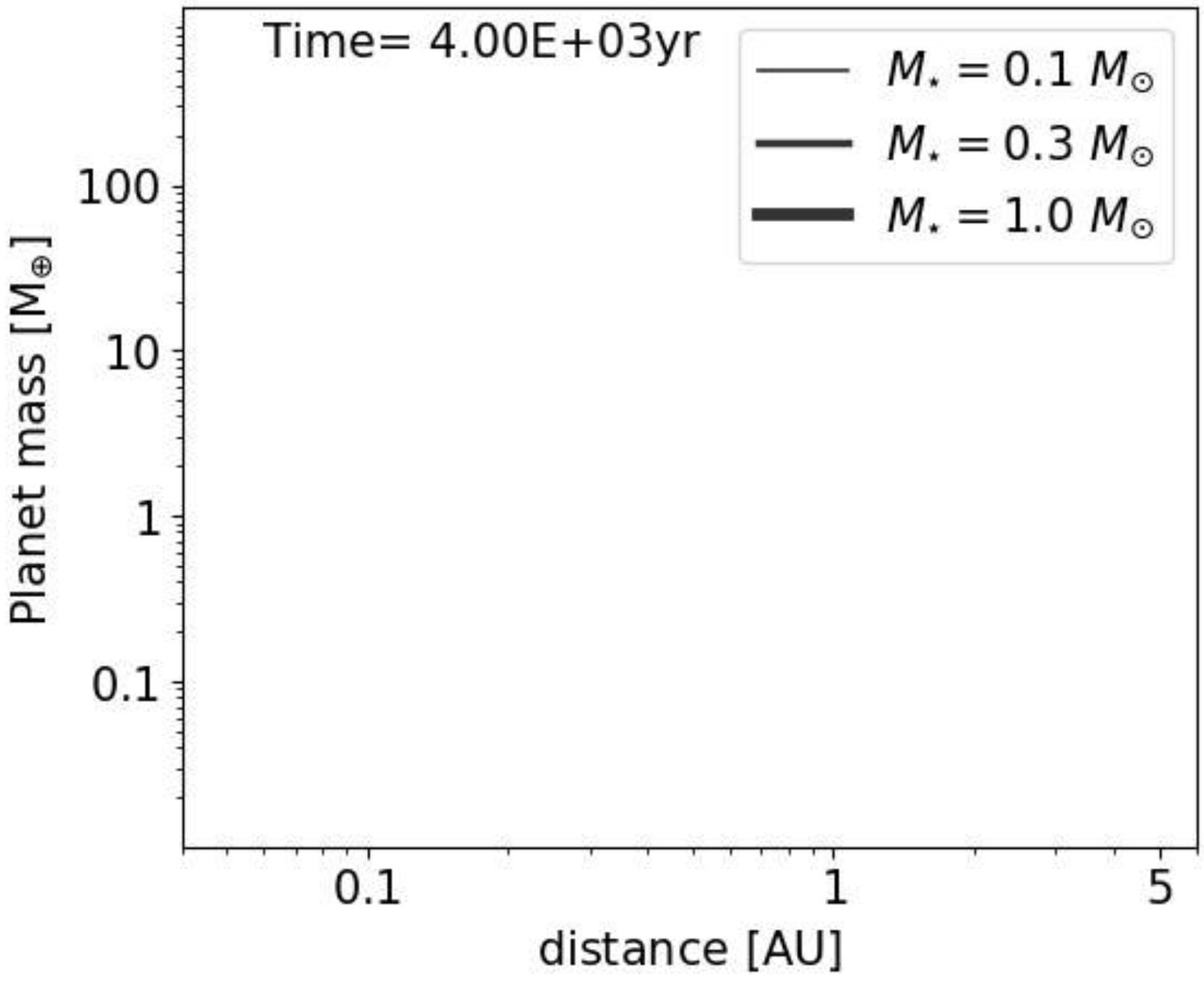
$\approx 1 M_\oplus$ around 0.1 $M_\odot$ star

$\approx 10 - 20\ M_\oplus$ around 1 $M_\odot$ star

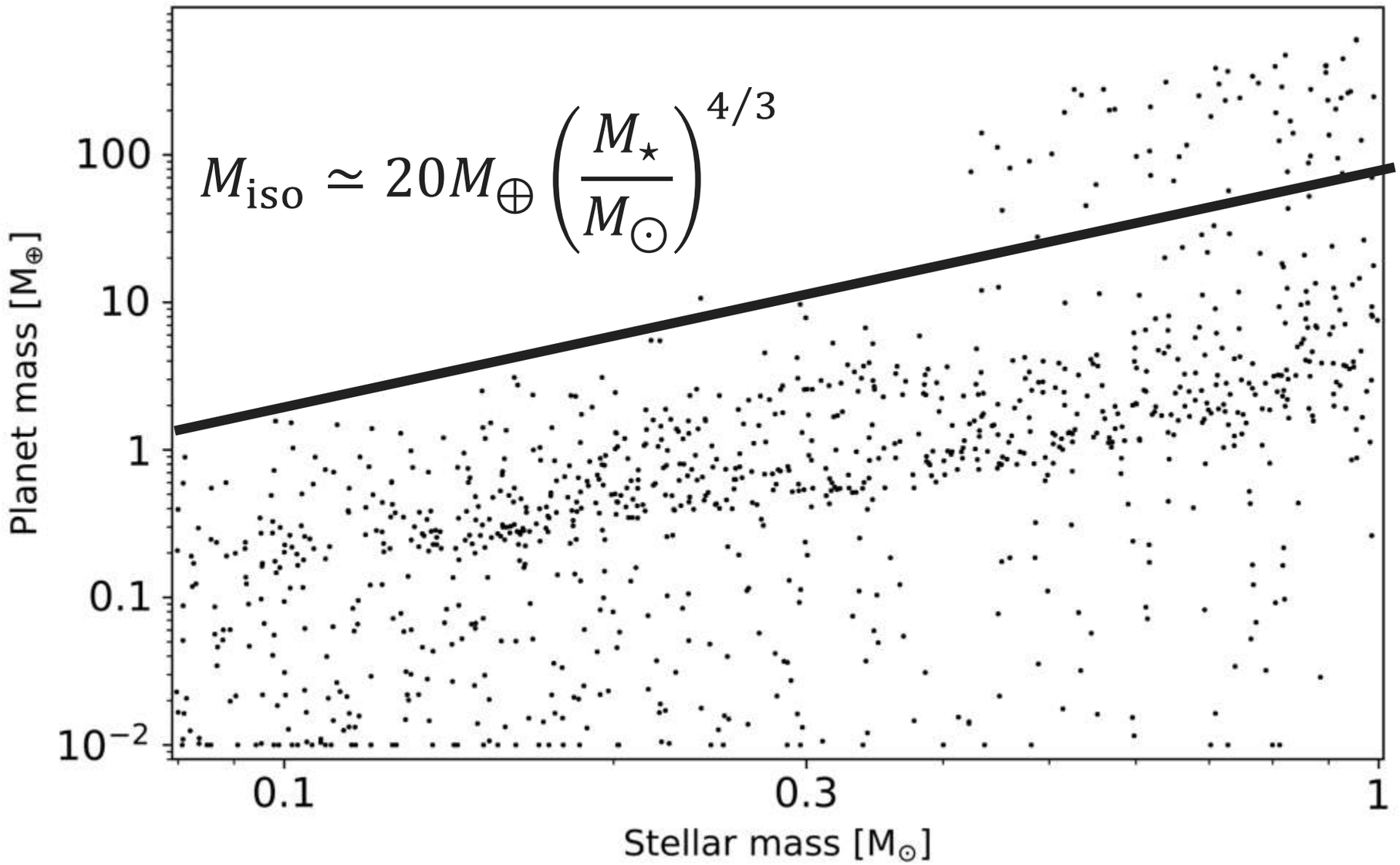
Lambrechts+2014

Smaller planets around lower-mass stars

- form at the water snow line



Planet mass correlates with stellar mass



Liu, Lambrechts & Johansen+2019, Liu & Ji 2020

1. Do planets have a characteristic mass, and does it correlate with the mass of the stellar host?

2. How does the occurrence rate of SE and GG populations correlate with stellar properties (mass and metallicity)?

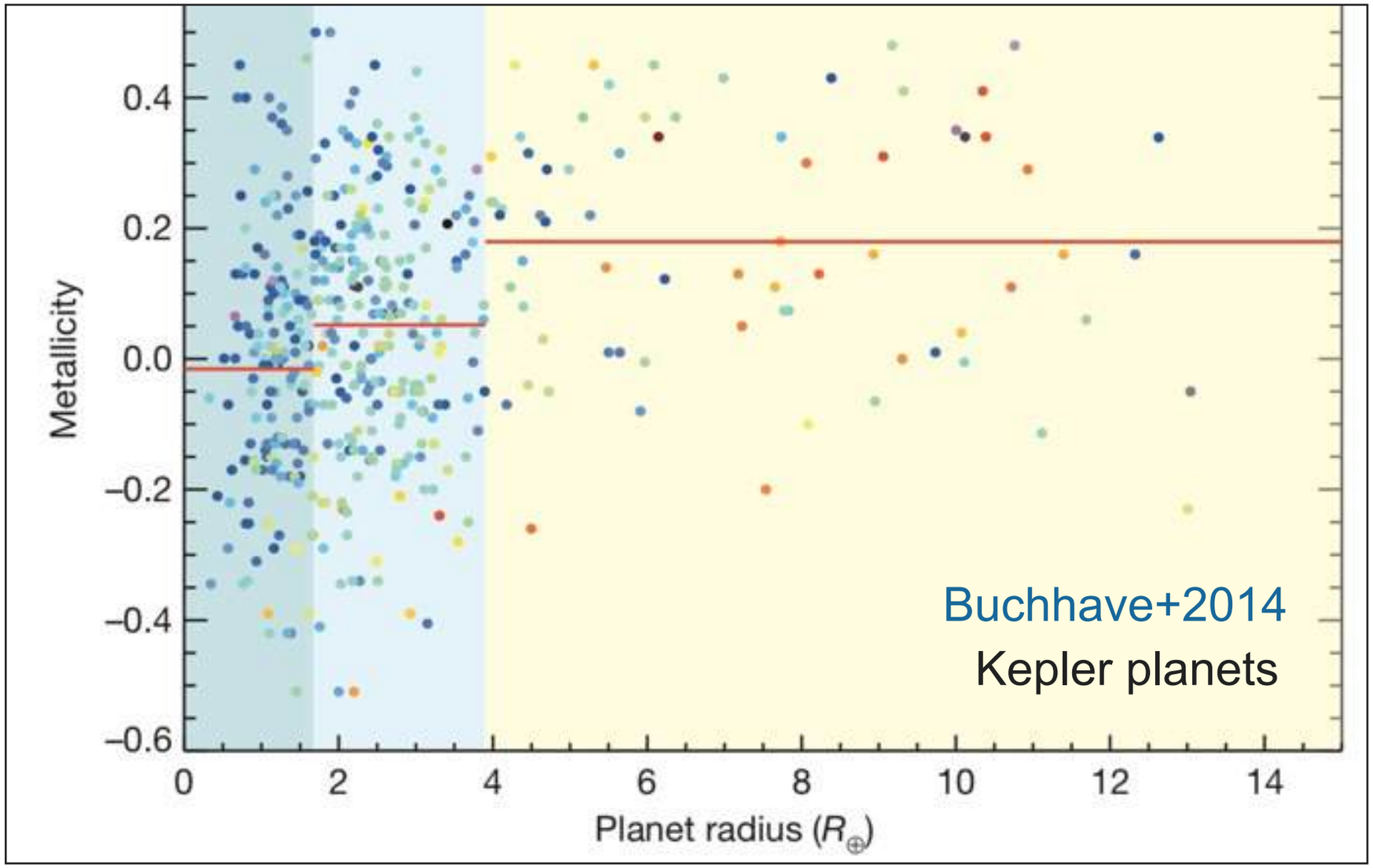
SEs and GGs have distinct stellar metallicity dependencies

- Gas giant occurrence **strongly correlates** with stellar metallicity;

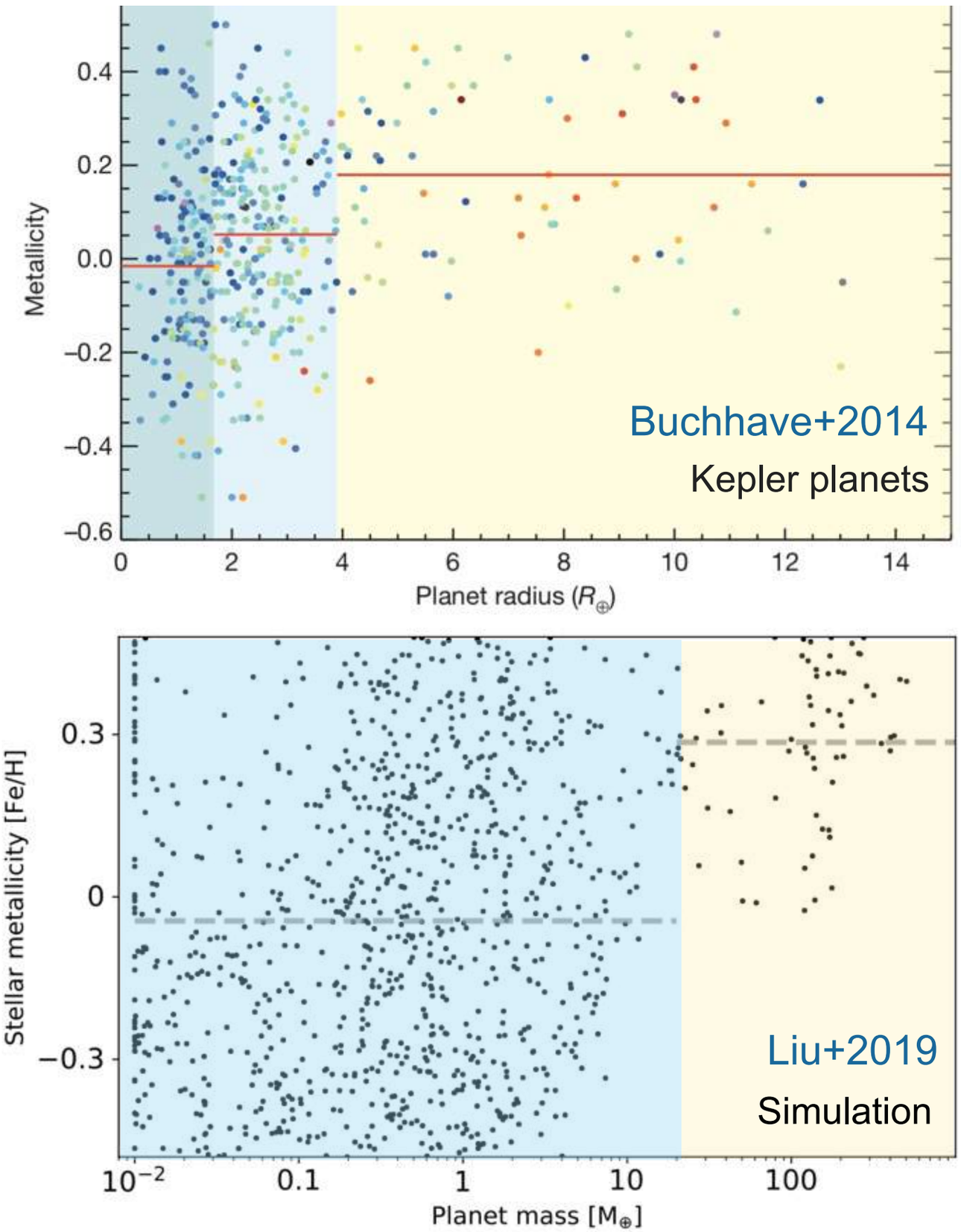
  Santos+2004, Fischer & Valenti2005

- Super-Earth exhibit **weak** or **no-correlation** with stellar metallicity.

  Sousa+2008, Mayor+2011,Schlaufman+2015, Petigura+2018

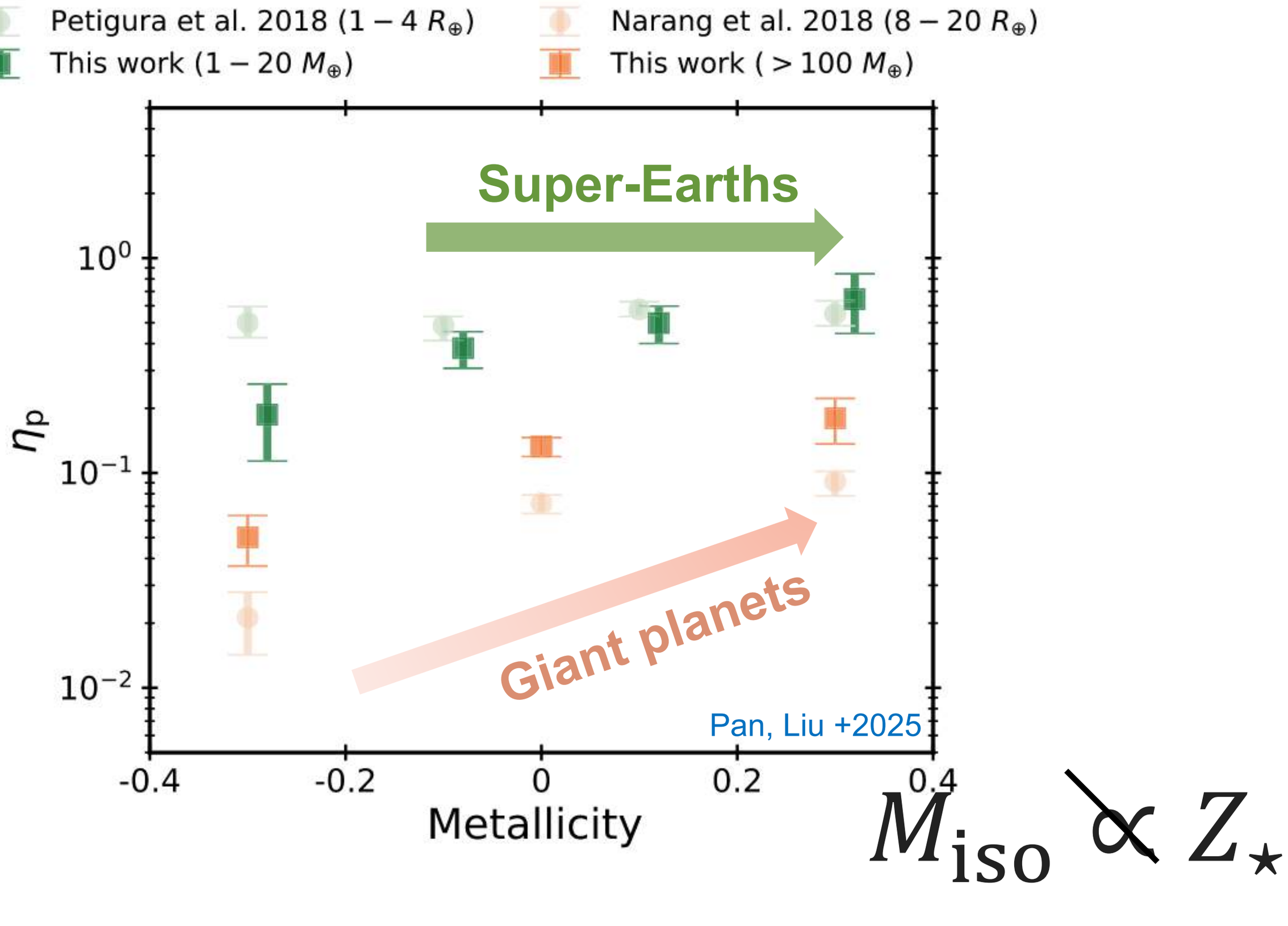


Pebble isolation mass has no metallicity dependence



$$M_{\rm iso} \not\propto Z_\star$$

Pebble isolation mass has no metallicity dependence



$$M_{\rm iso} \not\propto Z_\star$$

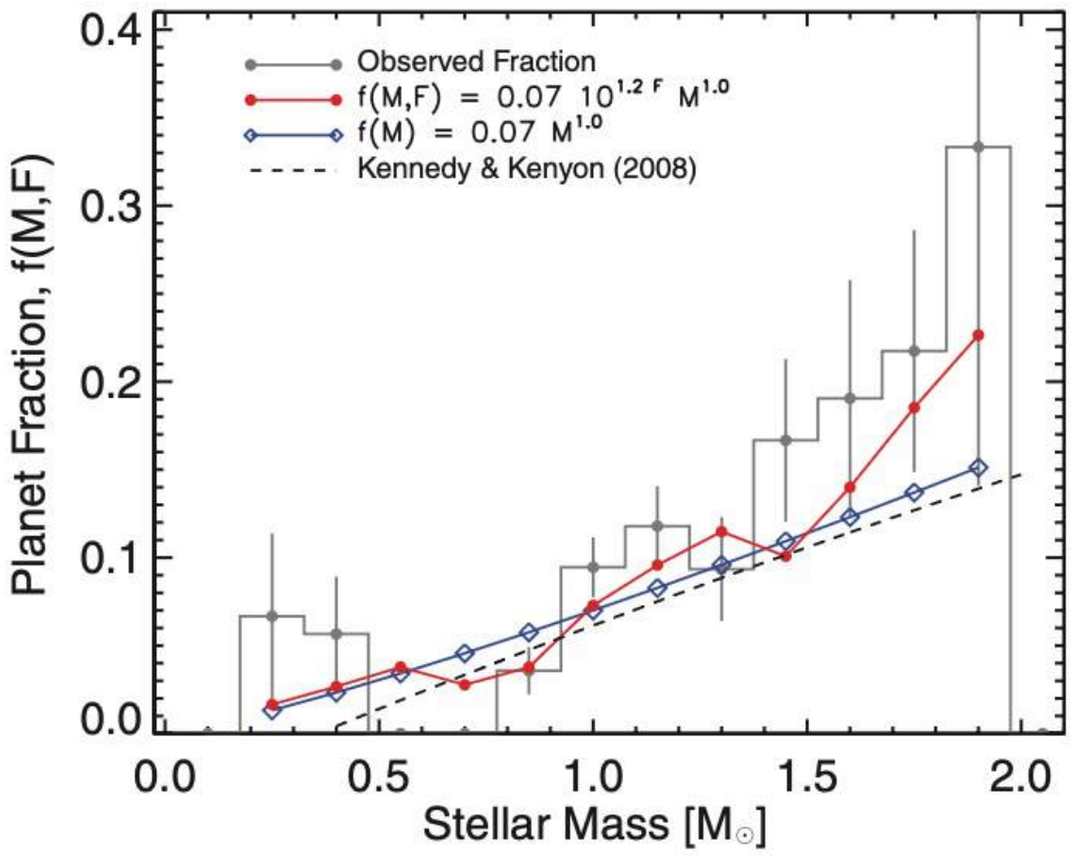
SEs and GGs have distinct stellar mass dependencies

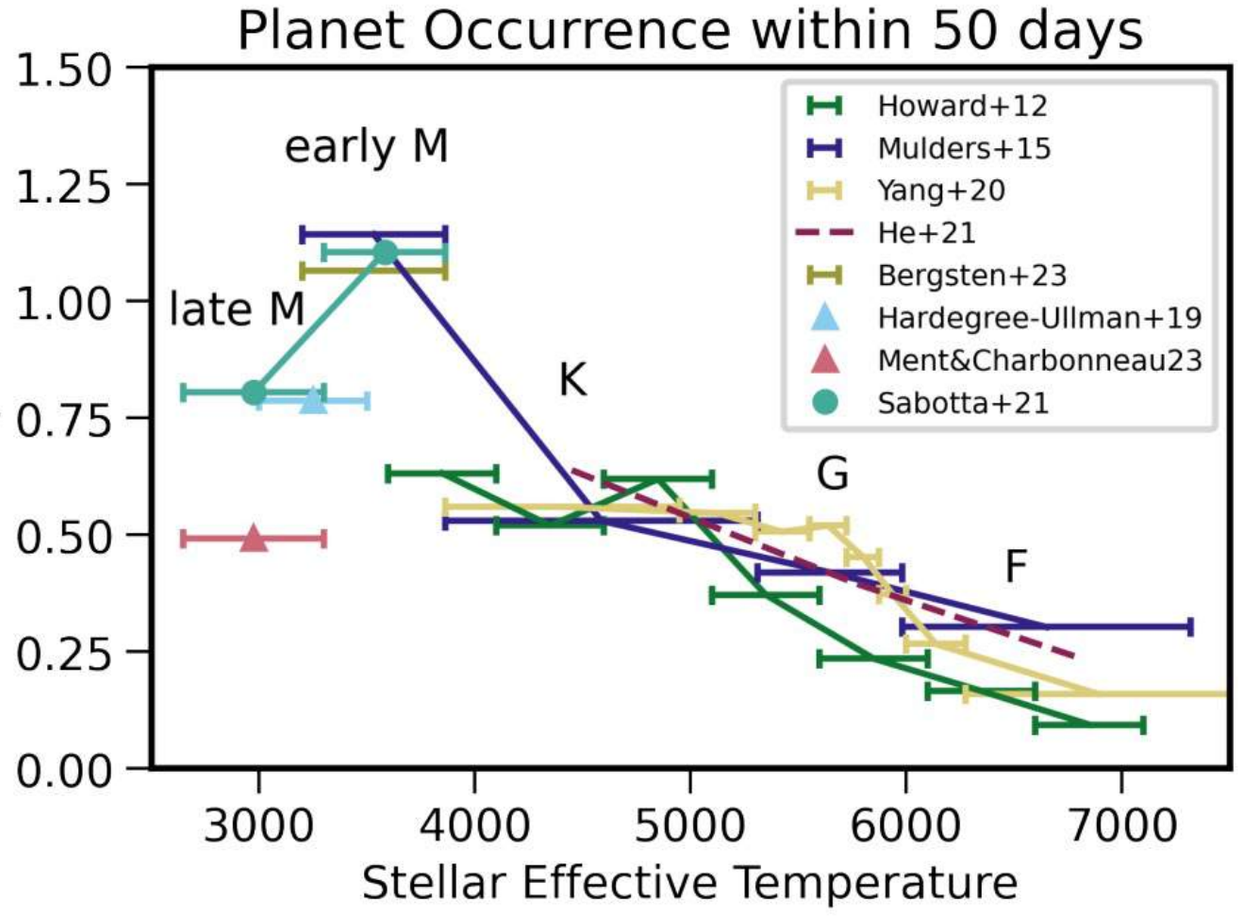
- Giant planet increases with stellar mass.

  Johnson+2007,2010, Fulton+2021

- Super Earth peaks at early M-dwarf.

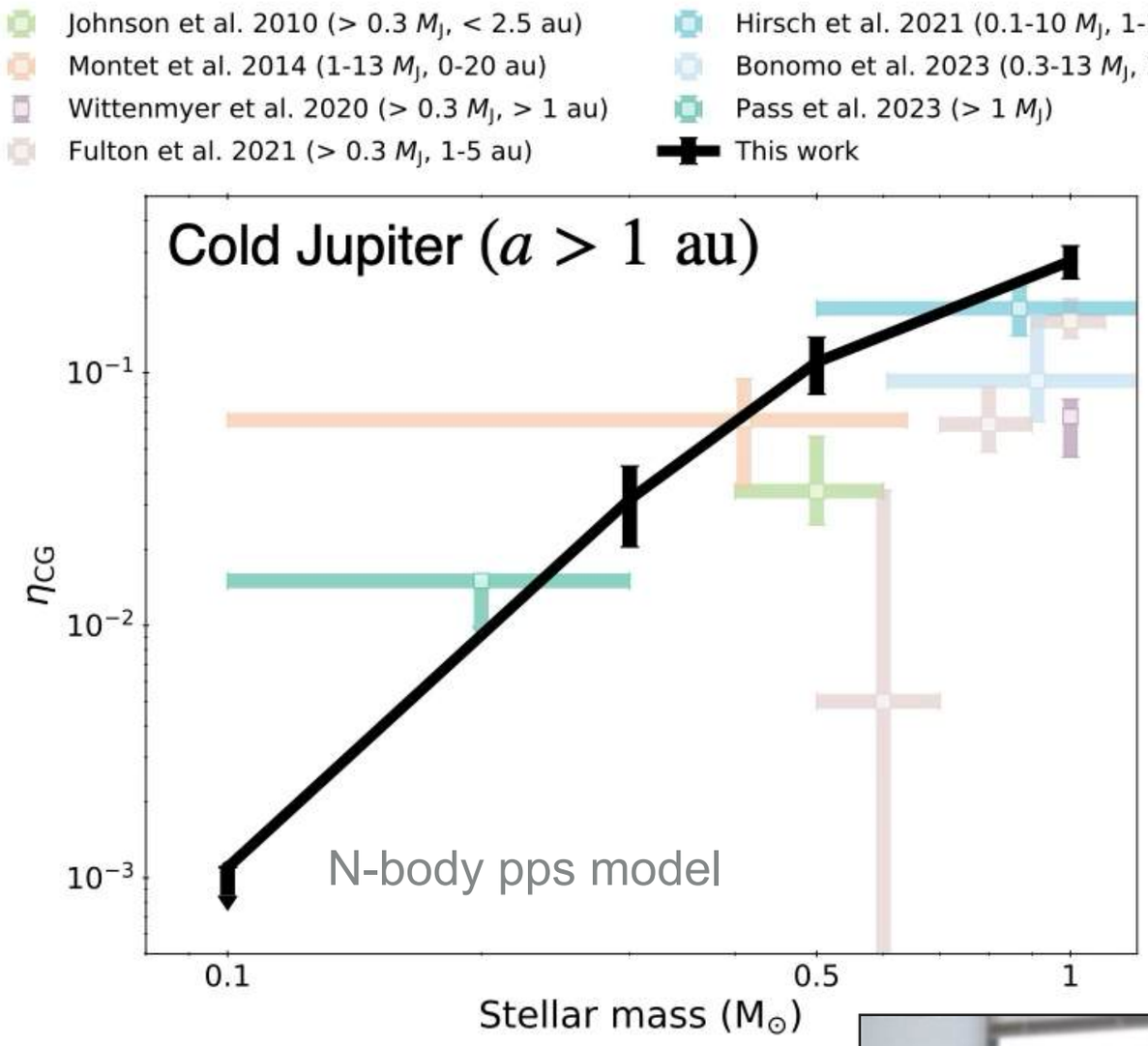
  Howard+2012,Dressing+2015,Mulders +2015, Yang+2020, Sabotta+2021





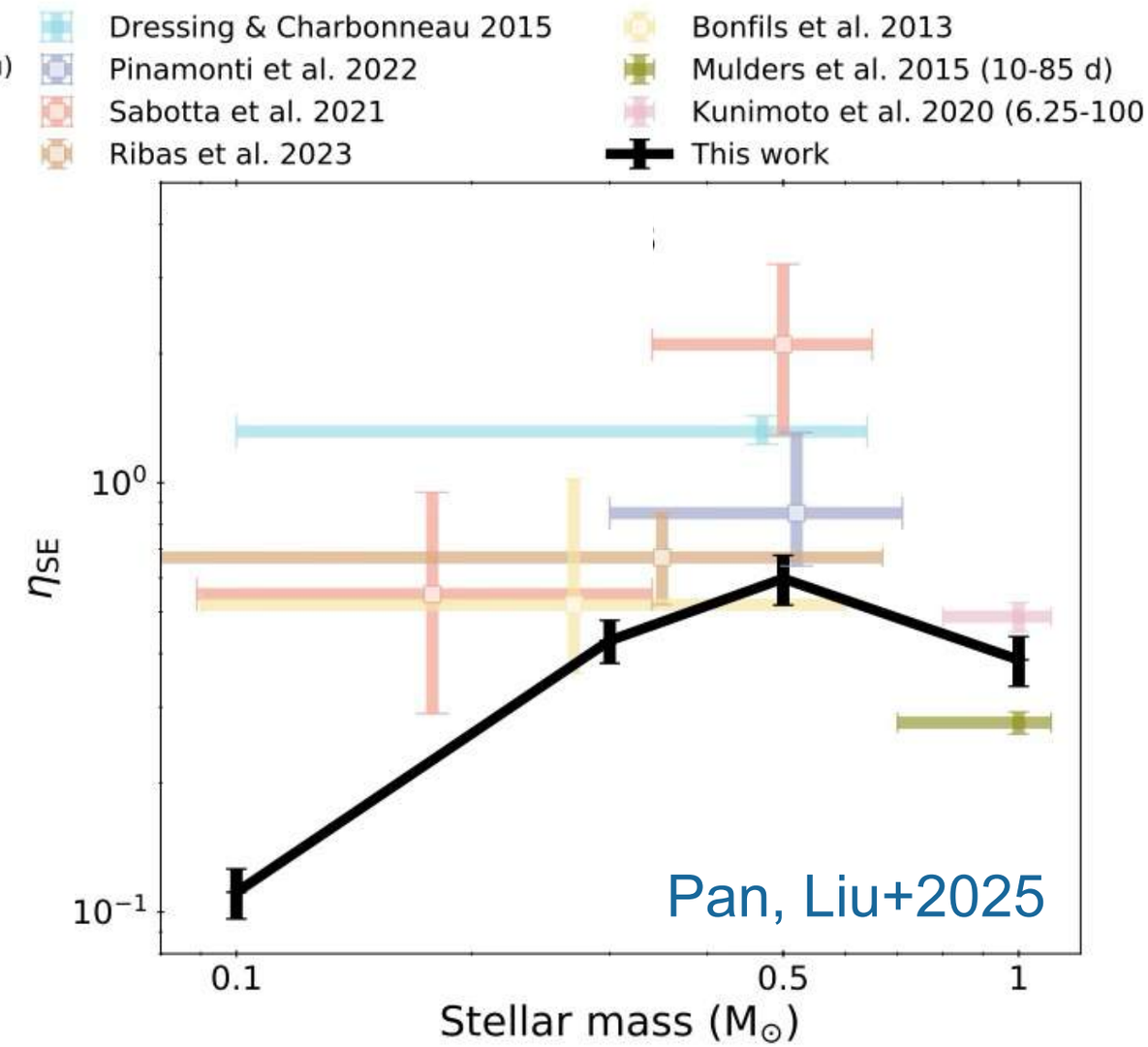
also see Burn+2021, Chachan & Lee2023

Small planets peak at early M-dwarfs



- disk mass

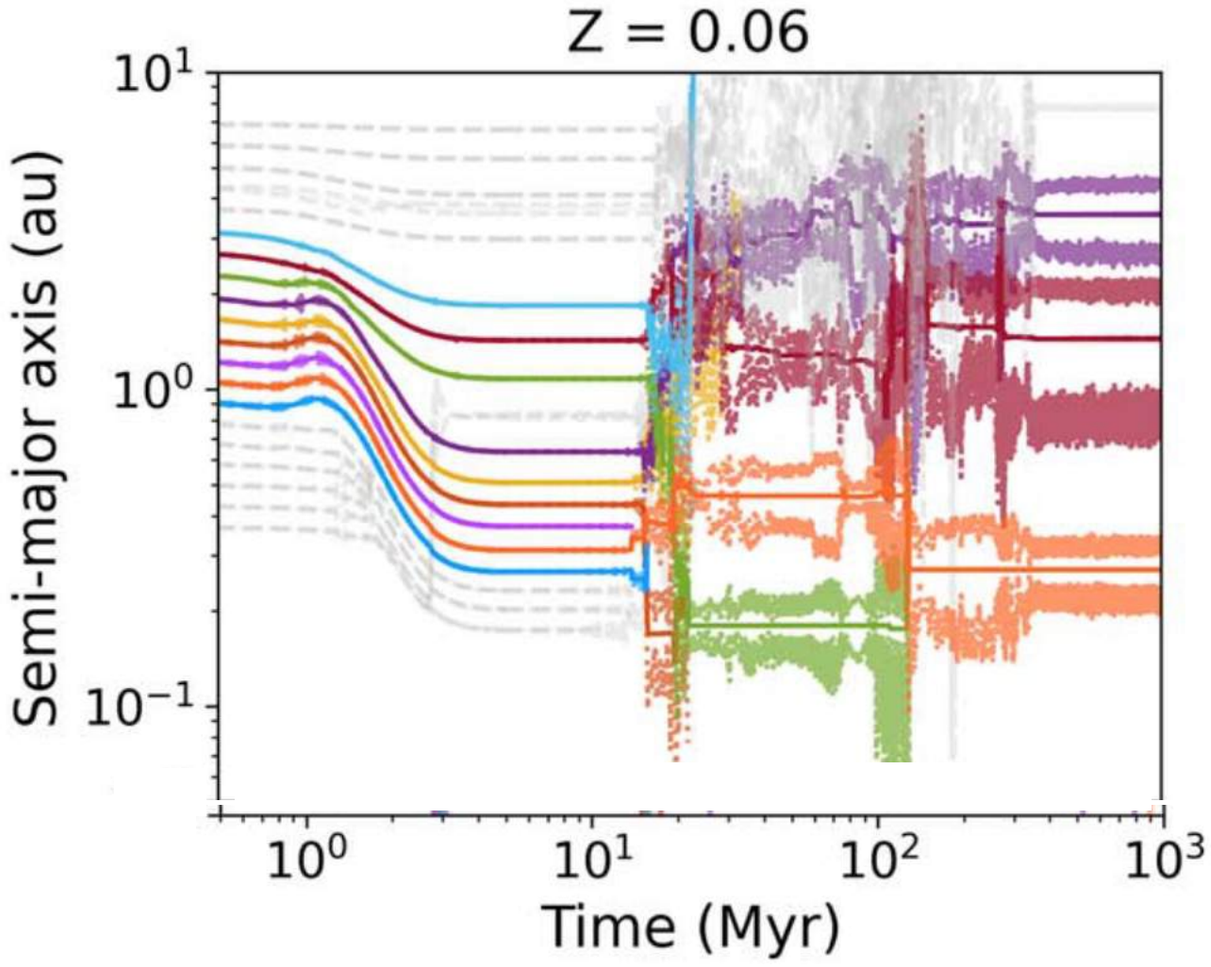
Pan Mengrui (postdoc @ Rice)

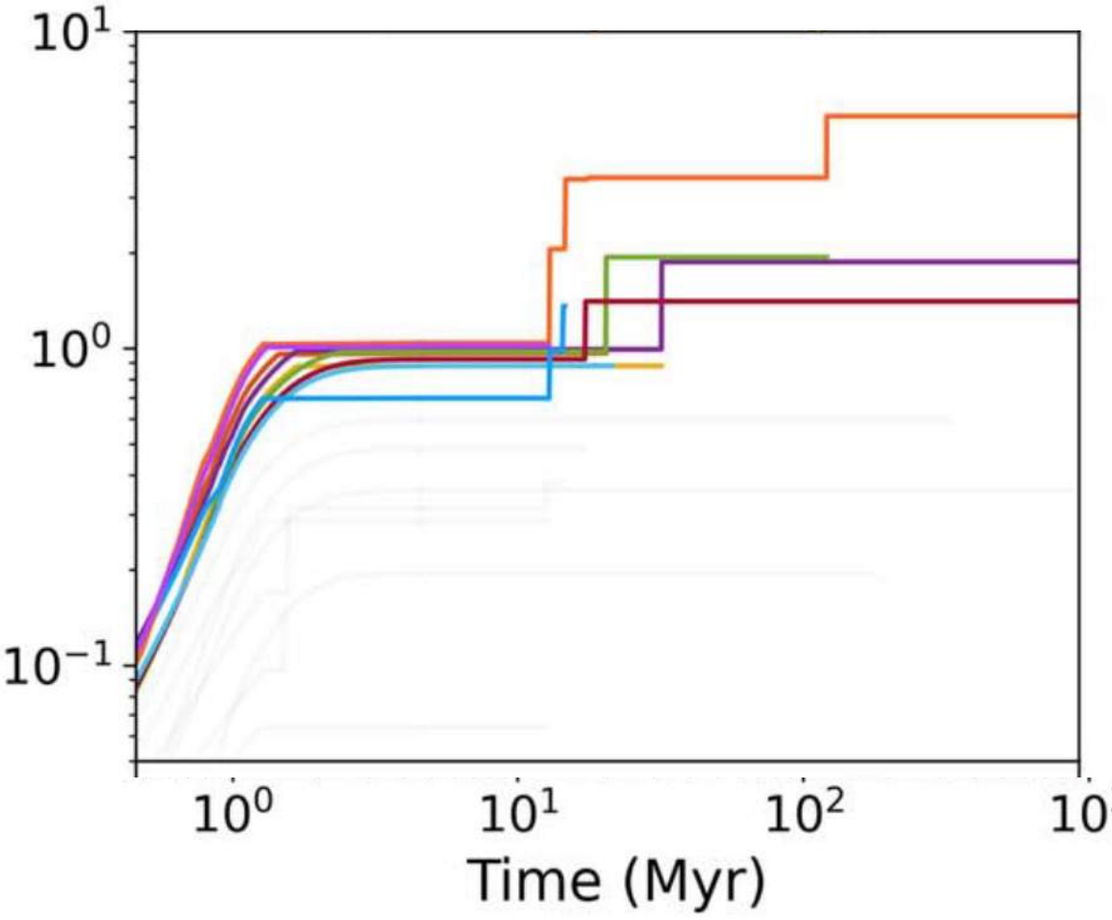


- disk mass
- disk size
- accretion efficiency
- giant planet influence

Dynamical hotter systems around metal-rich stars

- Single-transiting systems have high ecc of 0.3, while multi-transiting systems are nearly circular. Xie+2016, Van Eylen+2019
- Planets with higher ecc/inc around more metal-rch stars.
  Santos+2003, Dawson+2013,Mills+2019, An+2023, Hua+2025





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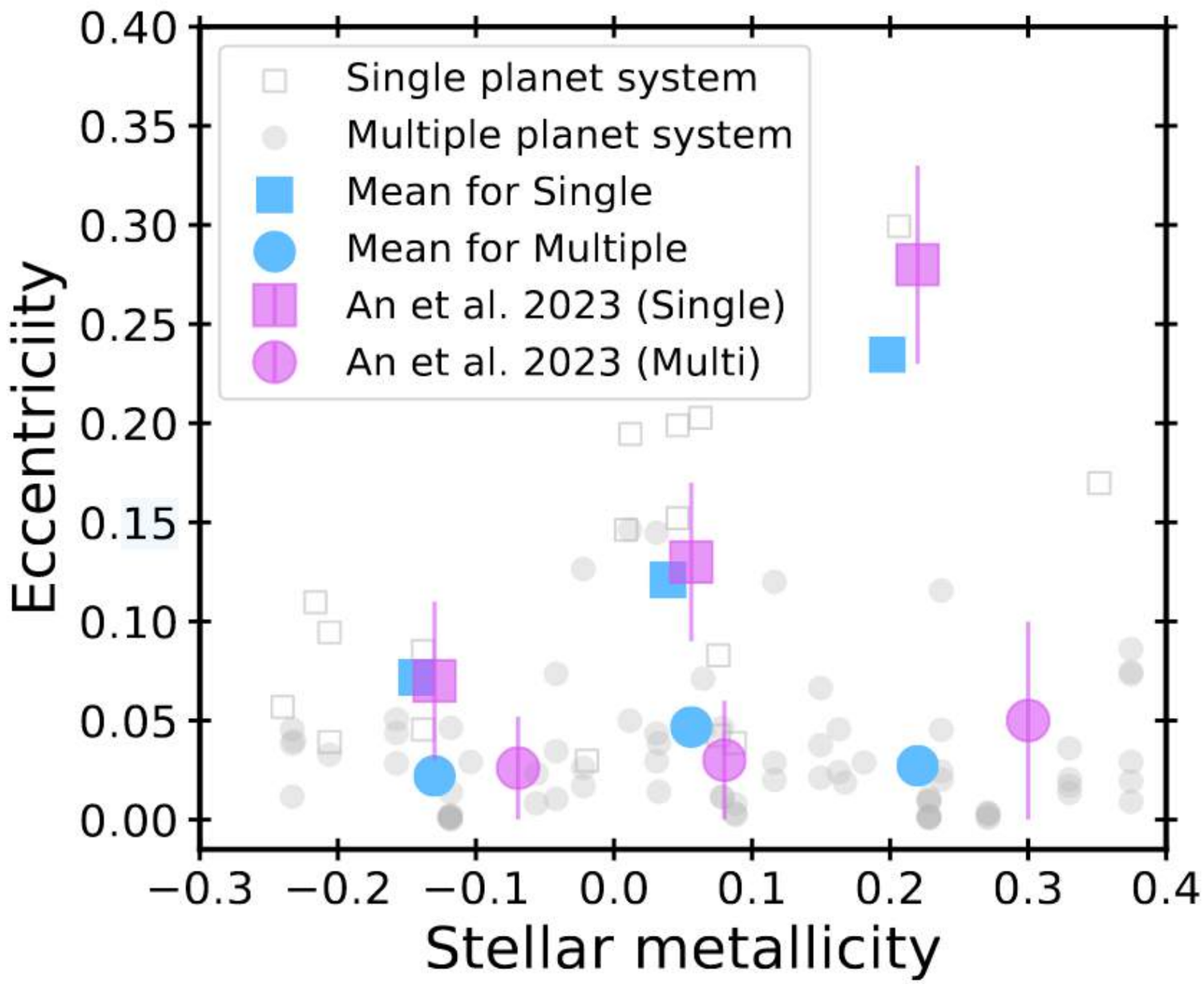

Conclusion

- The core mass of super Earth is set by **pebble isolation mass**, **scaling linearly** with the mass of the stellar host.

- Gas giant formation **strong correlates with** stellar metallicity/mass.

- The occurrence of super-Earths weakly depends on stellar metallicity, while it **peaks at early M-dwarfs** and declines towards stars of both higher and lower masses.