gbergsten@email.arizona.edu
@stellar_cyan

Kepler's Small Planets

& their dependence on stellar mass.

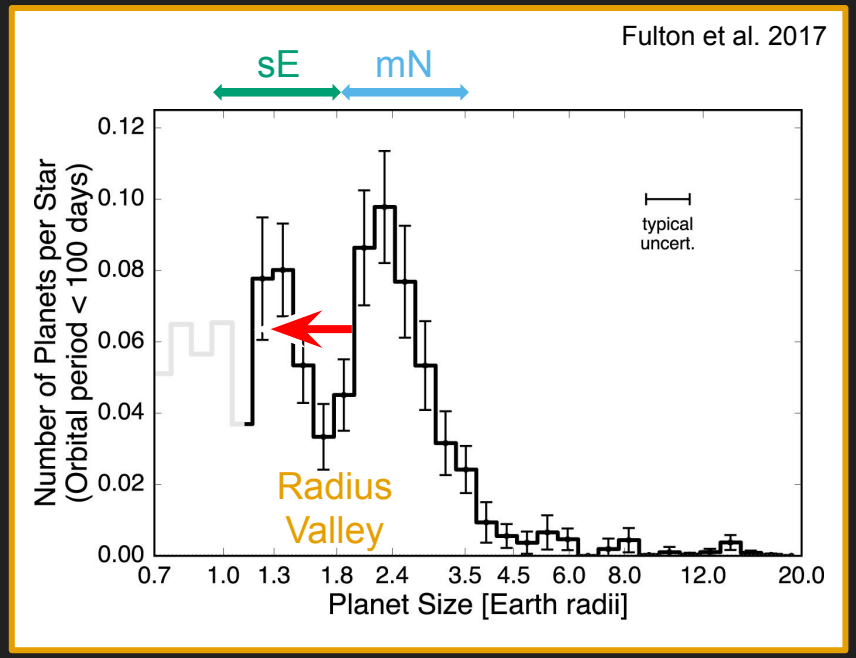
PLATO 10.13.2021 - Galen Bergsten.

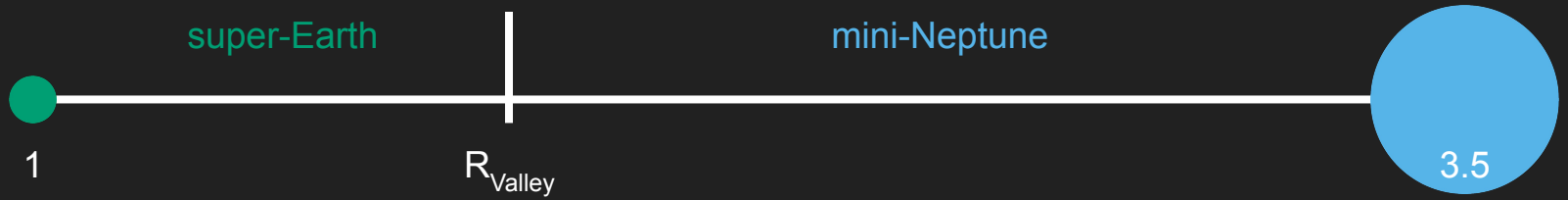
+ Ilaria Pascucci, Gijs Mulders, Rachel Fernandes, Tommi Koskinen

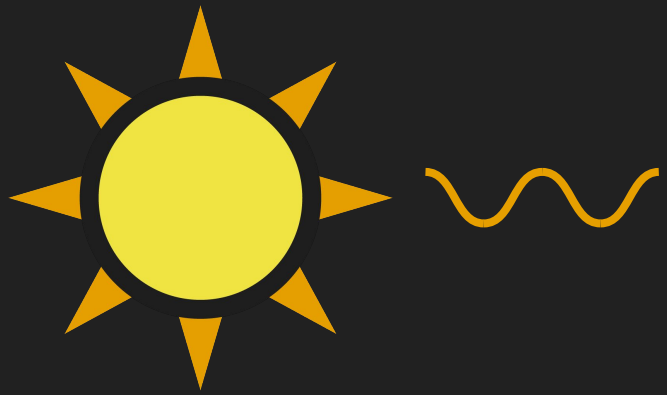
ALIEN EARTHS

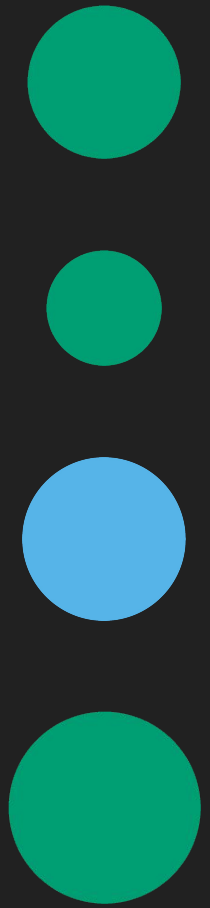
THE UNIVERSITY OF ARIZONA
COLLEGE OF SCIENCE
LUNAR & PLANETARY LABORATORY

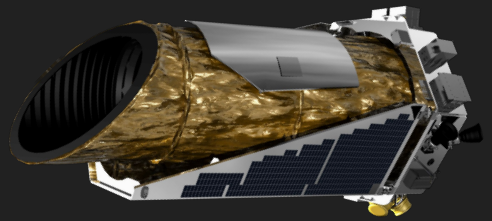
Planet Radius Valley



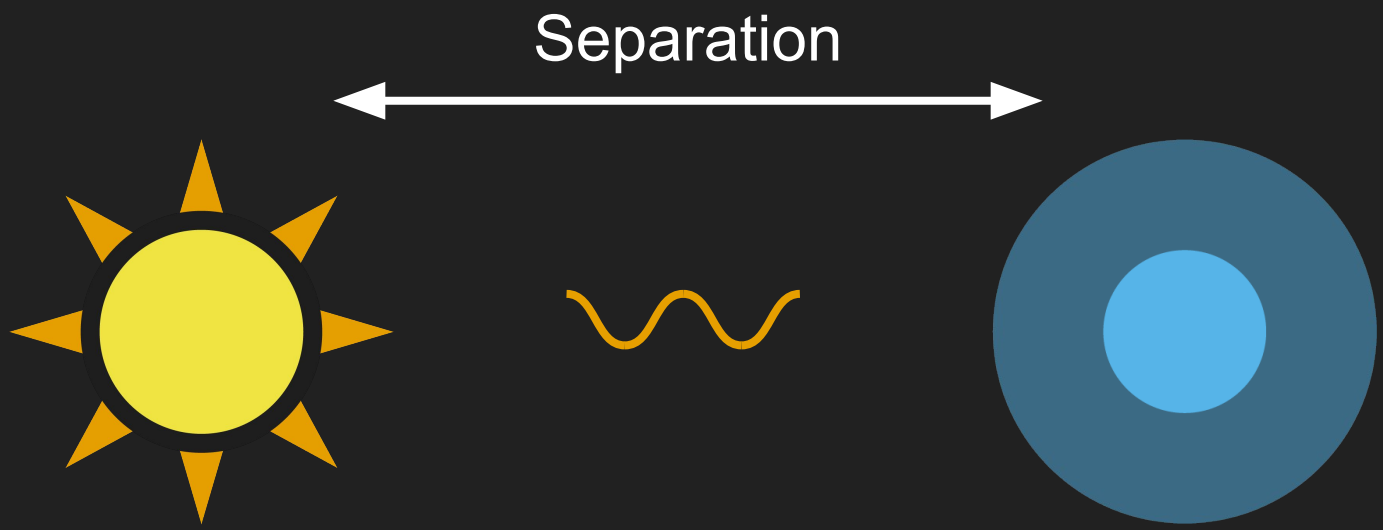








*not to scale



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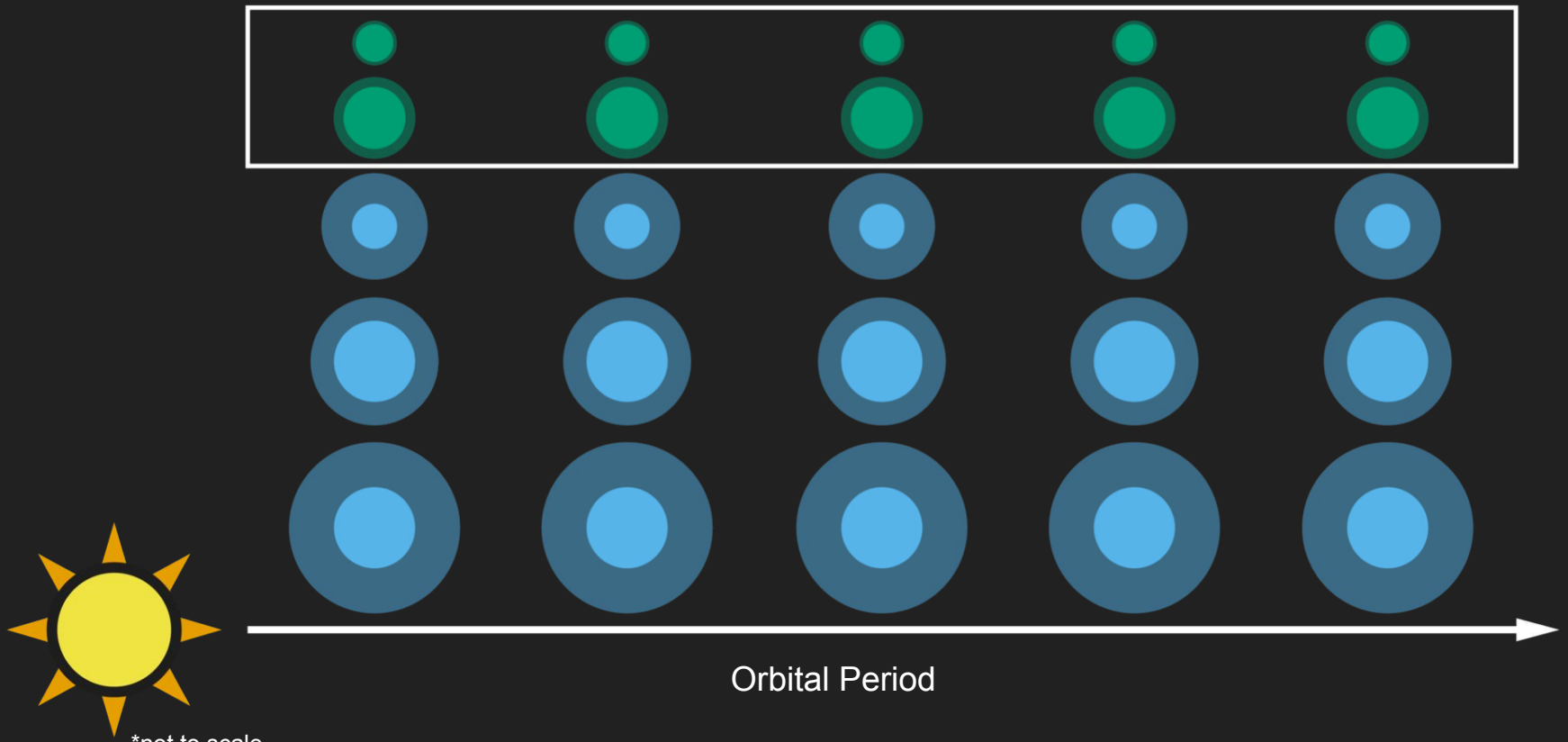
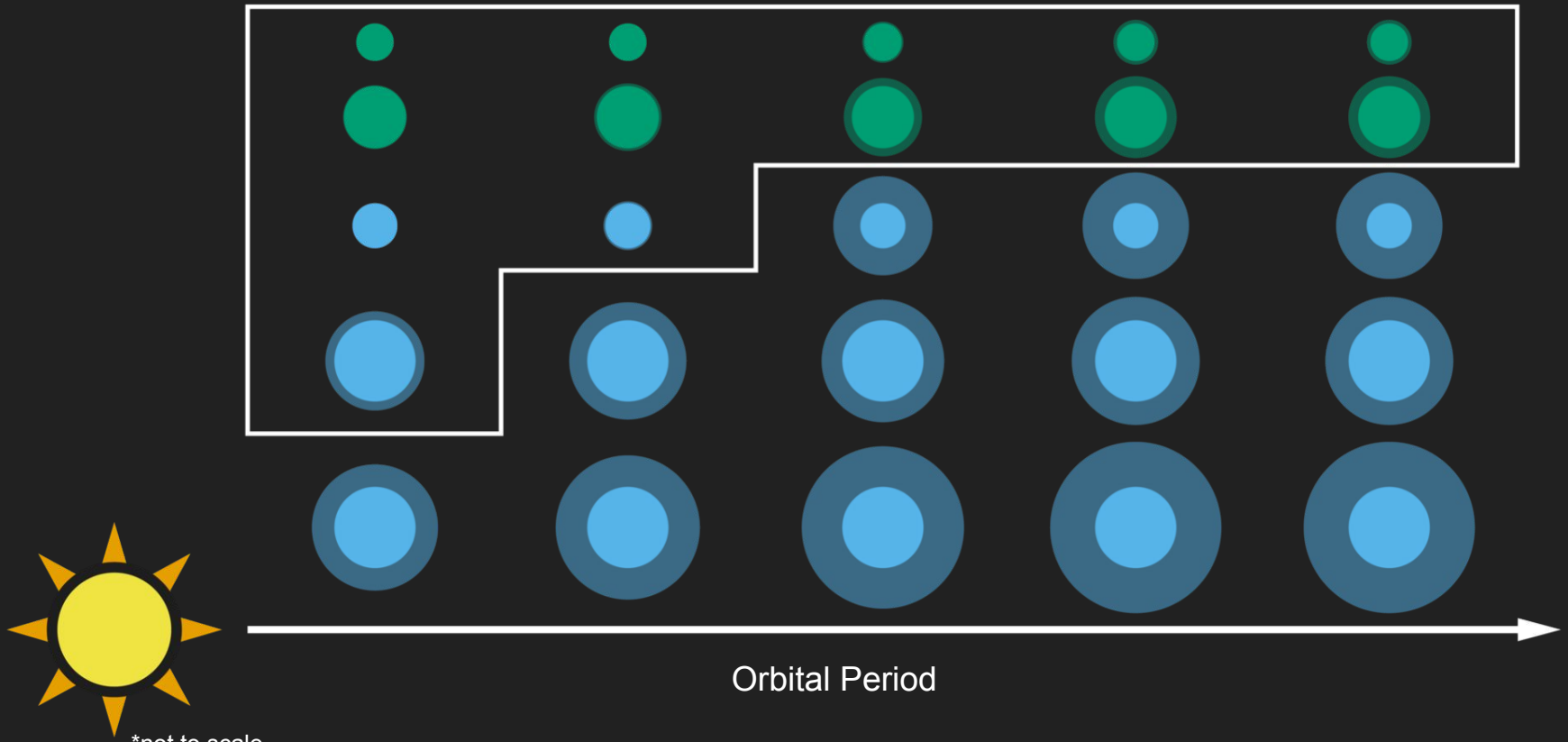
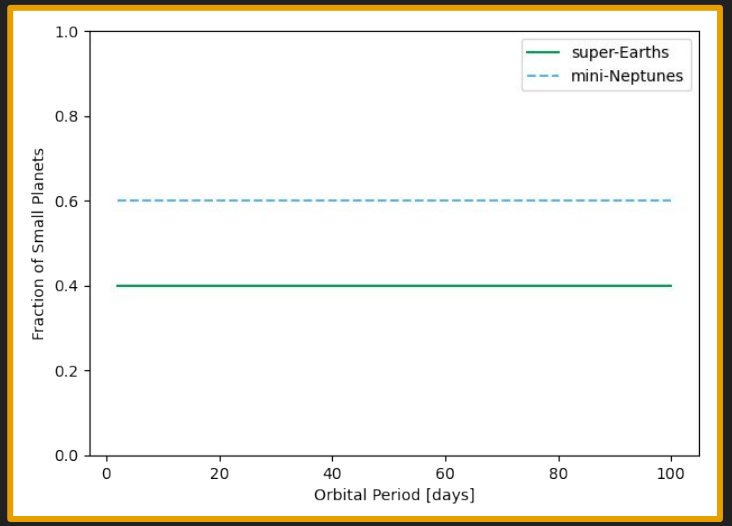
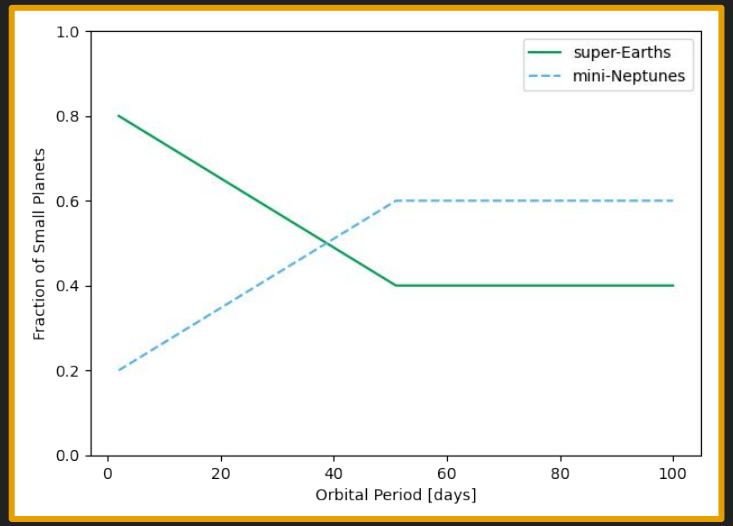

Orbital Period
*not to scale

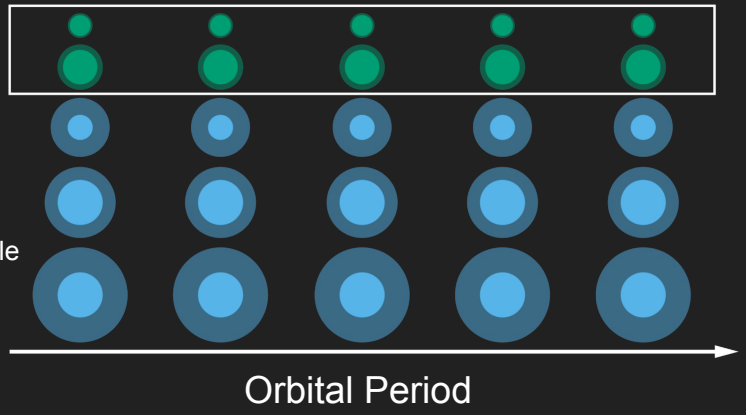

Orbital Period
*not to scale

Initial Population



Evolved Population





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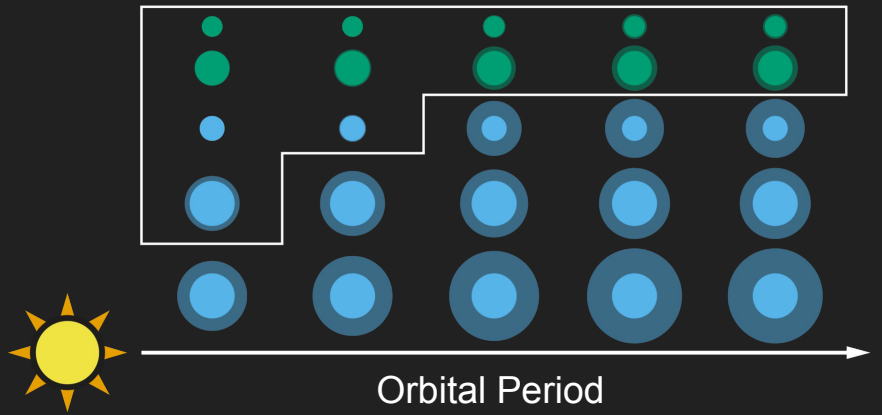
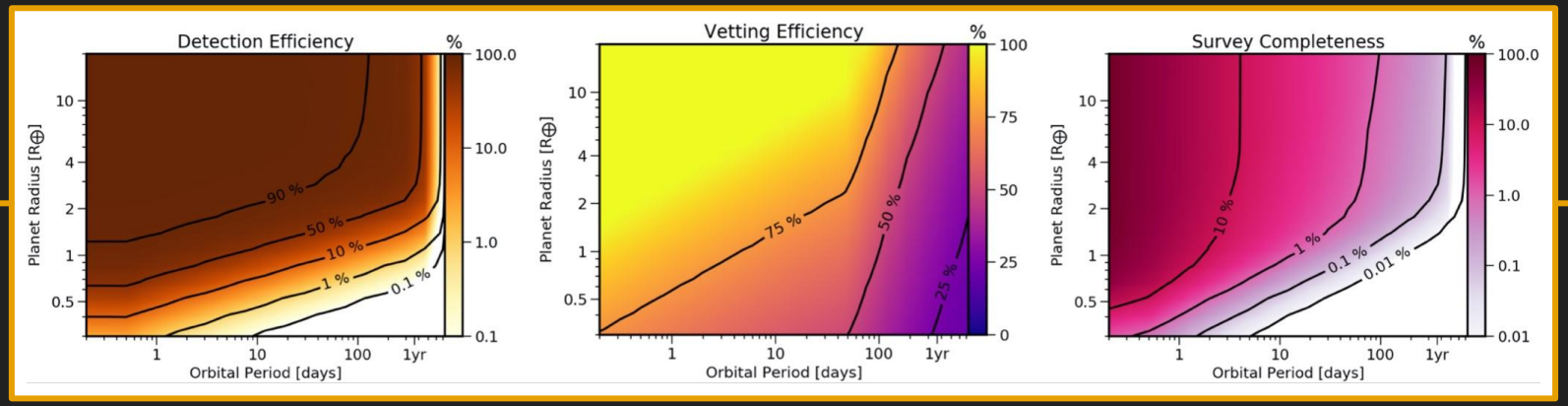




Observed Population

de-bias

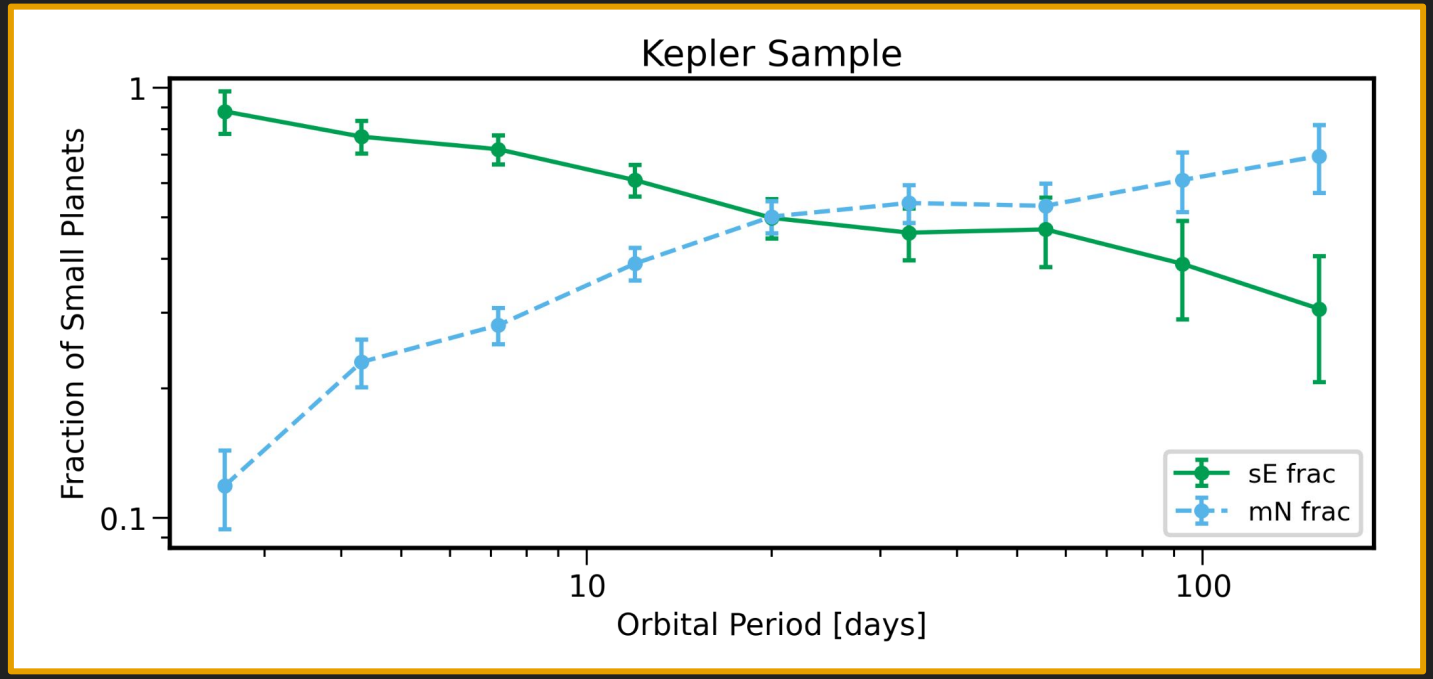
Intrinsic Population

epos

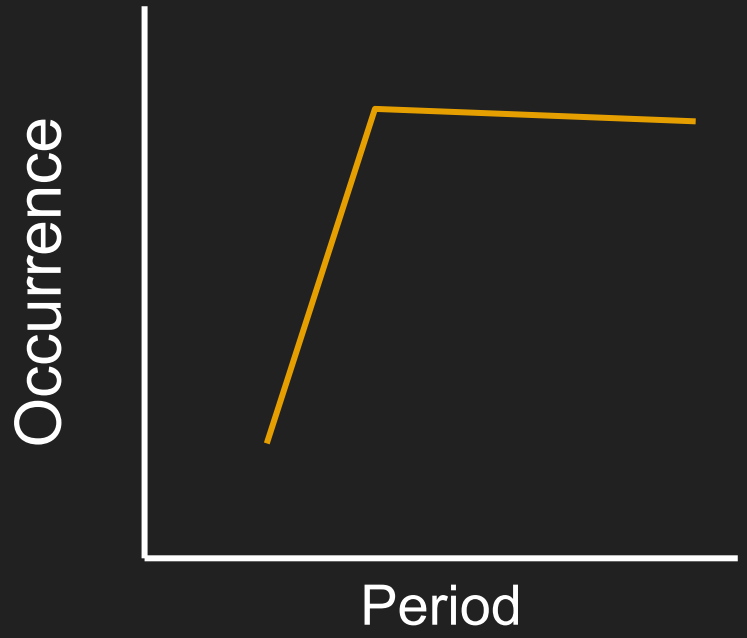
Exoplanet Population Observation Simulator

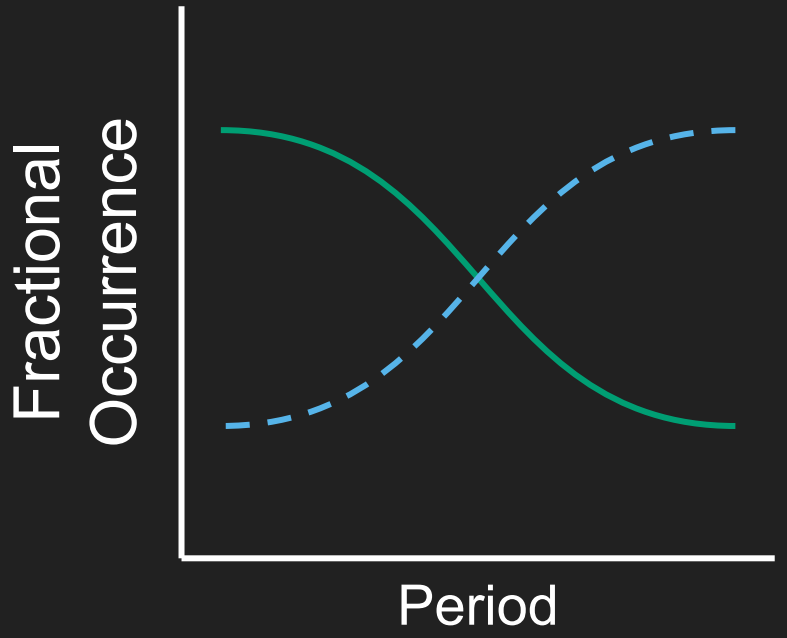
+ Reliability (Bryson et al. 2020)

epos: Mulders et al. (2018)

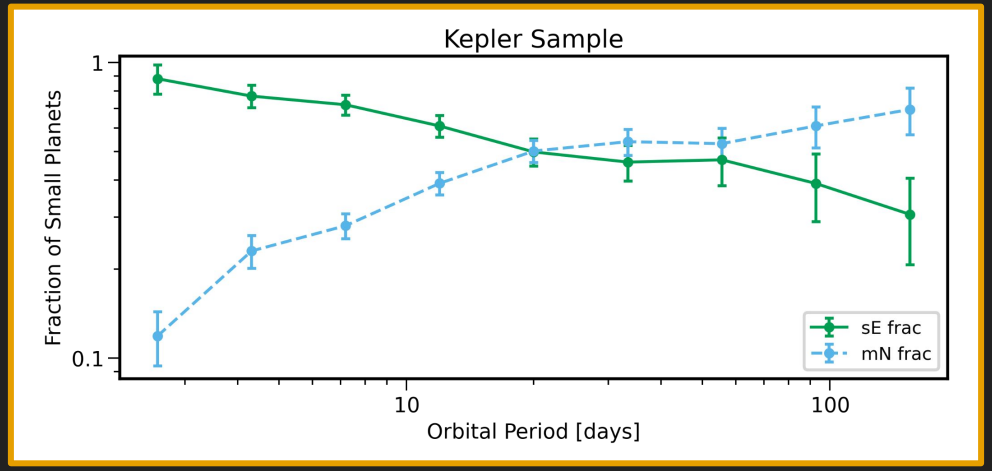

Kepler Sample
Fraction of Small Planets
1
0.1
10
100
Orbital Period [days]
sE frac
mN frac

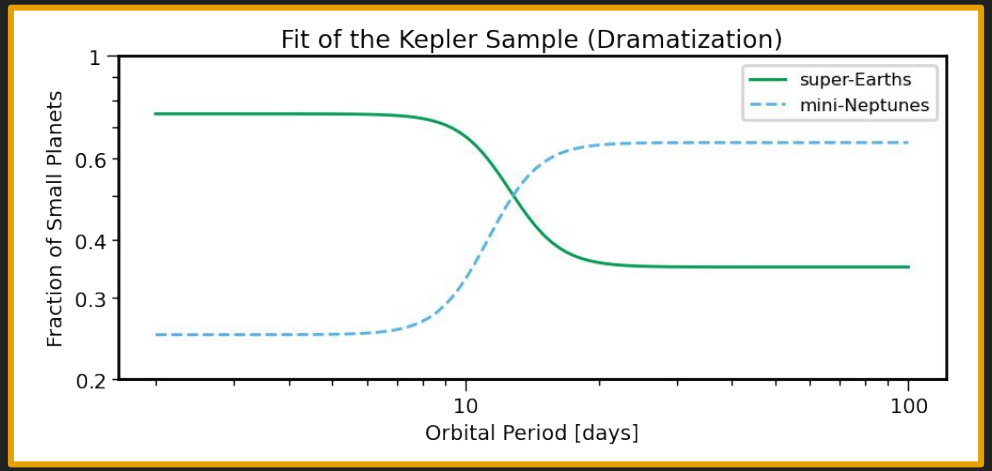
Planet Distribution Function

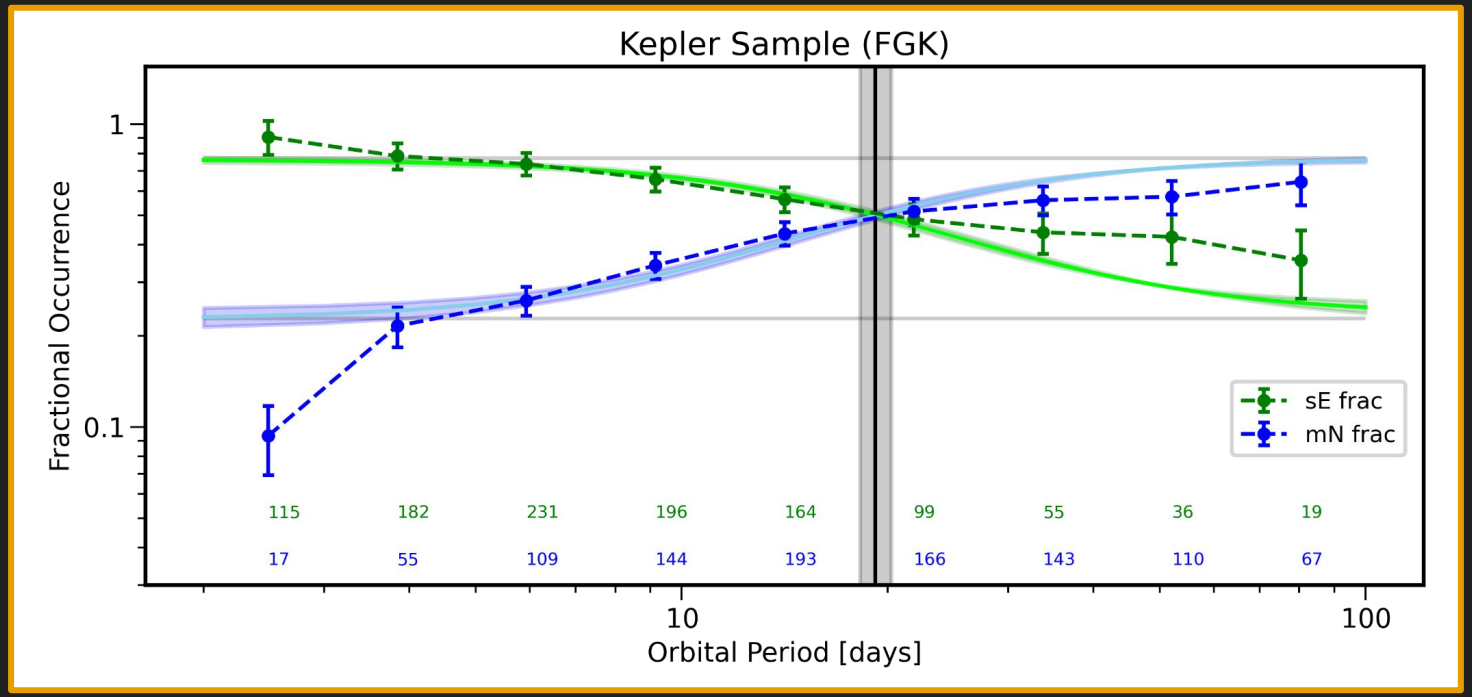




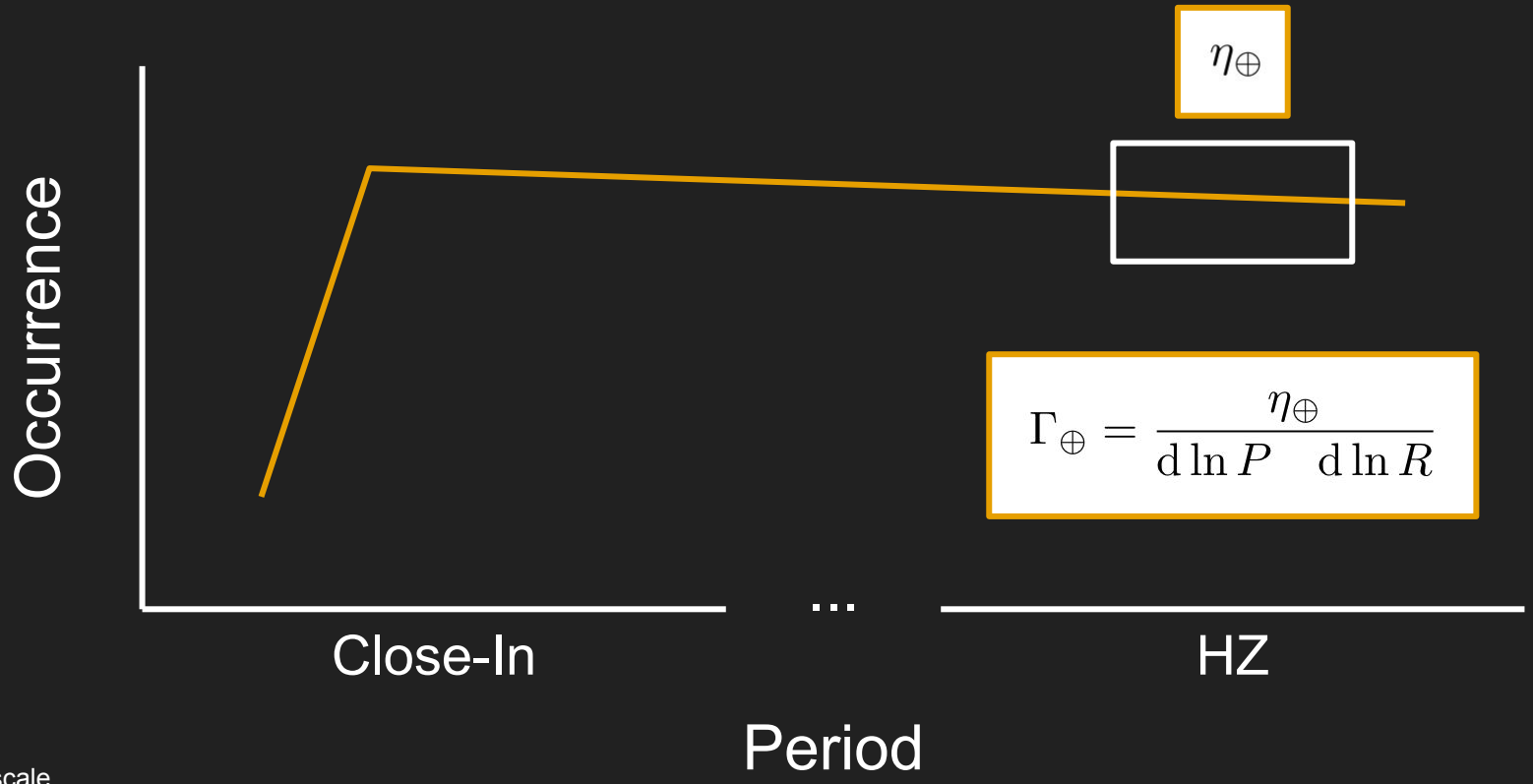
e.g. Mulders et al. (2018); Pascucci et al. (2019)


Kepler Sample
Fraction of Small Planets
1
0.1
10
100
Orbital Period [days]
sE frac
mN frac


Fit of the Kepler Sample (Dramatization)
Fraction of Small Planets
1
0.6
0.4
0.3
0.2
10
100
Orbital Period [days]
super-Earths
mini-Neptunes

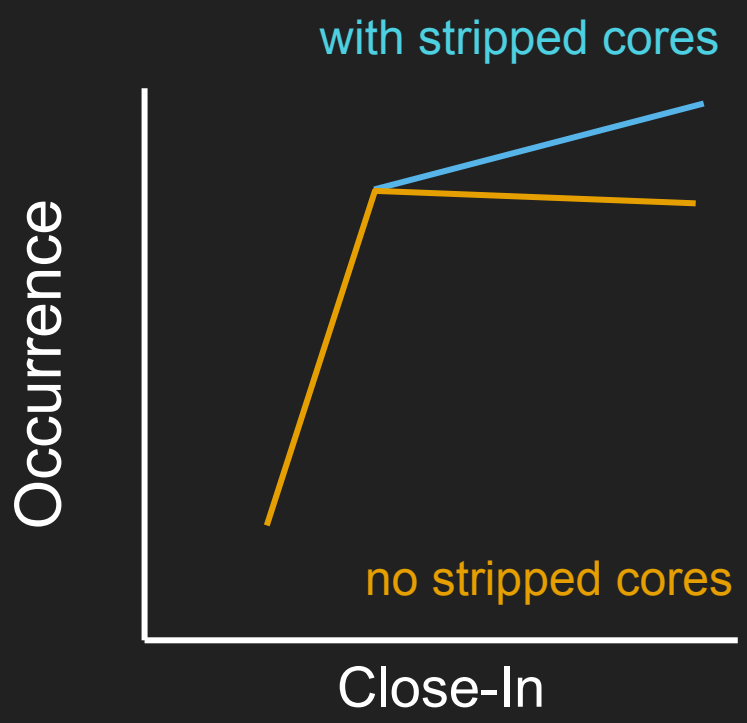

Kepler Sample (FGK)
Fractional Occurrence
1
0.1
10
100
Orbital Period [days]
sE frac
mN frac
115
182
231
196
164
99
55
36
19
17
55
109
144
193
166
143
110
67

Estimating HZ Occurrence Rates



*not to scale

Estimating HZ Occurrence Rates



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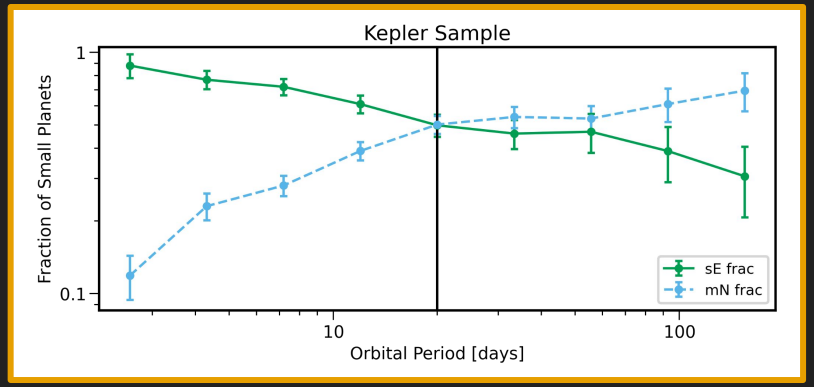
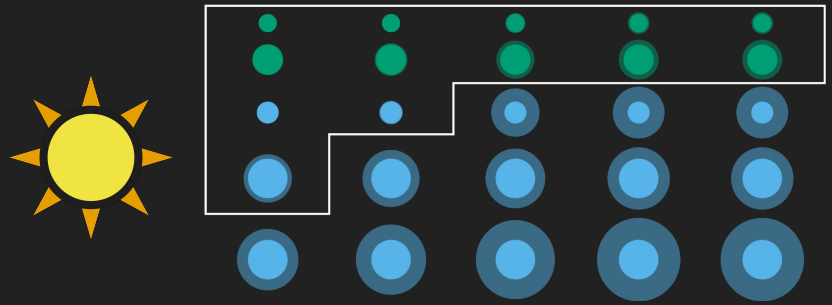
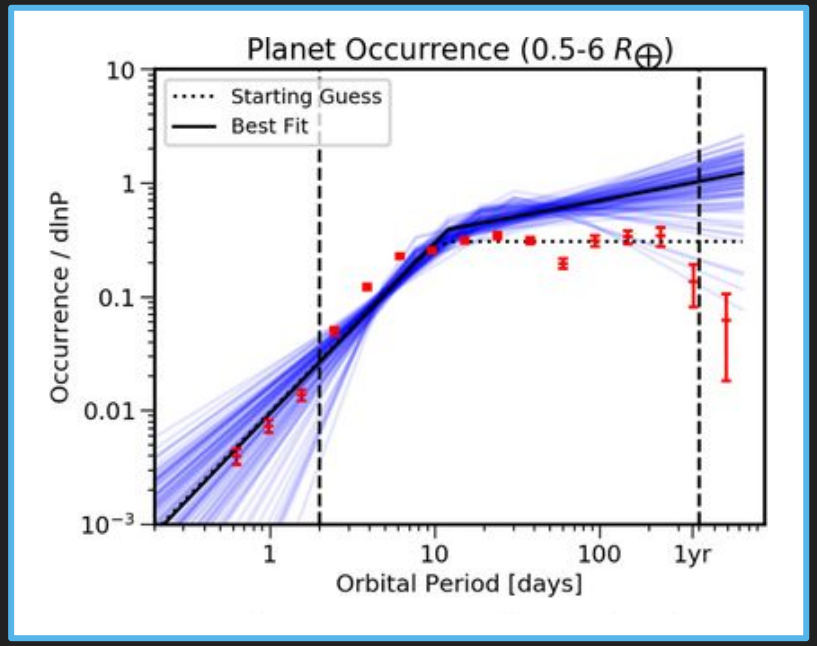
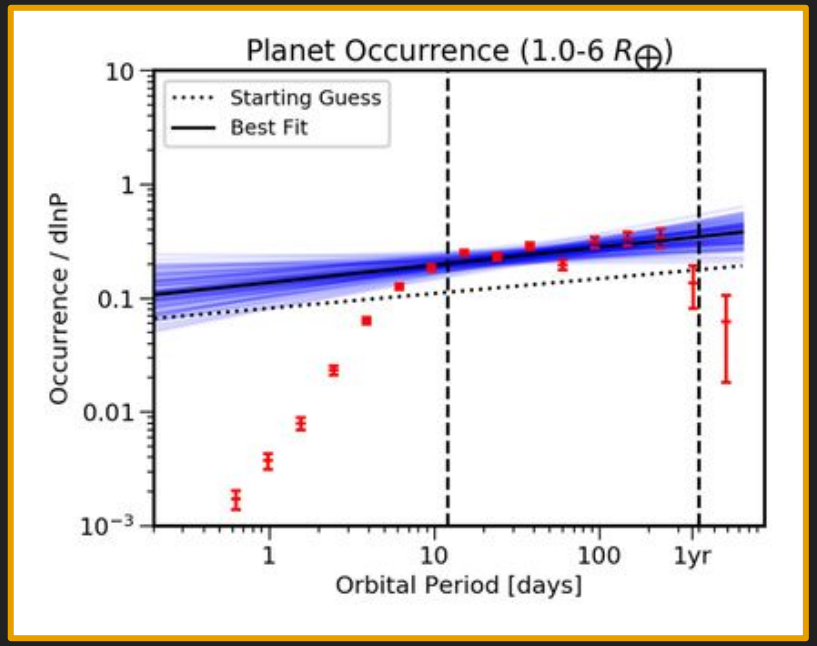




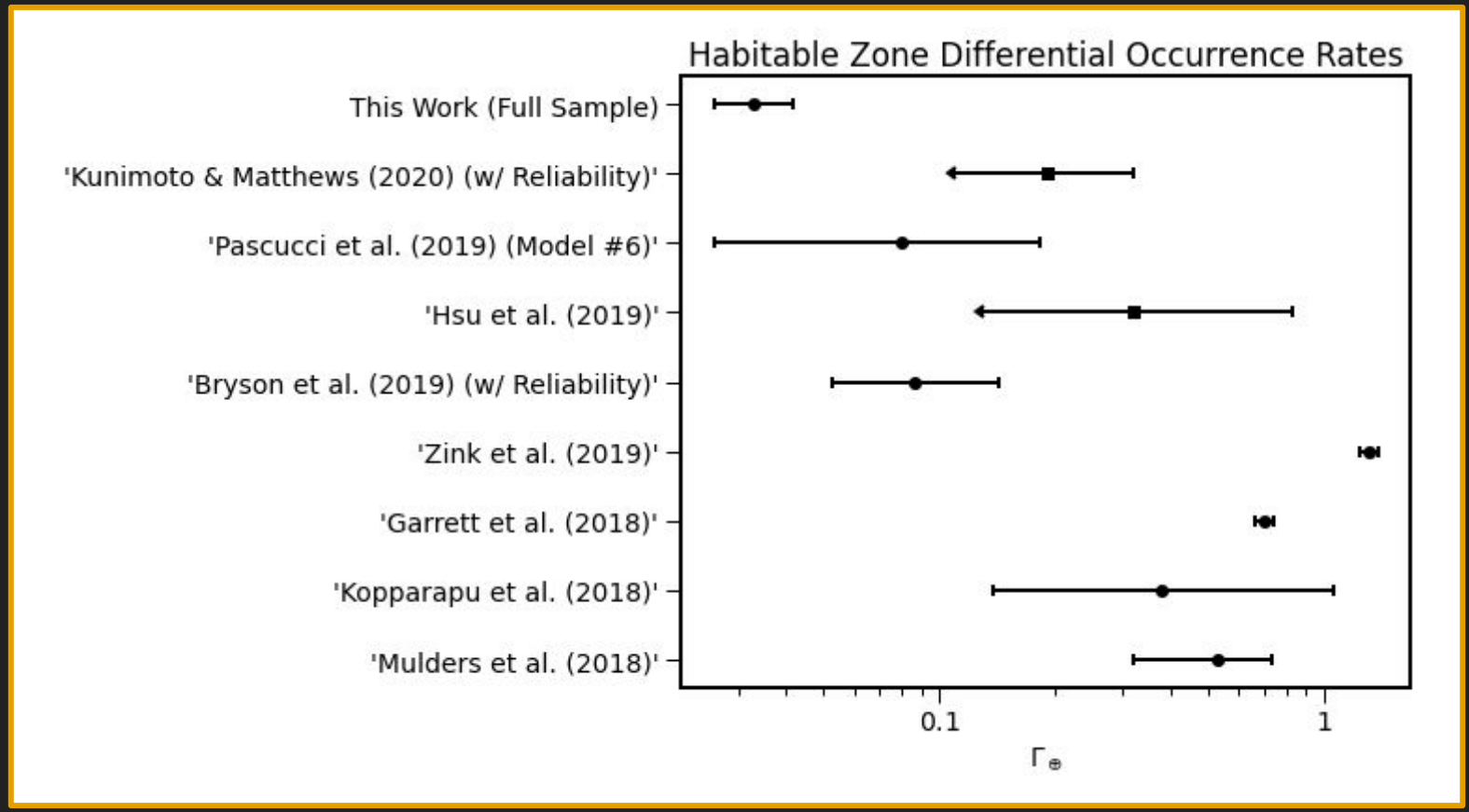
Includes Stripped Cores



Excludes Stripped Cores



Pascucci et al. 2019


Habitable Zone Differential Occurrence Rates
This Work (Full Sample)
'Kunimoto & Matthews (2020) (w/ Reliability)'
'Pascucci et al. (2019) (Model #6)'
'Hsu et al. (2019)'
'Bryson et al. (2019) (w/ Reliability)'
'Zink et al. (2019)'
'Garrett et al. (2018)'
'Kopparapu et al. (2018)'
'Mulders et al. (2018)'
0.1
1
$\Gamma_\oplus$

PLATO Mission Yields

$$2\,\% < \eta_{\oplus} < 100\,\%$$

	stellar sample	24 N-cam (2+2)	24 N-cam (3+1)	24 N-cam (3+2+1)
small planets ($R < 2\,R_E$), in HZ, $V \leq 11$	P1+P5 bright	6 - 280	3 - 140	6 - 280

PLATO Definition Study Report (2017)

This Work: $\eta_{\oplus} \approx 4.2\,\%$

Atmospheric Loss

↓

Brightness

↓

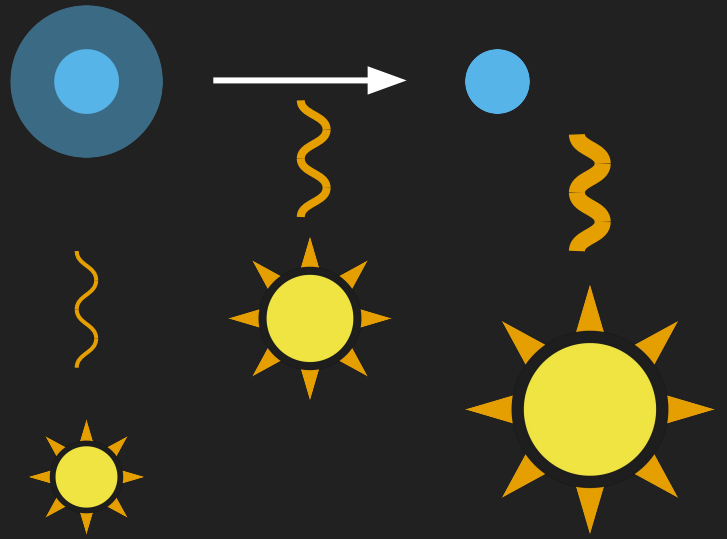
Stellar Mass

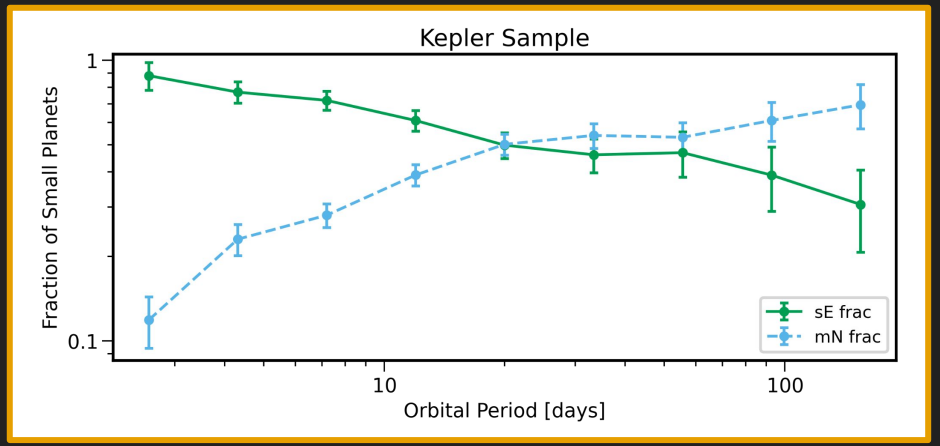
↓

?

↓

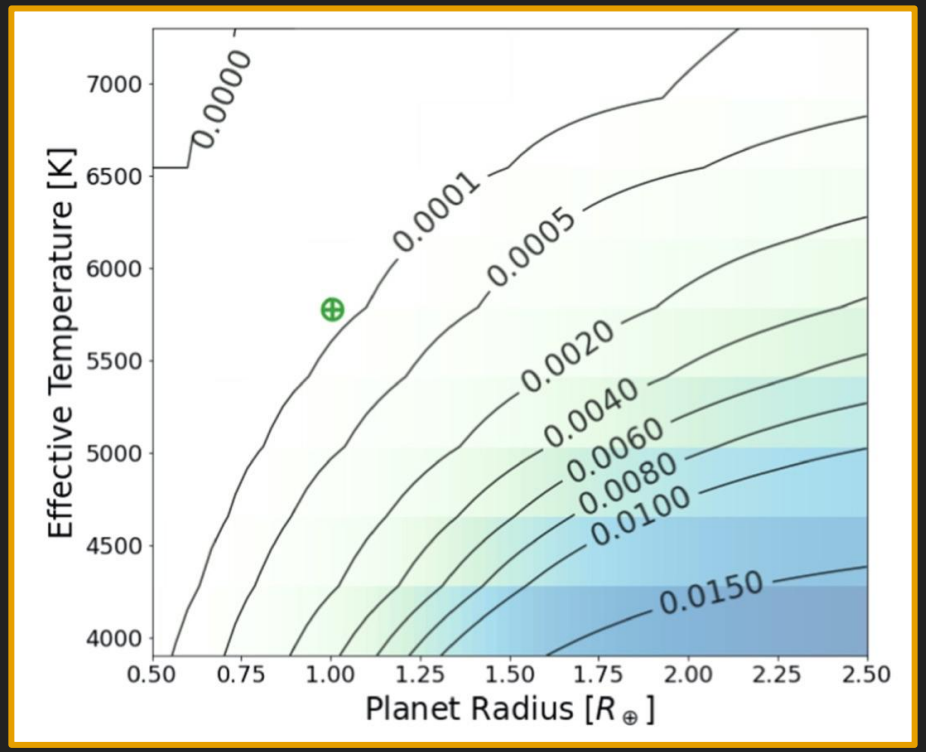
Observed Trend





*not to scale

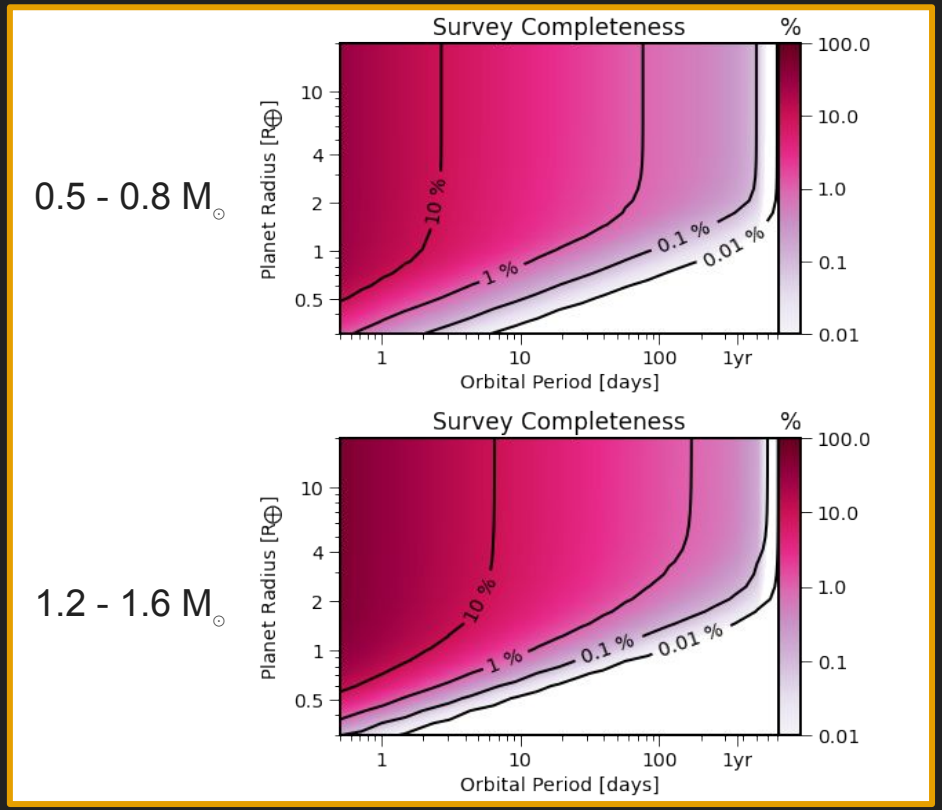
Completeness for Different Stars



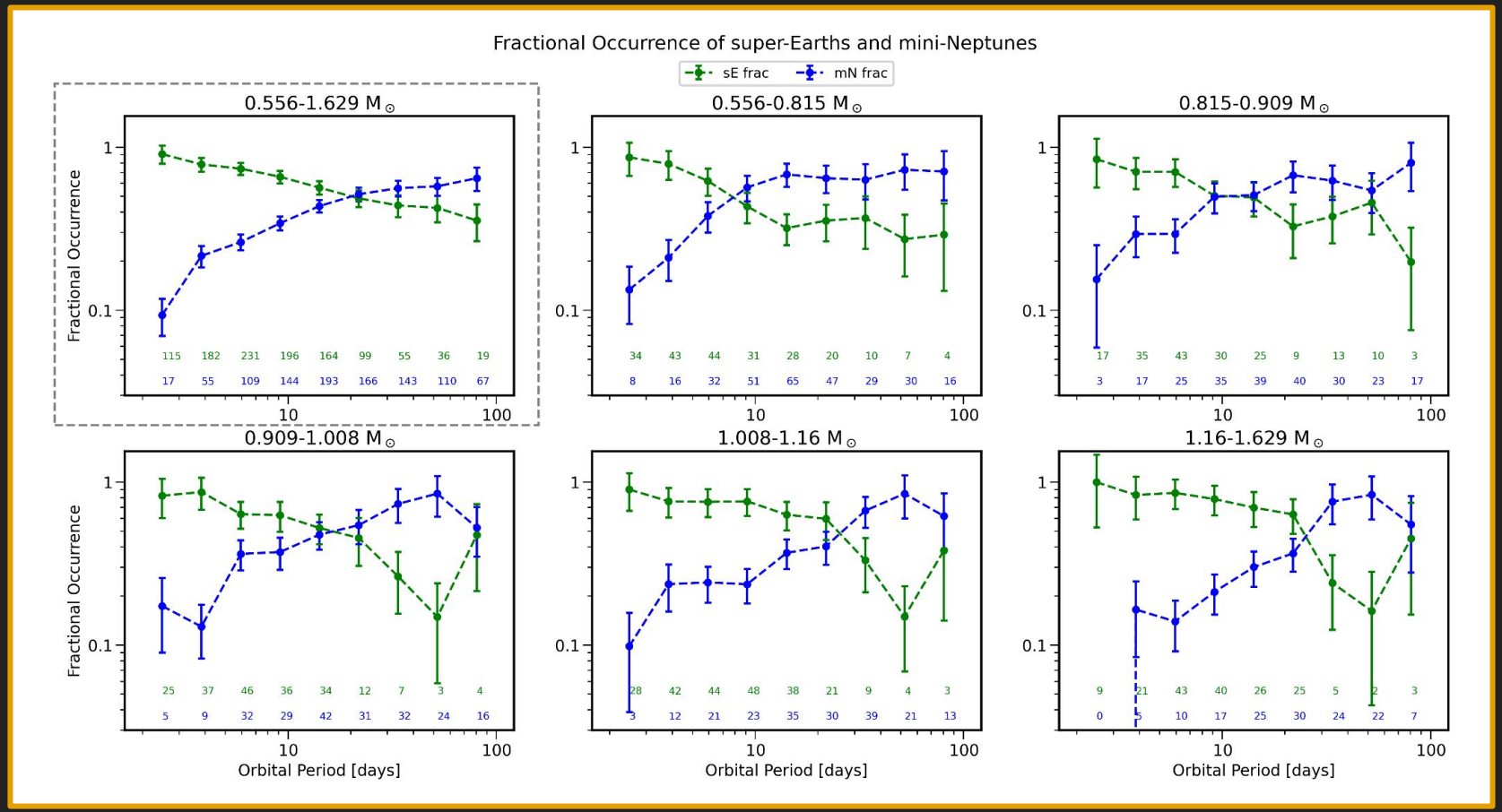
Bryson et al. 2021

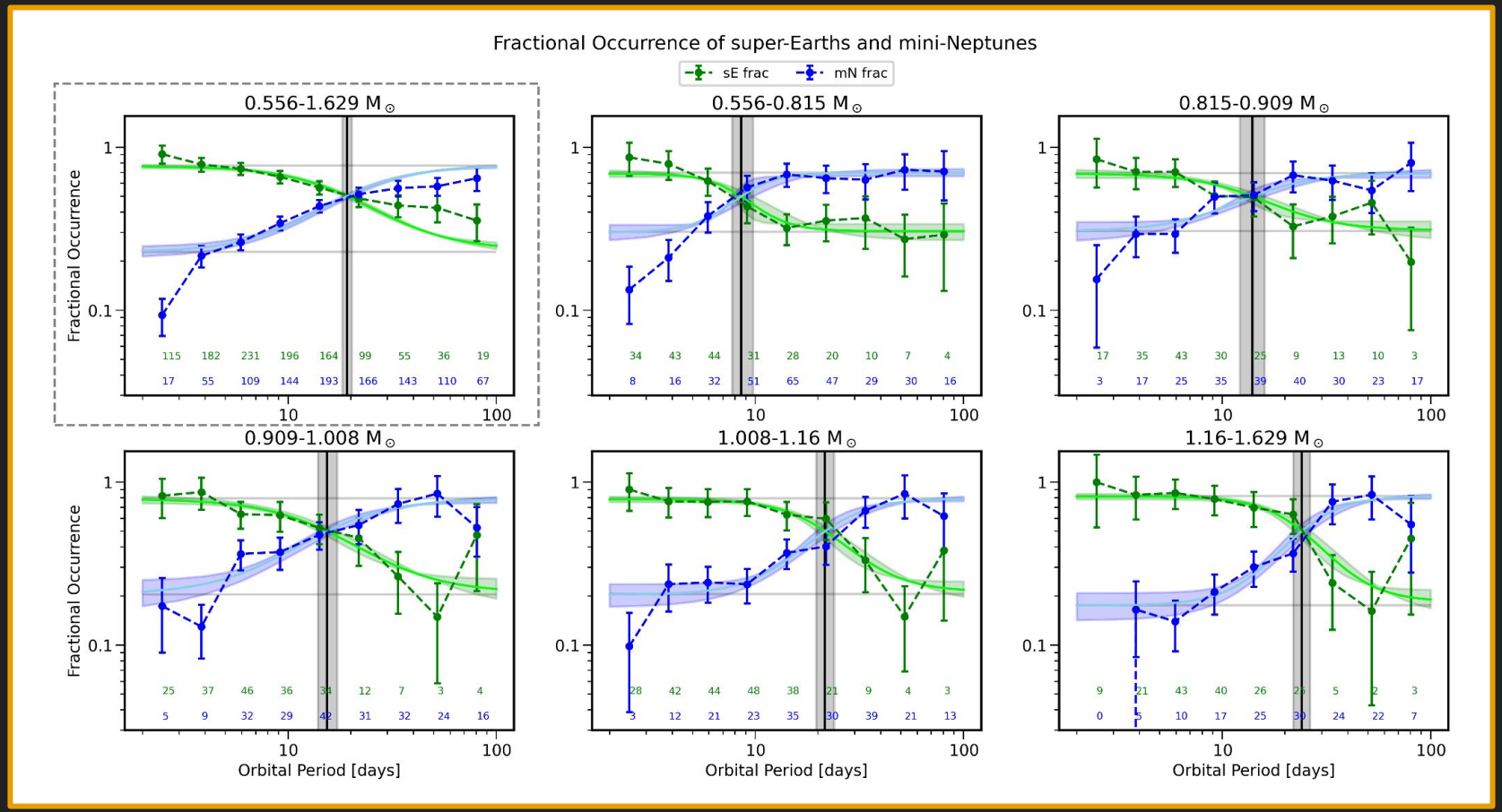
epos with Stellar Mass

- Completeness maps made separately for each stellar mass bin (small but important!).
- Automated process, update coming soon.



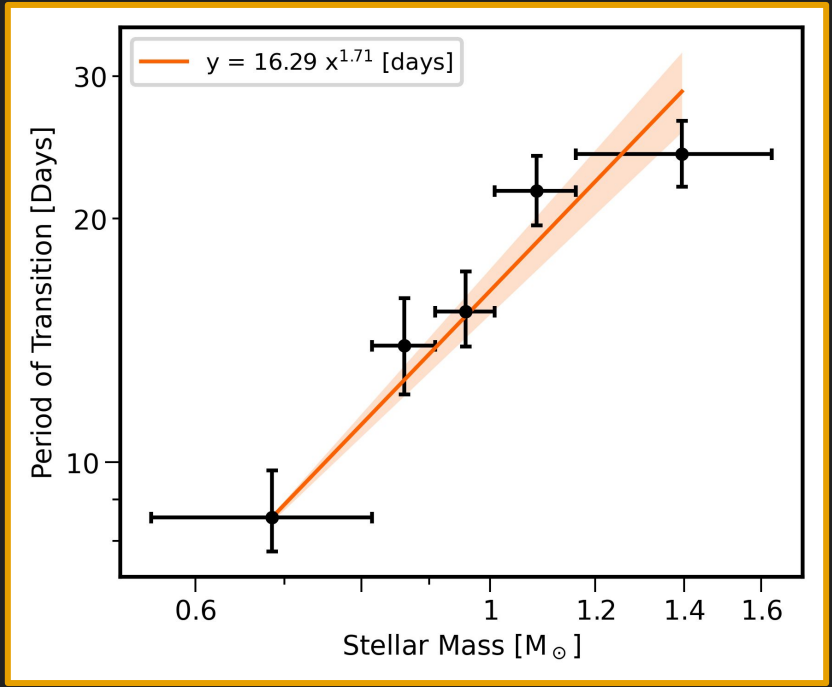
epos: Mulders et al. (2018)


Fractional Occurrence of super-Earths and mini-Neptunes
sE frac
mN frac
0.556-1.629 M⊙
0.556-0.815 M⊙
0.815-0.909 M⊙
0.909-1.008 M⊙
1.008-1.16 M⊙
1.16-1.629 M⊙
Fractional Occurrence
Orbital Period [days]
1
0.1
10
100
115 182 231 196 164 99 55 36 19
17 55 109 144 193 166 143 110 67
34 43 44 31 28 20 10 7 4
8 16 32 51 65 47 29 30 16
17 35 43 30 25 9 13 10 3
3 17 25 35 39 40 30 23 17
25 37 46 36 34 12 7 3 4
5 9 32 29 42 31 32 24 16
28 42 44 48 38 21 9 4 3
3 12 21 23 35 30 39 21 13
9 21 43 40 26 25 5 2 3
0 5 10 17 25 30 24 22 7


Fractional Occurrence of super-Earths and mini-Neptunes
sE frac
mN frac
0.556-1.629 M⊙
0.556-0.815 M⊙
0.815-0.909 M⊙
0.909-1.008 M⊙
1.008-1.16 M⊙
1.16-1.629 M⊙
Fractional Occurrence
Orbital Period [days]
1
0.1
10
100
115 182 231 196 164 99 55 36 19
17 55 109 144 193 166 143 110 67
34 43 44 31 28 20 10 7 4
8 16 32 51 65 47 29 30 16
17 35 43 30 25 9 13 10 3
3 17 25 35 39 40 30 23 17
25 37 46 36 38 12 7 3 4
5 9 32 29 42 31 32 24 16
28 42 44 48 38 21 9 4 3
3 12 21 23 35 30 39 21 13
9 21 43 40 26 28 5 2 3
0 5 10 17 25 30 24 22 7

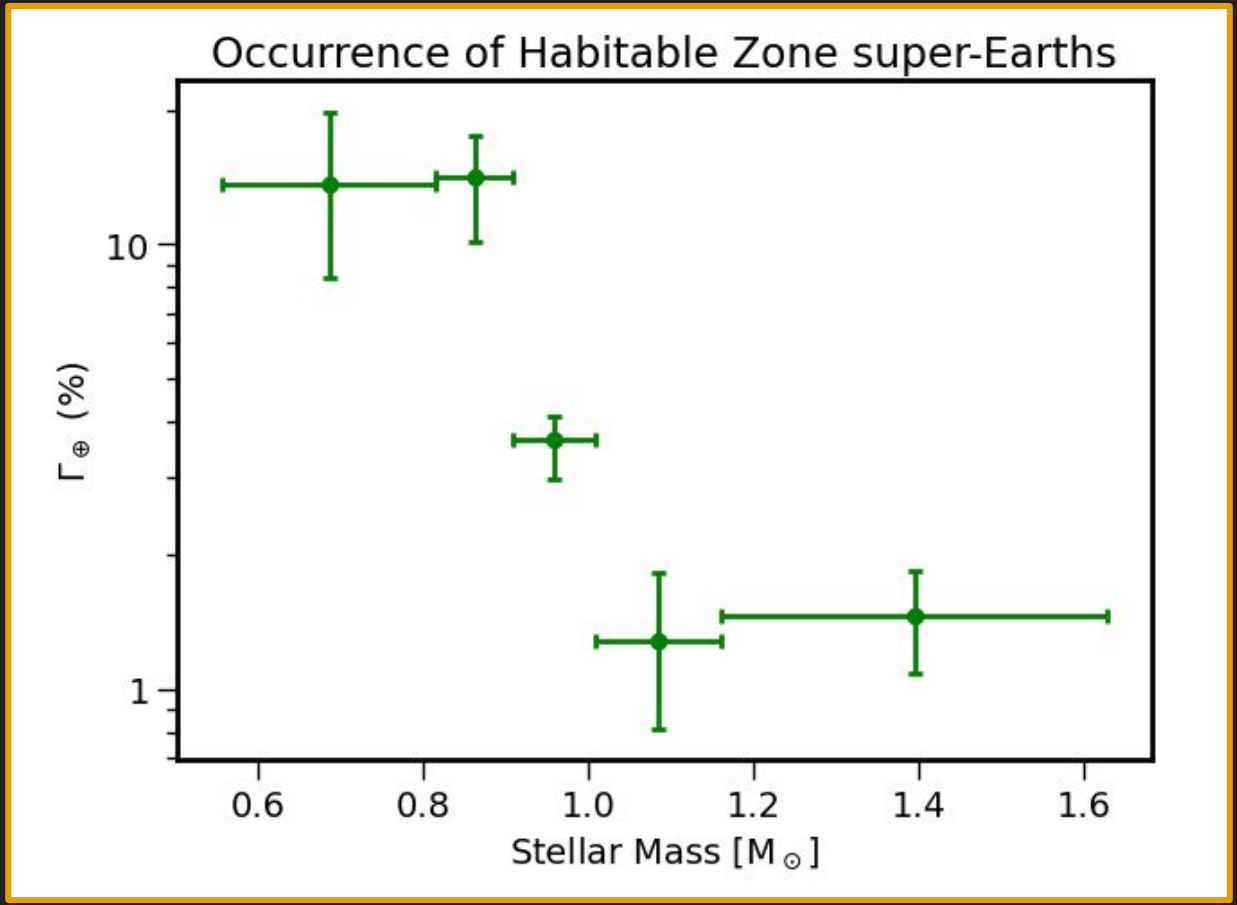
Stellar Mass Dependence!

Transition Periods
Useful for constraining the relevant regime of atmospheric loss.



Bergsten et al. (in prep)

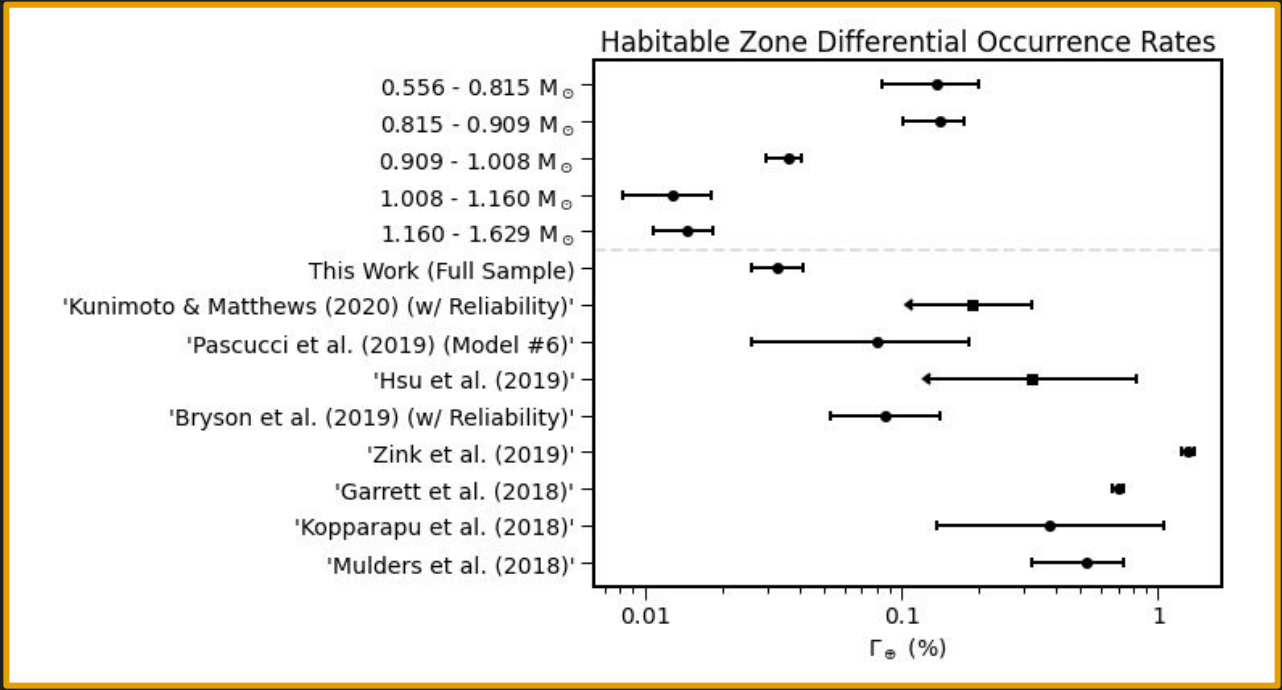
Mass Dependence
Useful comparison for the predictions of different atmospheric loss models. Also a check for end products of evolutionary simulations.



Bergsten et al. (in prep)

gbergsten@email.arizona.edu
@stellar_cyan

Comparison Plot w/ Stellar Mass Bins



Bergsten et al. (in prep)