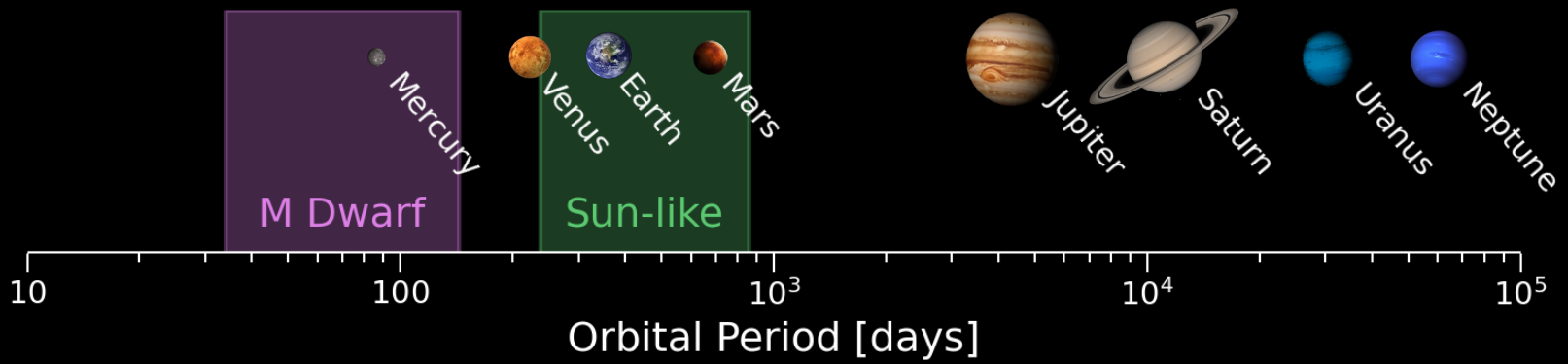# No Evidence for More Earth-sized Planets in the Habitable Zone of *Kepler*'s M versus FGK Stars

Galen Bergsten – ExoPAG 29 – Jan. 6, 2024

+ Ilaria Pascucci, Kevin Hardegree-Ullman,
Rachel Fernandes, Jessie Christiansen, Gijs Mulders

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How has the *Kepler* sample changed in the last 8 years?

since 2015

of Earth-sized planets — orbiting M dwarfs

$R_P = [0.5, 1.5] \, R_\oplus$ $T_{\rm eff} \approx [2000, 4000] \, K$

M Dwarf   Sun-like

Mercury   Venus   Earth   Mars   Jupiter   Saturn   Uranus   Neptune

10   100 10^3 10^4 10^5

Orbital Period [days]

2015

$n = 6$

$\eta_{\oplus} = 24\,^{+18}_{-8}\,\%$

2023

Δ forehead $\approx$ 3 in.

Earth-sized Planets around Kepler's M Dwarfs (2015)
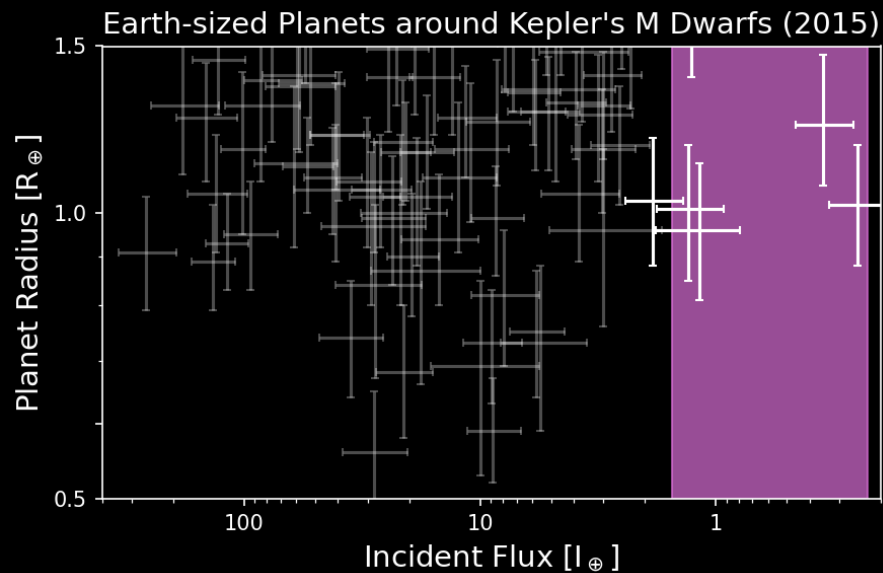
Kepler DR25
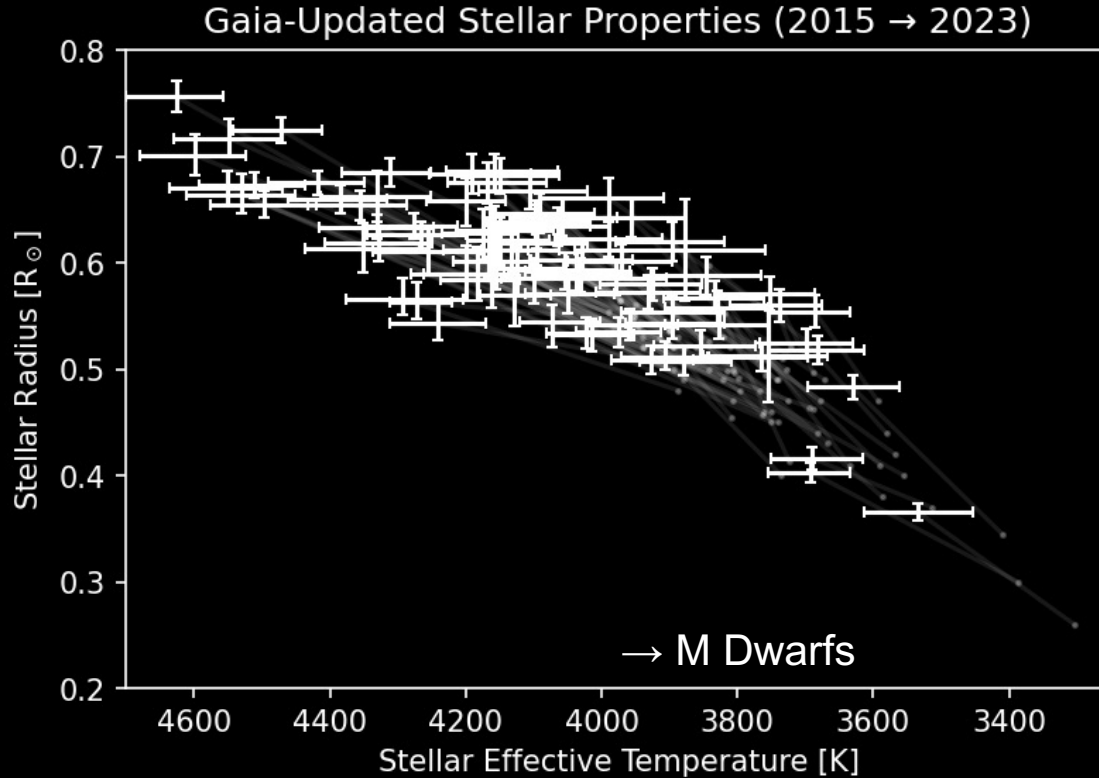Thompson et al. (2018)

Candidate Reliability
e.g., Bryson et al. (2020)

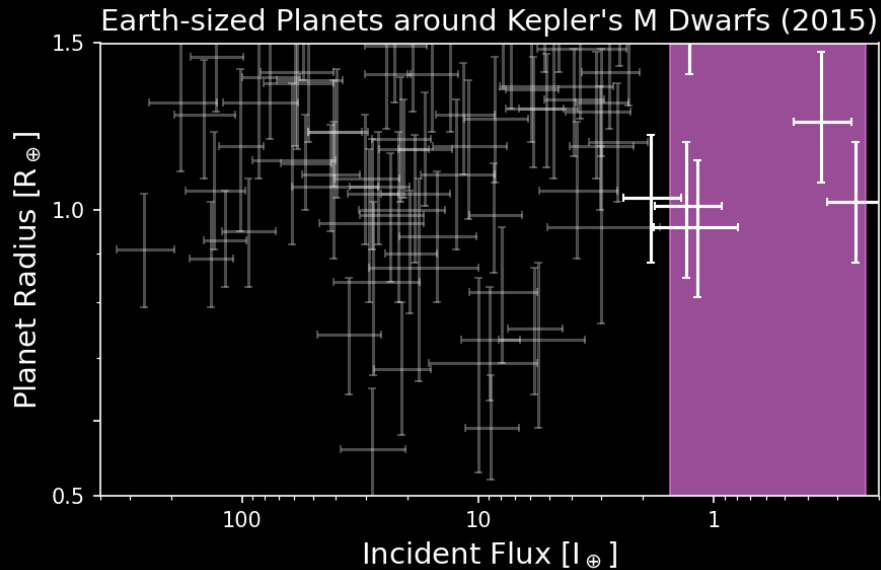*Gaia*-Revised Properties
e.g., Berger et al. (2020)

Dressing & Charbonneau (2015)

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Gaia-Updated Stellar Properties (2015 → 2023)

→ M Dwarfs

→ some planet hosts are still here   +   *Kepler* observed more stars and planets after 2015

Dressing & Charbonneau (2015)
Berger et al. (2020)

2015

n = 6

$\eta_\oplus = 24^{+18}_{-8}\%$

Kepler DR25 +
Gaia DR2

2023

n ≤ 1

Thompson et al. (2018),
Berger et al. (2020)

$\eta_\oplus = ??^{+?}_{-?}\%$

Earth-sized Planets around Kepler's M Dwarfs (2015)

Earth-sized Planets around Kepler's M Dwarfs (2023)

60%
Reliable
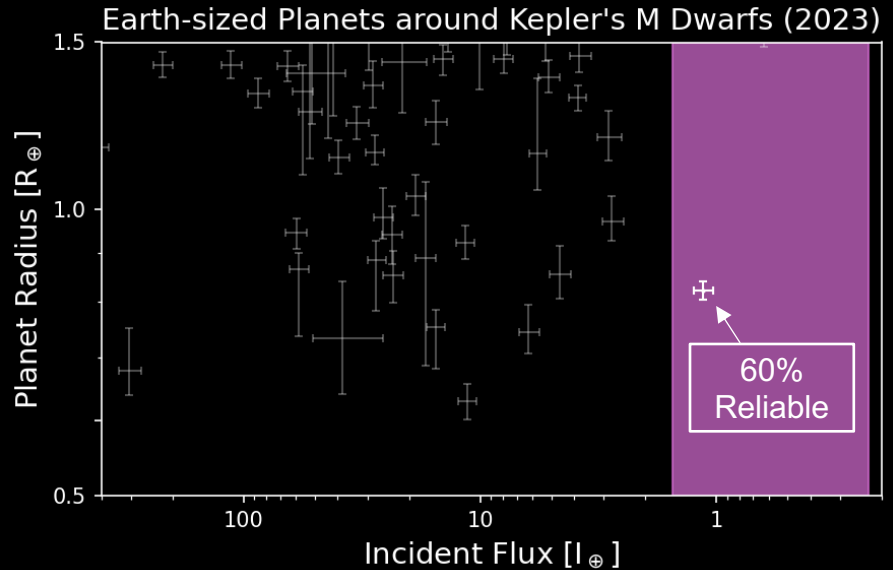
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Current *Kepler* Sample
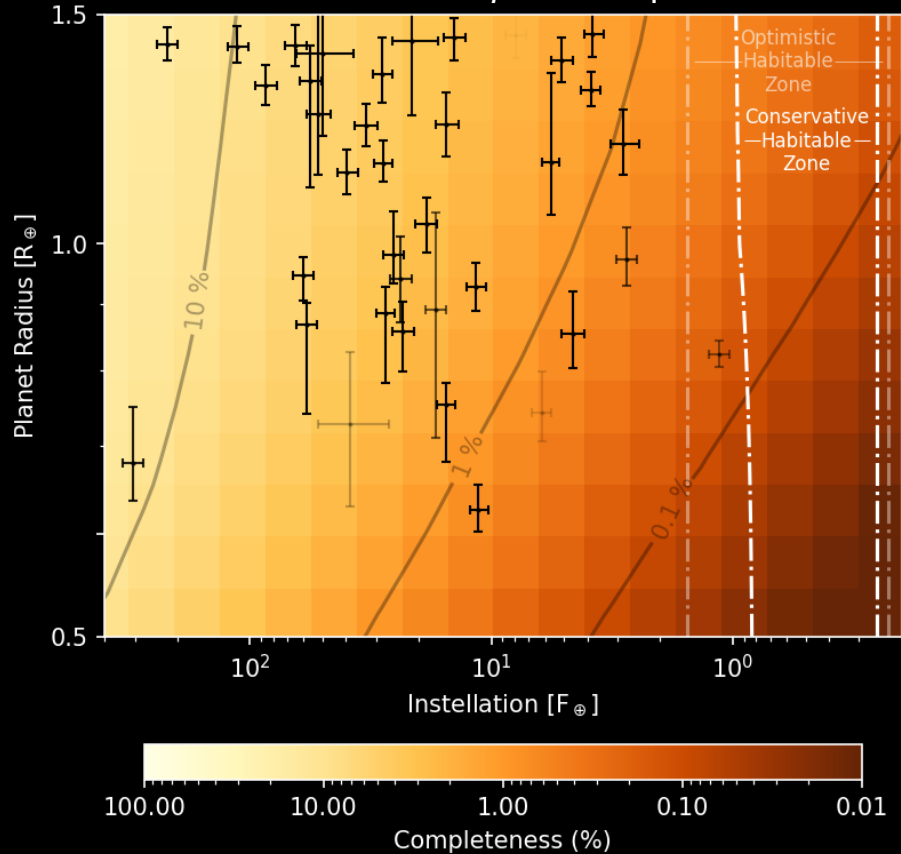
Directly Measured Occurrence Rates
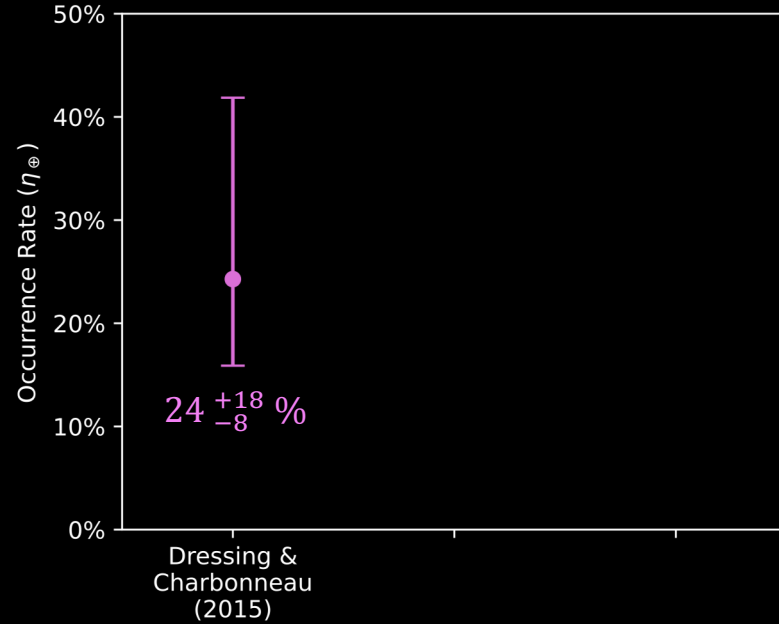
via the Inverse Detection Efficiency Method
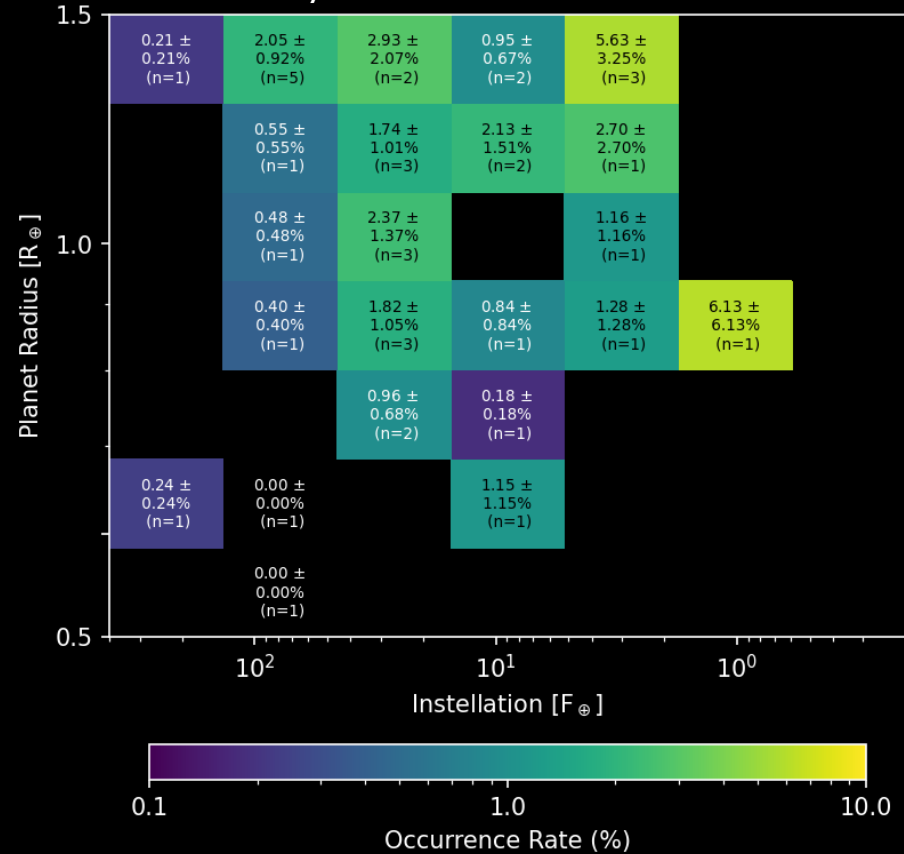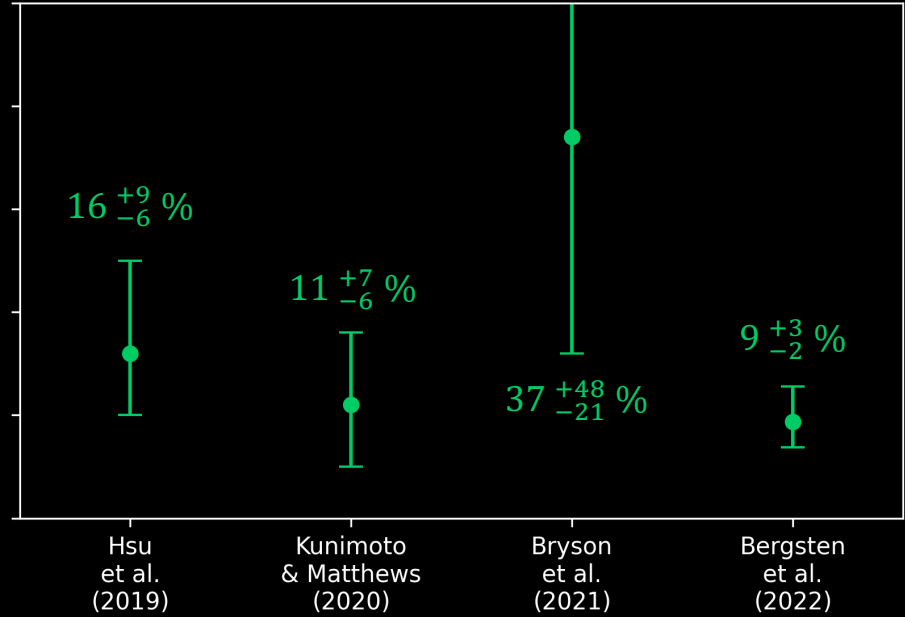
Earth-sized Planets around Kepler's M Dwarfs
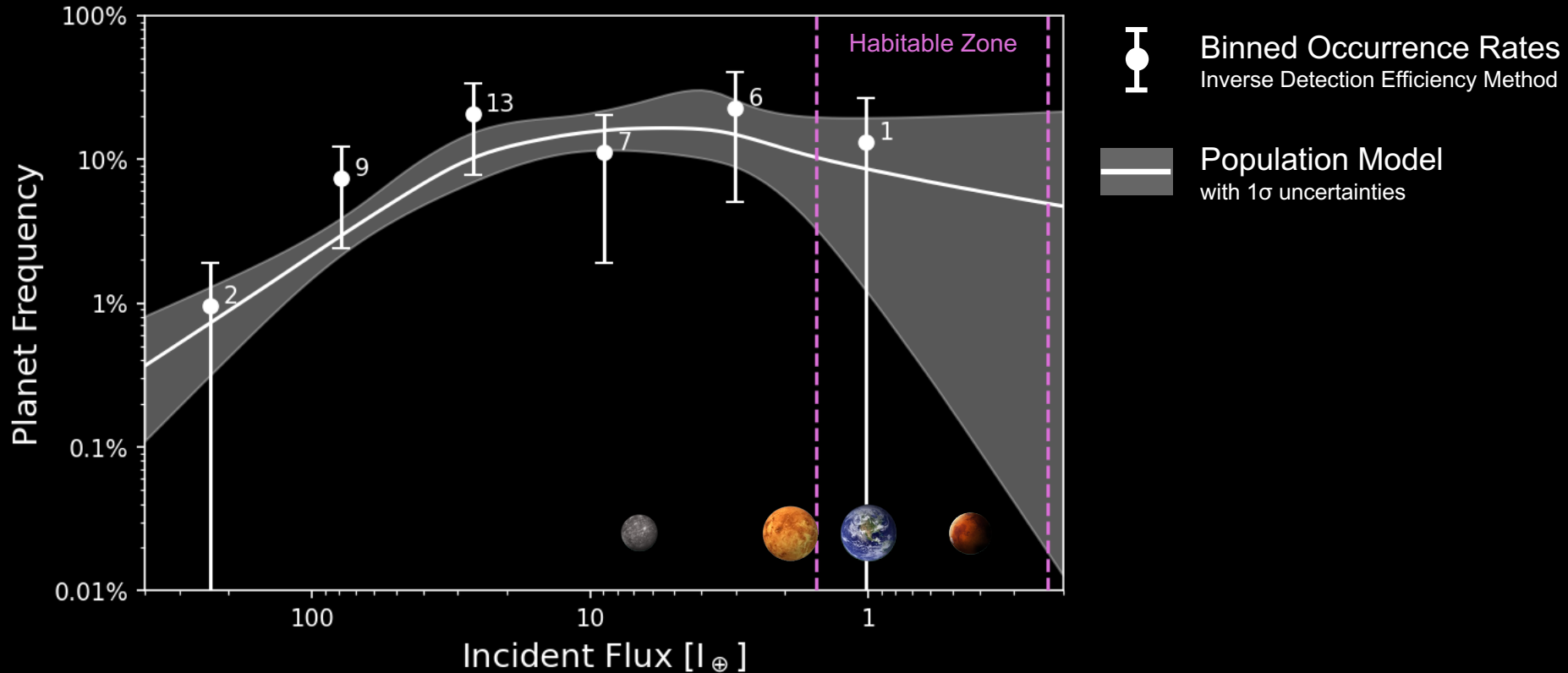
M Dwarfs

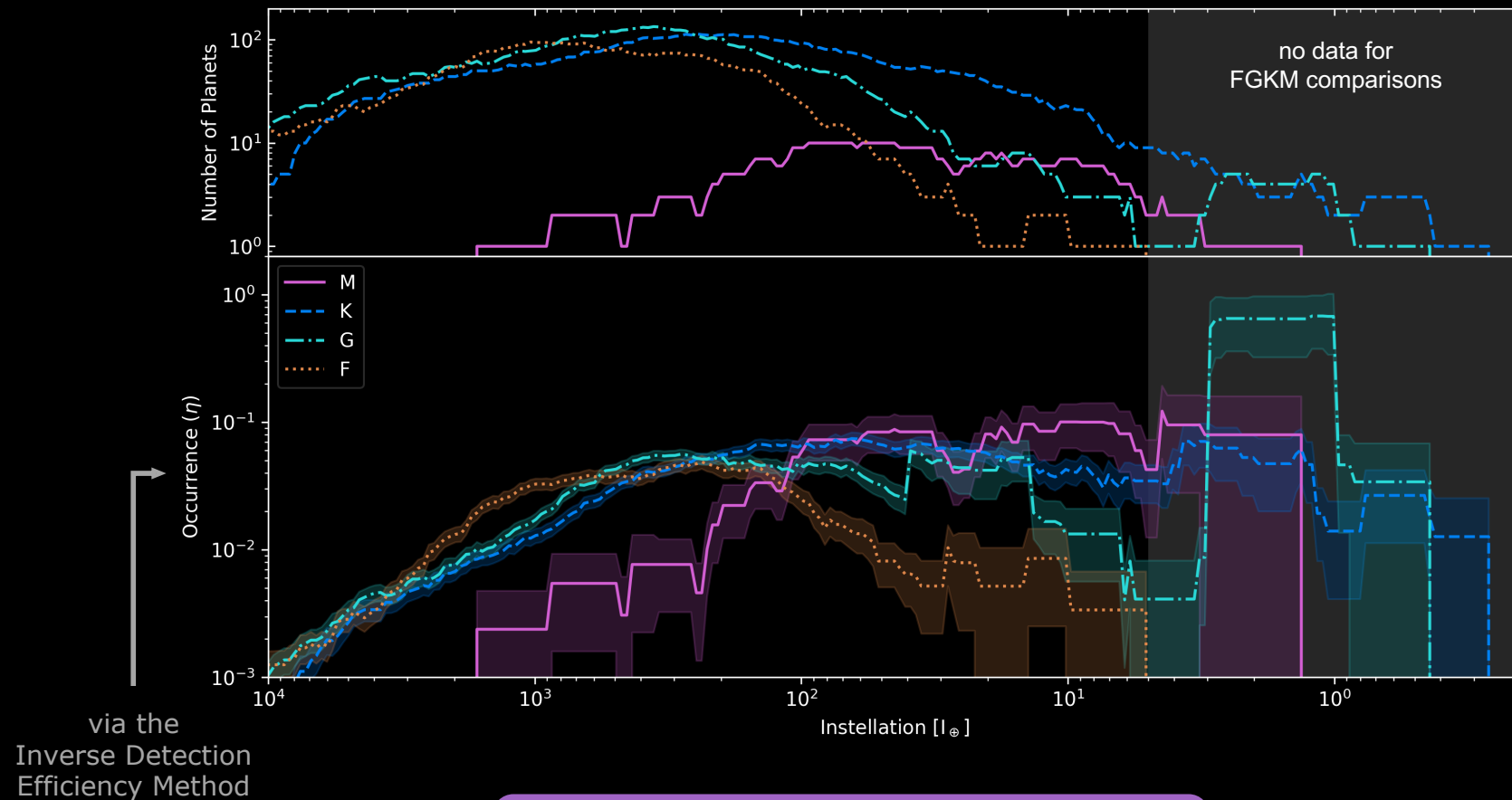## Sun-like Stars

For M dwarfs, $\eta_\oplus$ is less observationally constrained than previously believed.

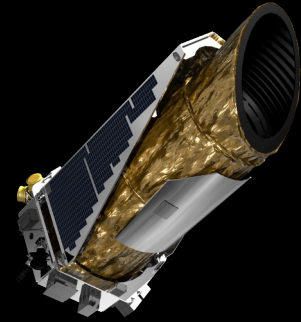*Kepler* offers no evidence for higher $\eta_\oplus$ around M versus FGK stars.
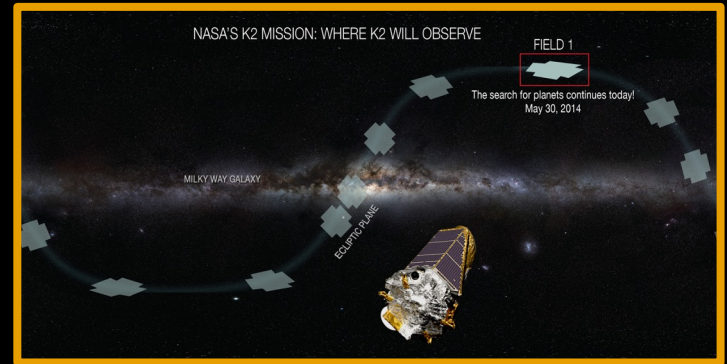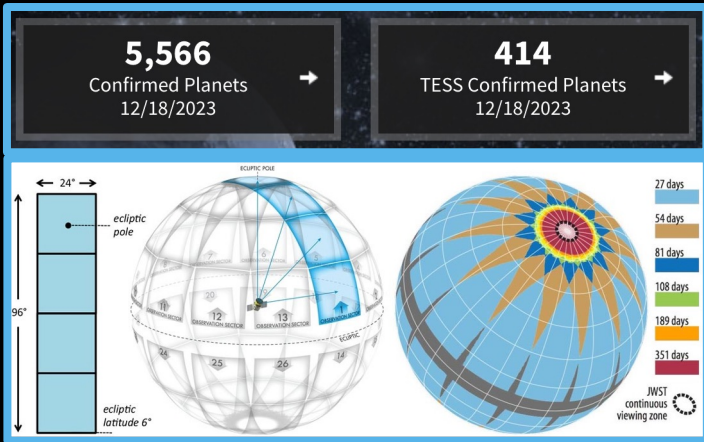
Kepler's Earth-sized ([0.5,1.5] R⊕) Planets

via the
Inverse Detection
Efficiency Method

TESS

K2

check out Ment & Charbonneau (2023)!

check out works by the Scaling K2 team!

50%
n = 6　n ≤ 1

40%

Planet Frequency

30%

20%

10%

0%
　　2015　2023
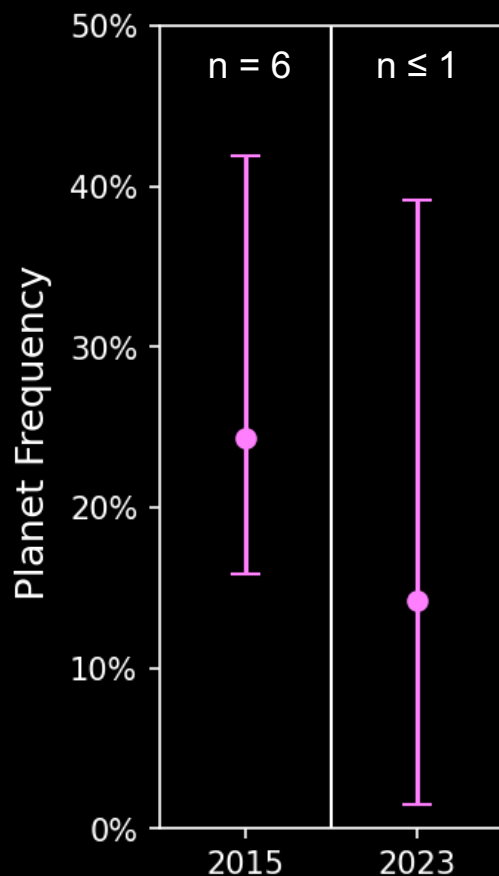
Earth-sized Habitable Zone Planets around M Dwarfs
- Not well-constrained from observations
- New models suggest a frequency of $14\,^{+25}_{-13}$ %
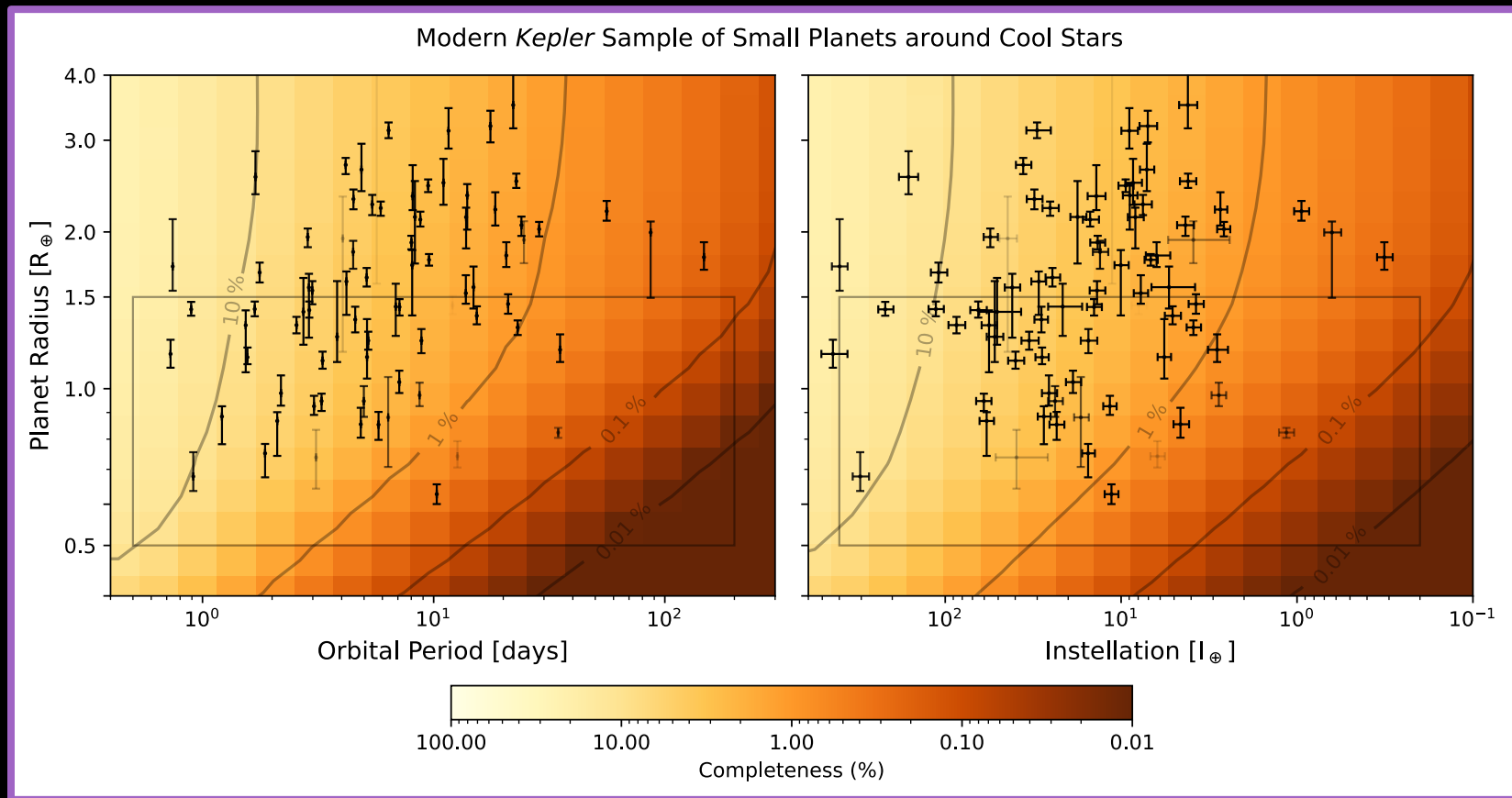- Ongoing & future surveys will improve uncertainties

Also in Bergsten et al. (2023):
- Modeling in instellation vs. in orbital period
- Detailed comparisons across spectral subtypes
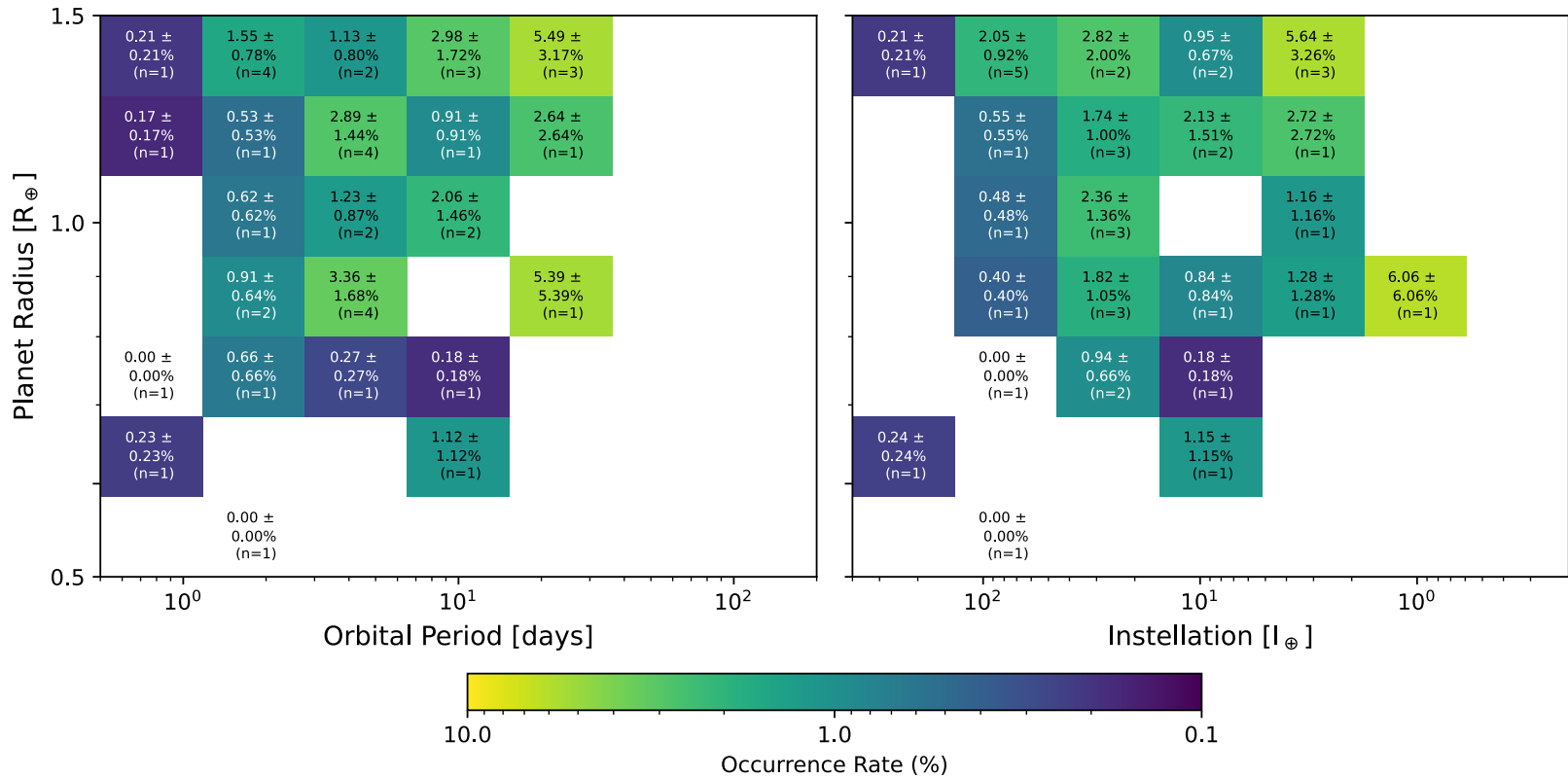- Implications for planet formation / evolution
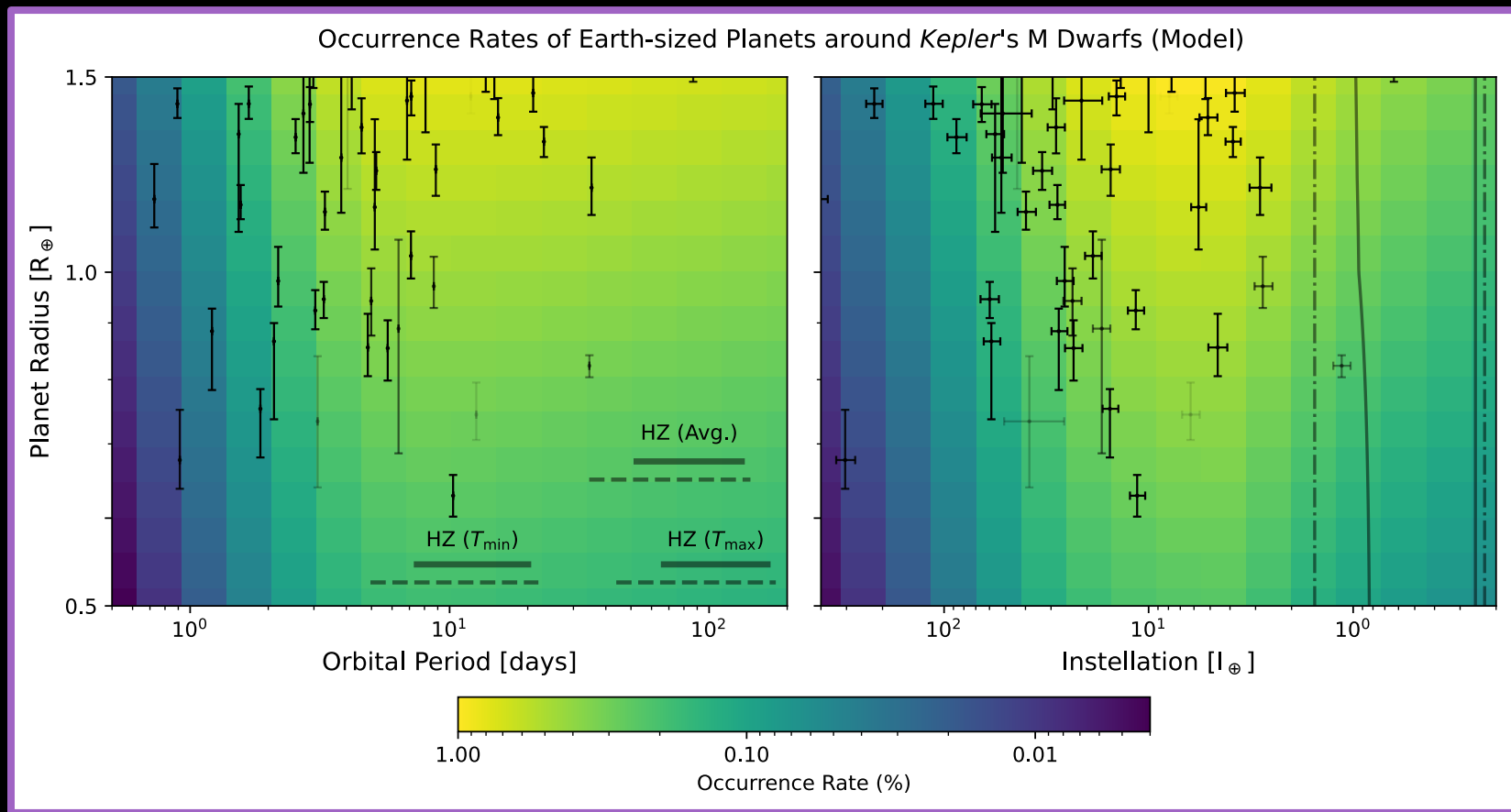
Backup Slides
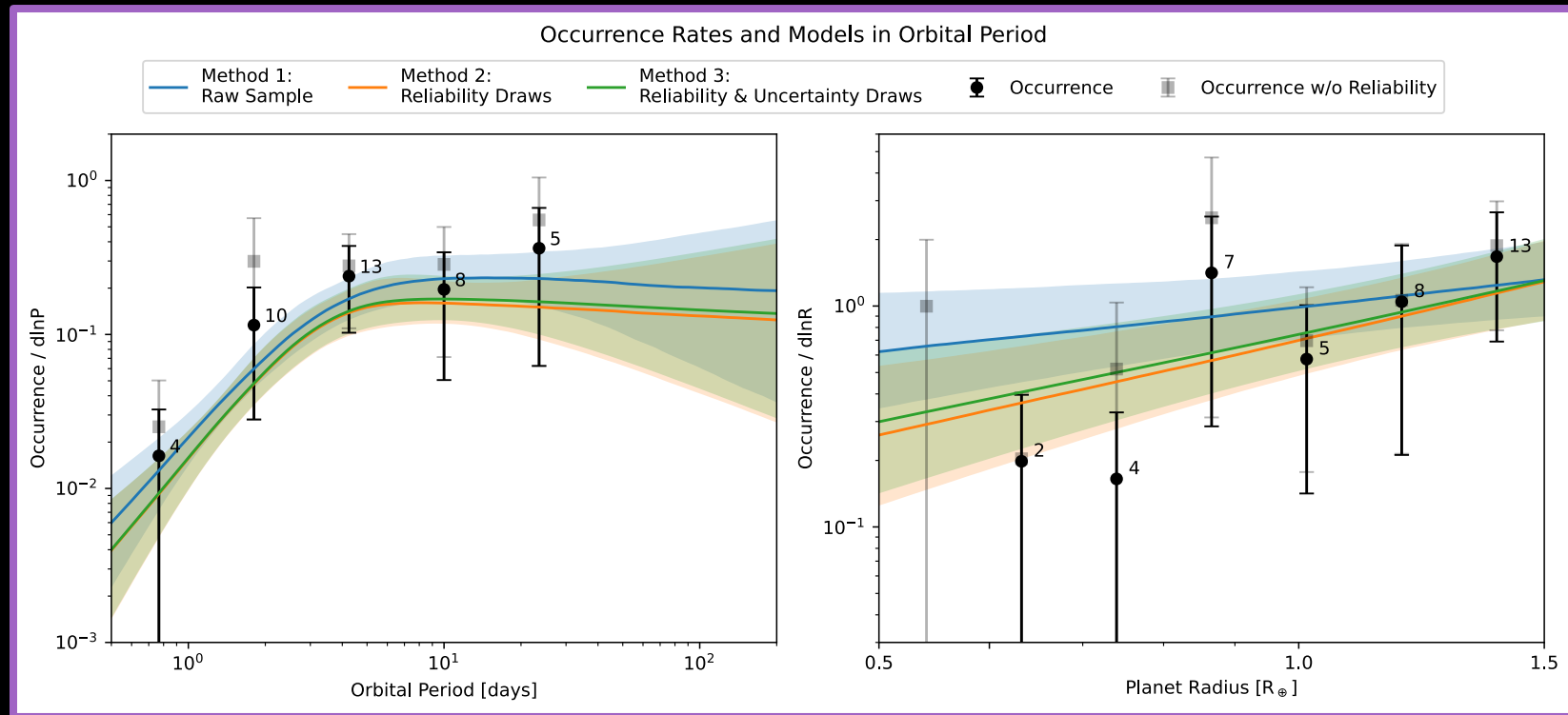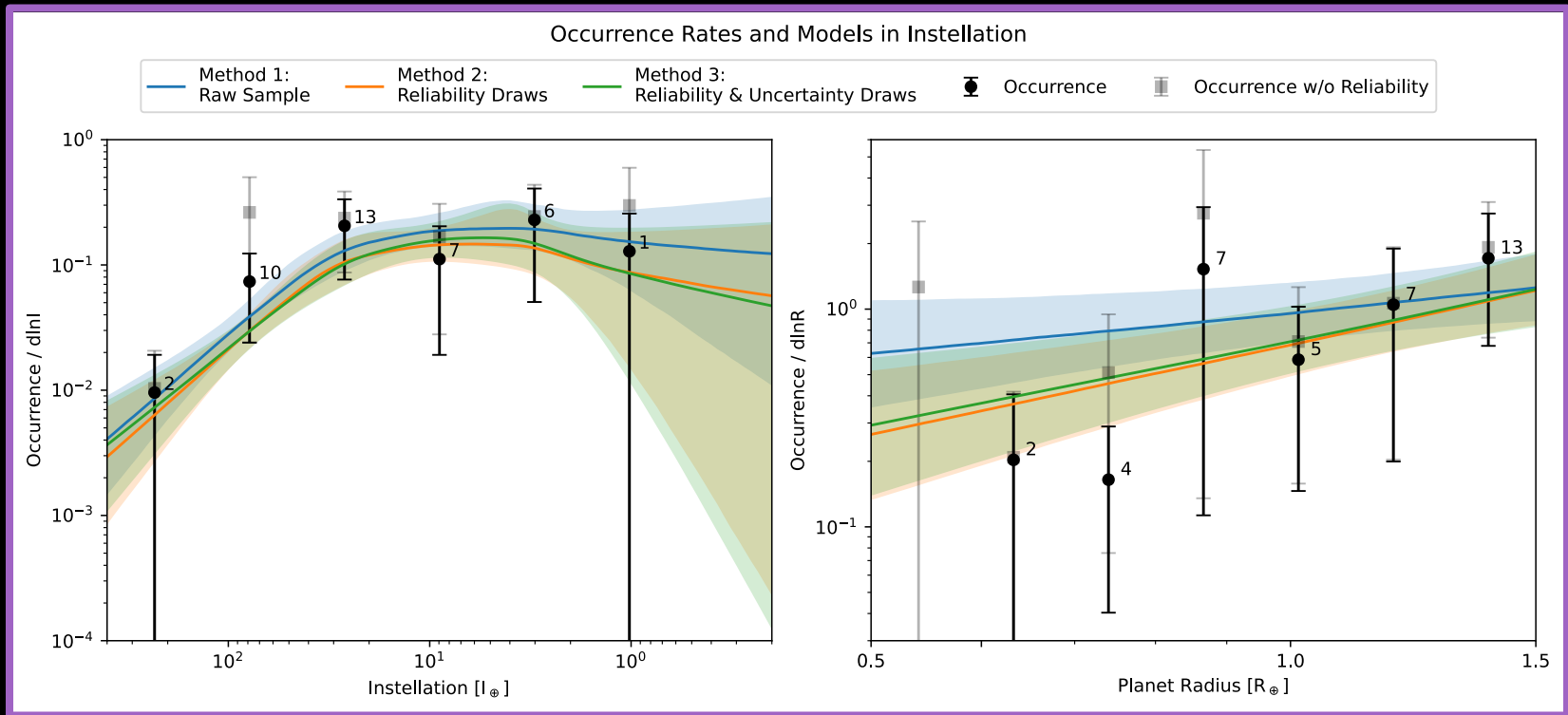
for the Inquisitive Audience

Kepler Cool Star Distribution

Modern *Kepler* Sample of Small Planets around Cool Stars
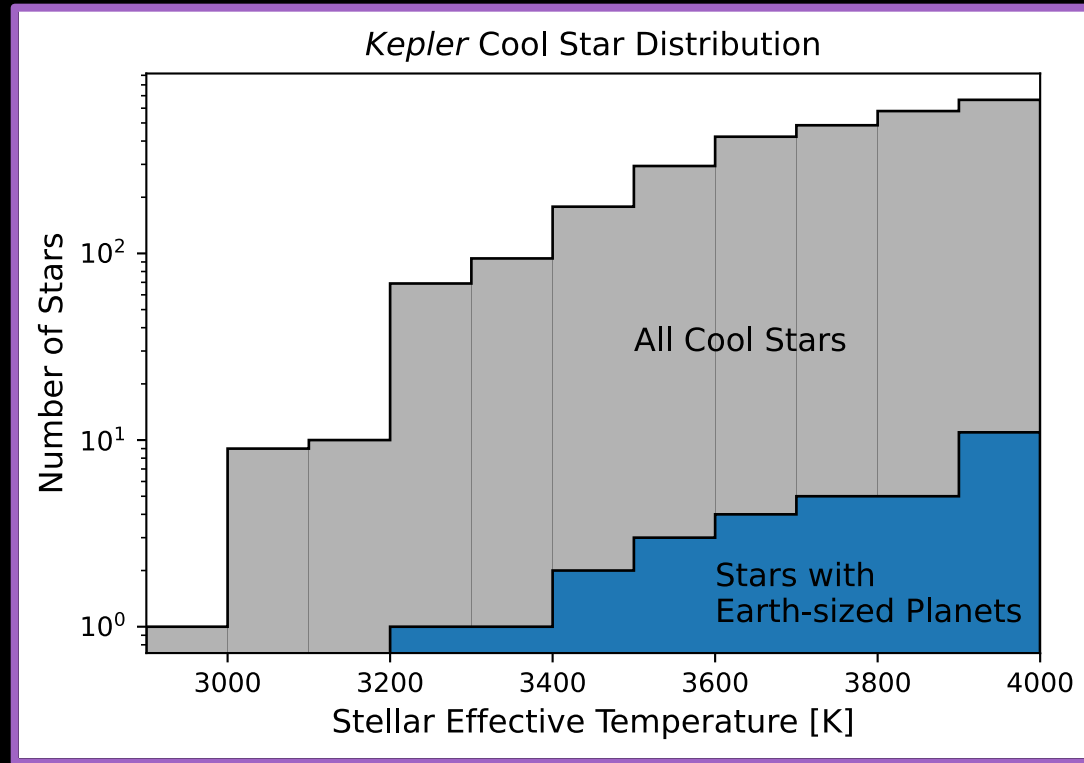
Occurrence Rates of Earth-sized Planets around *Kepler*'s Cool Stars (IDEM)

Occurrence Rates of Earth-sized Planets around *Kepler*'s M Dwarfs (Model)

Occurrence Rates and Models in Orbital Period

Occurrence Rates and Models in Instellation

Occurrence of Earth Analogs around Cool Stars
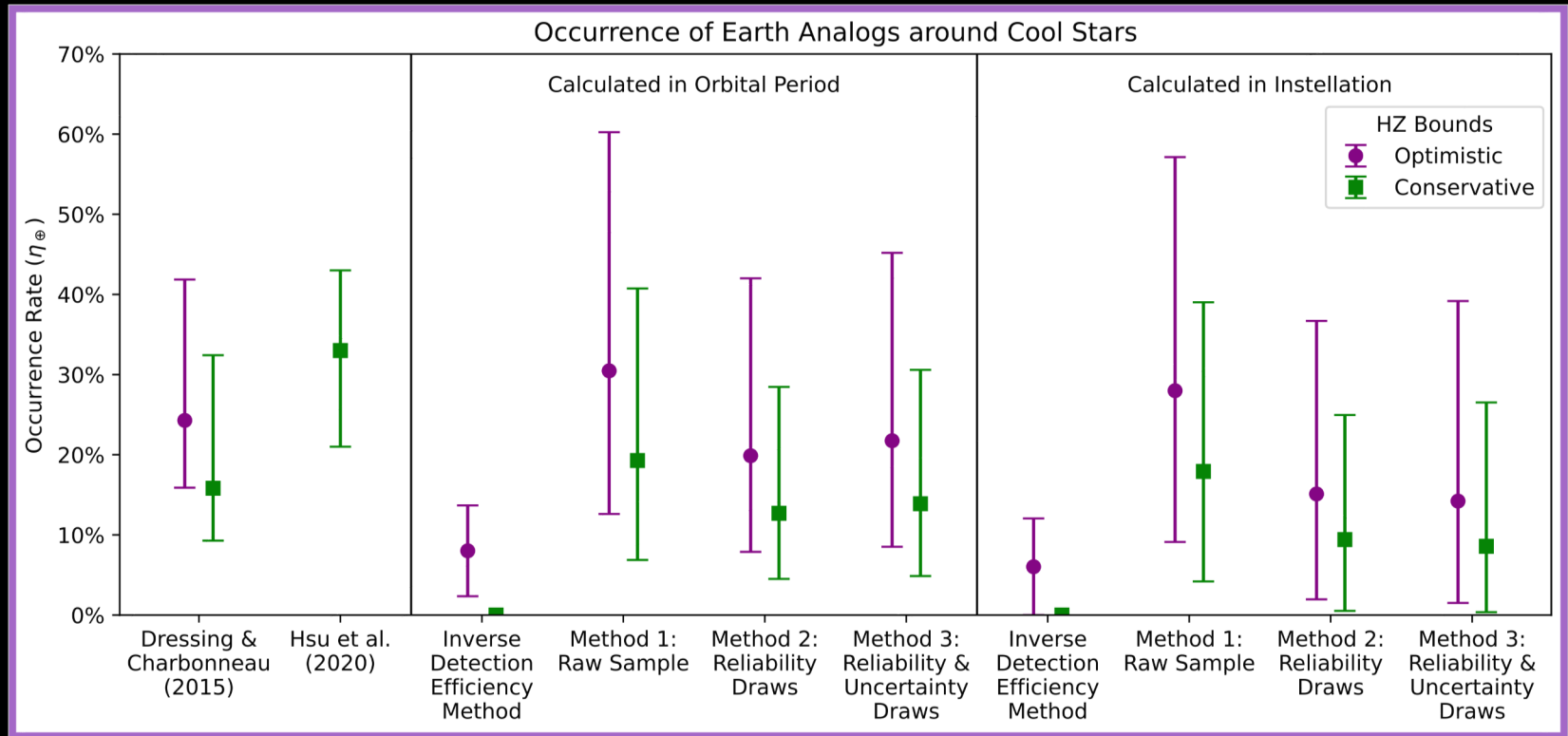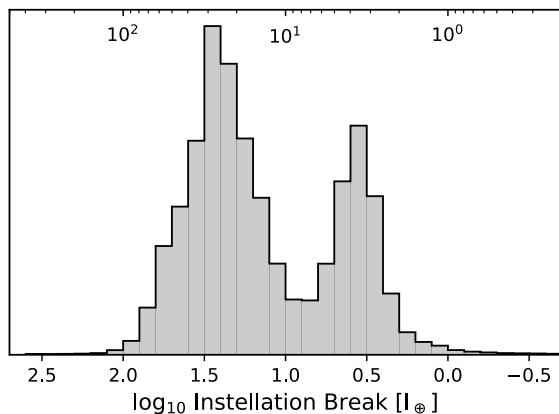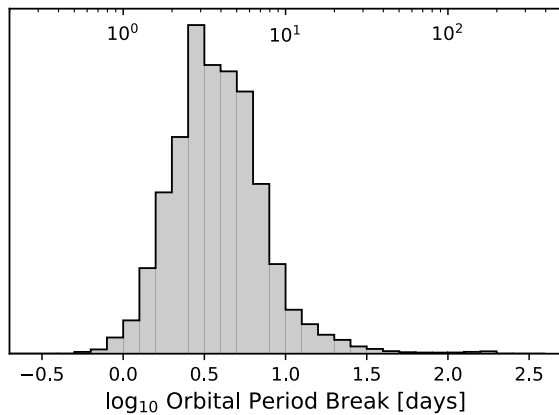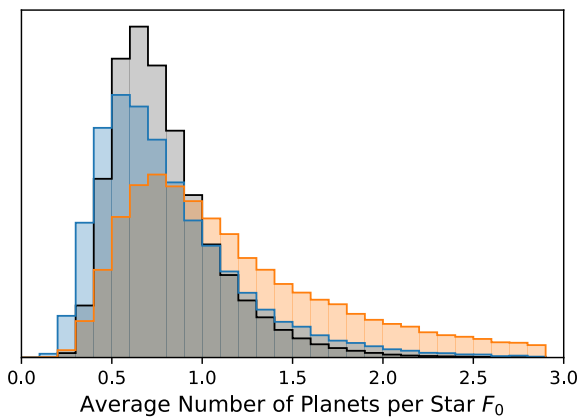
Posterior Distributions of Power Law Breaks

$\log_{10}$ Orbital Period Break [days]

$\log_{10}$ Instellation Break [$I_\oplus$]

Posterior Distributions of Key Parameters for Full and Temperature-Split Samples

$\log_{10}$ Instellation Break [$I_\oplus$]

Average Number of Planets per Star F_0
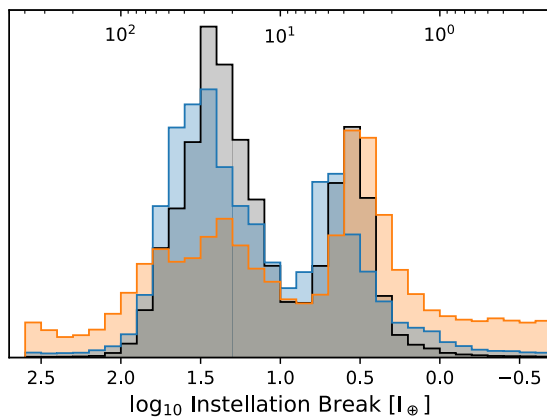
Full Sample ($T_{\rm eff} < 4000\,{\rm K}$)   Warmer Bin ($3770 \lesssim T_{\rm eff} < 4000\,{\rm K}$)   Cooler Bin ($T_{\rm eff} \lesssim 3770\,{\rm K}$)

Kepler Cool Star Distribution

Number of Stars

All Cool Stars

Stars with Earth-sized Planets

Stellar Effective Temperature [K]