



Estimating the Frequency of Potentially Habitable Planets with Kepler

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Harvard-Smithsonian Center for Astrophysics

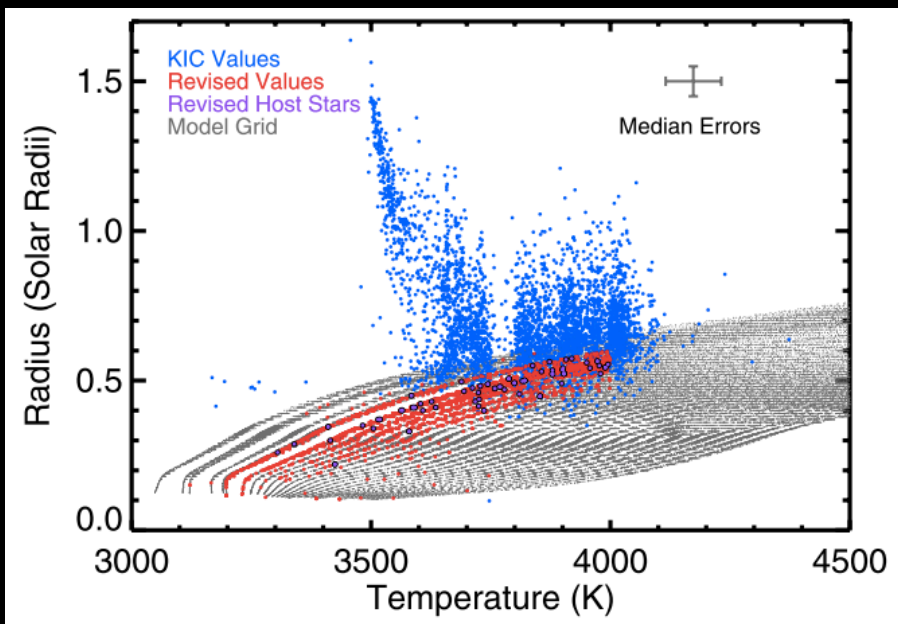
ExoPAG 8

Previous M Dwarf Planet Occurrence Estimate using Q1-Q6 Data

- 3897 M dwarfs
- 95 planet candidates orbiting 64 stars

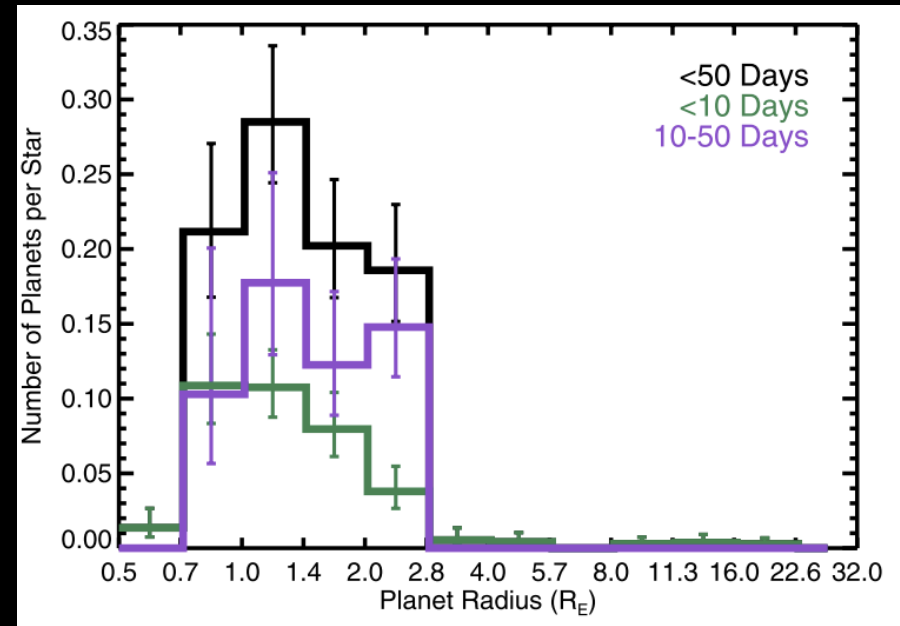
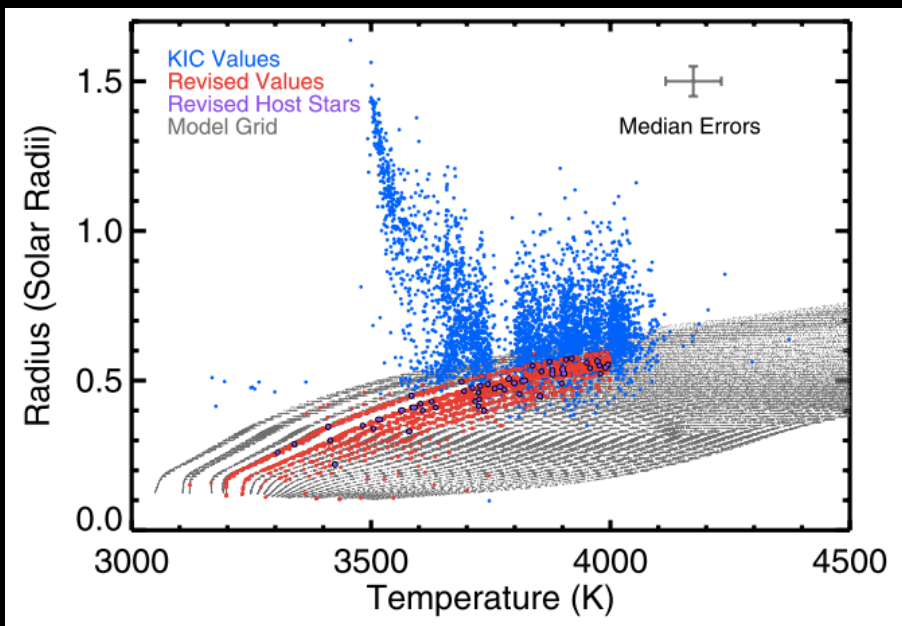
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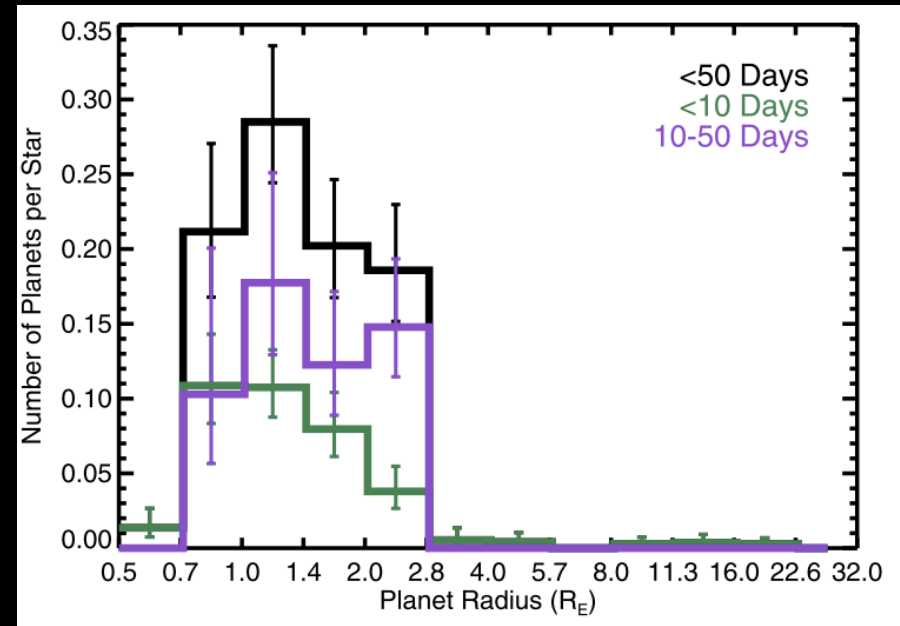
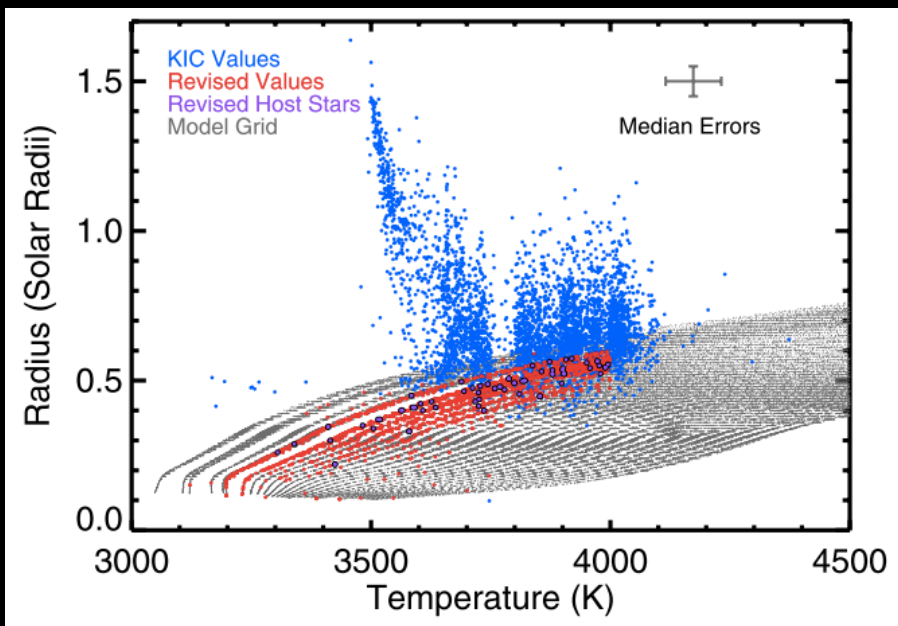
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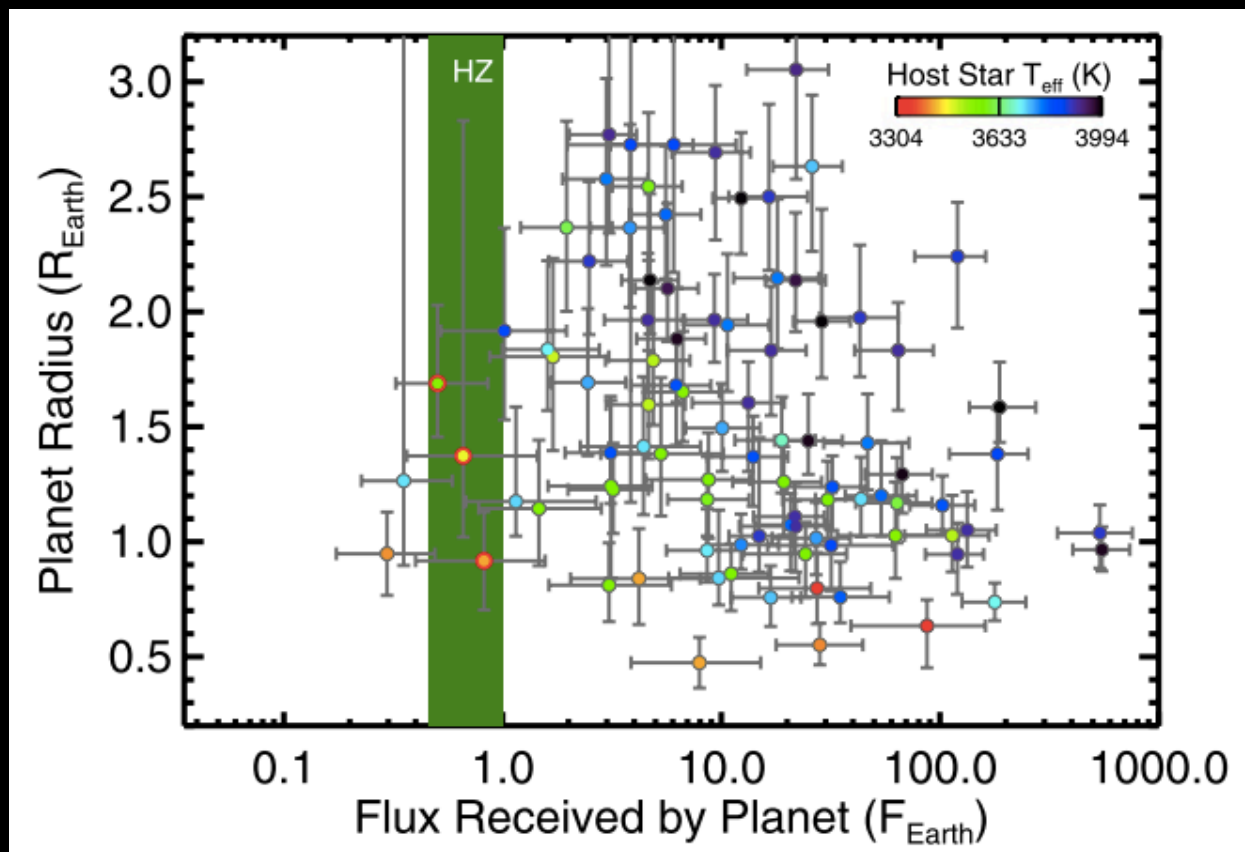
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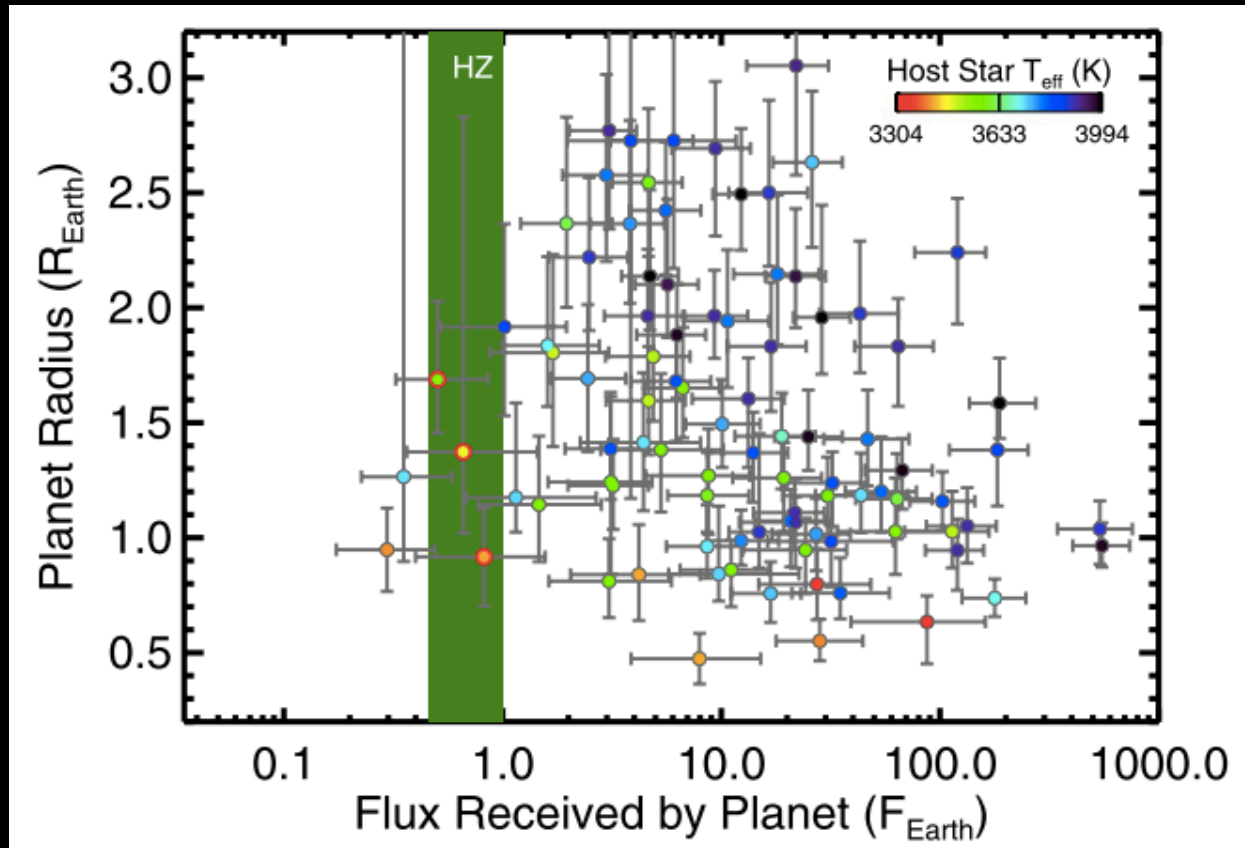


0.51 (+0.06/-0.05) **Earth-size planets per star** with $P < 50$ days

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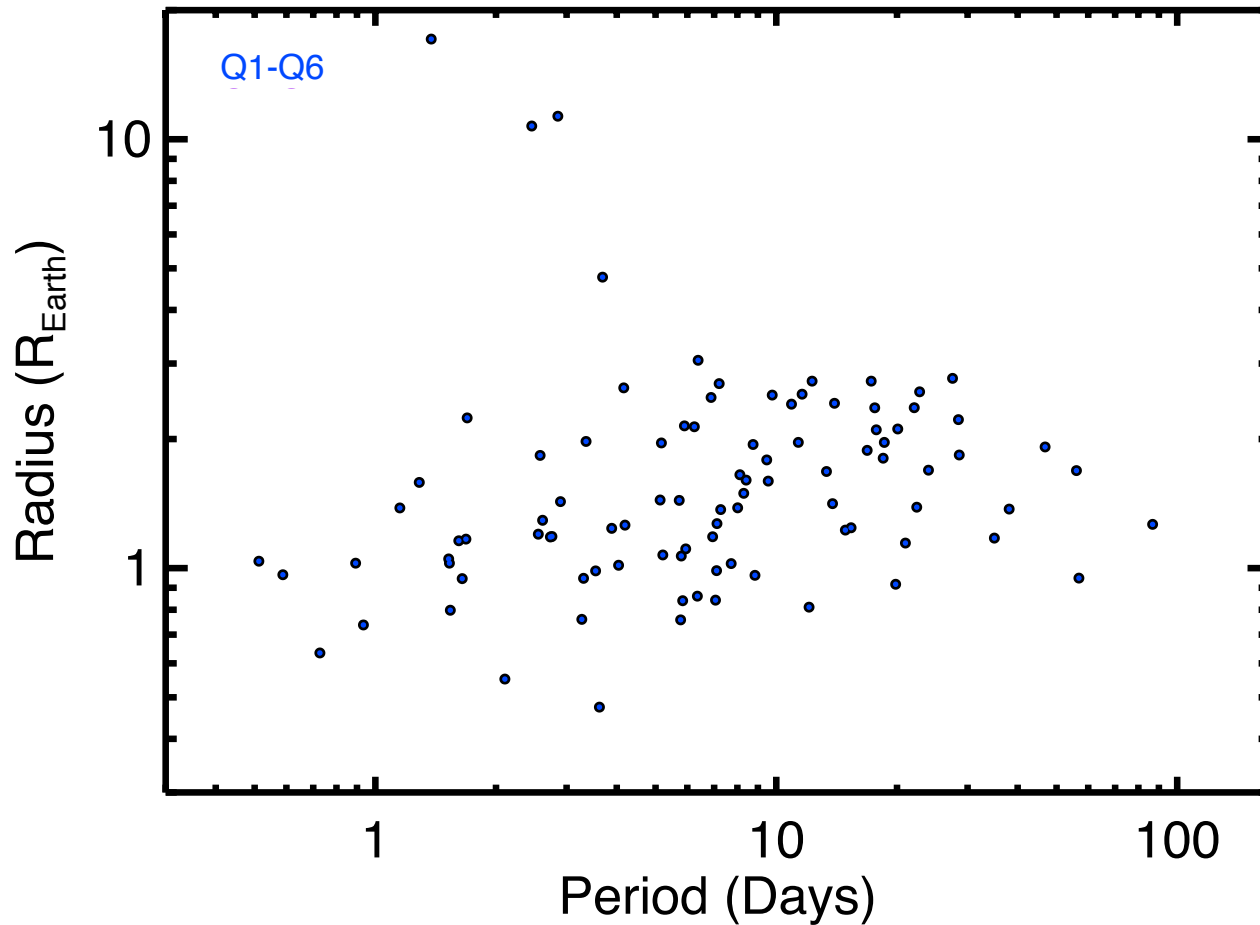


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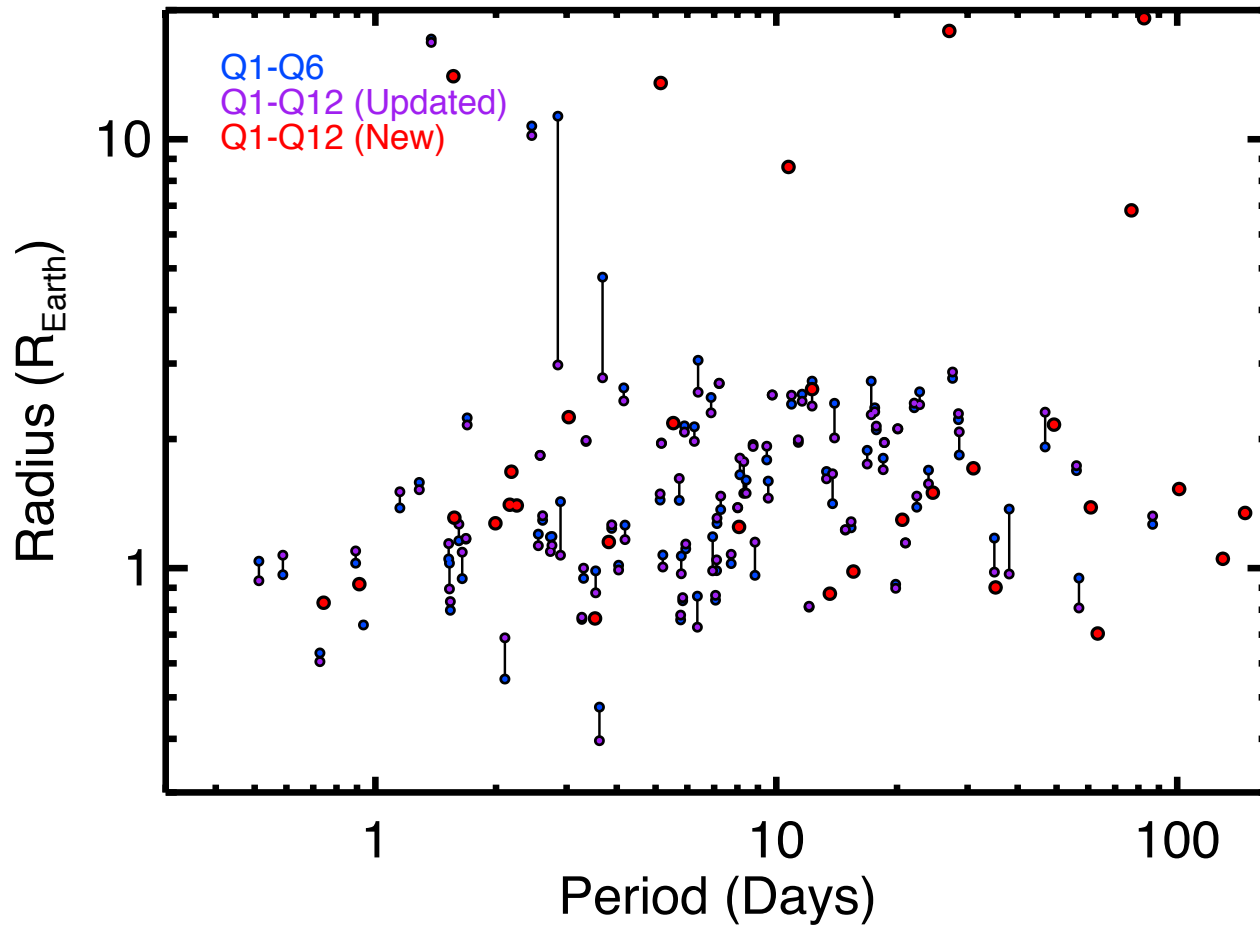


0.15 (+0.13/-0.06) **Earth-size planets per HZ**

Updated M Dwarf KOI Sample



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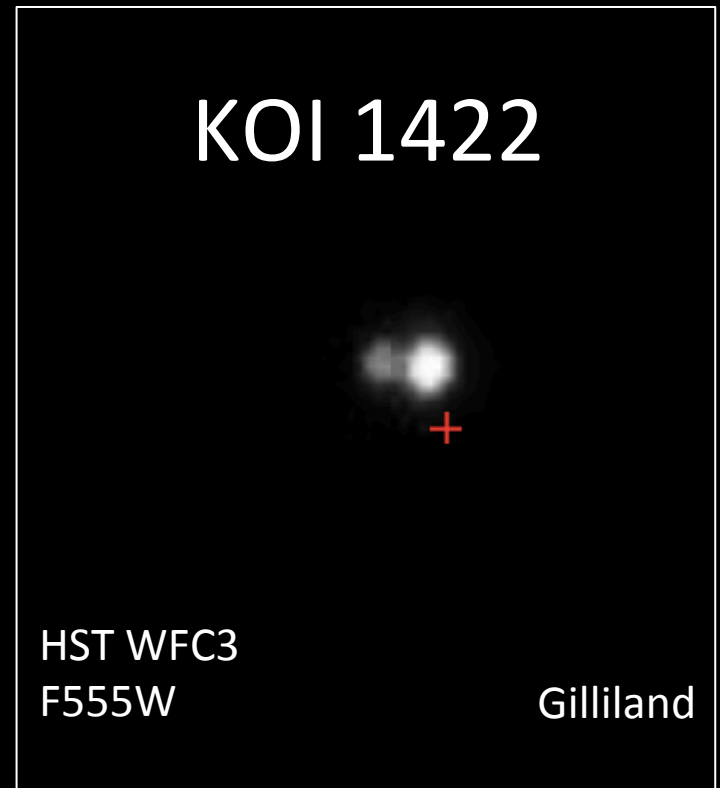
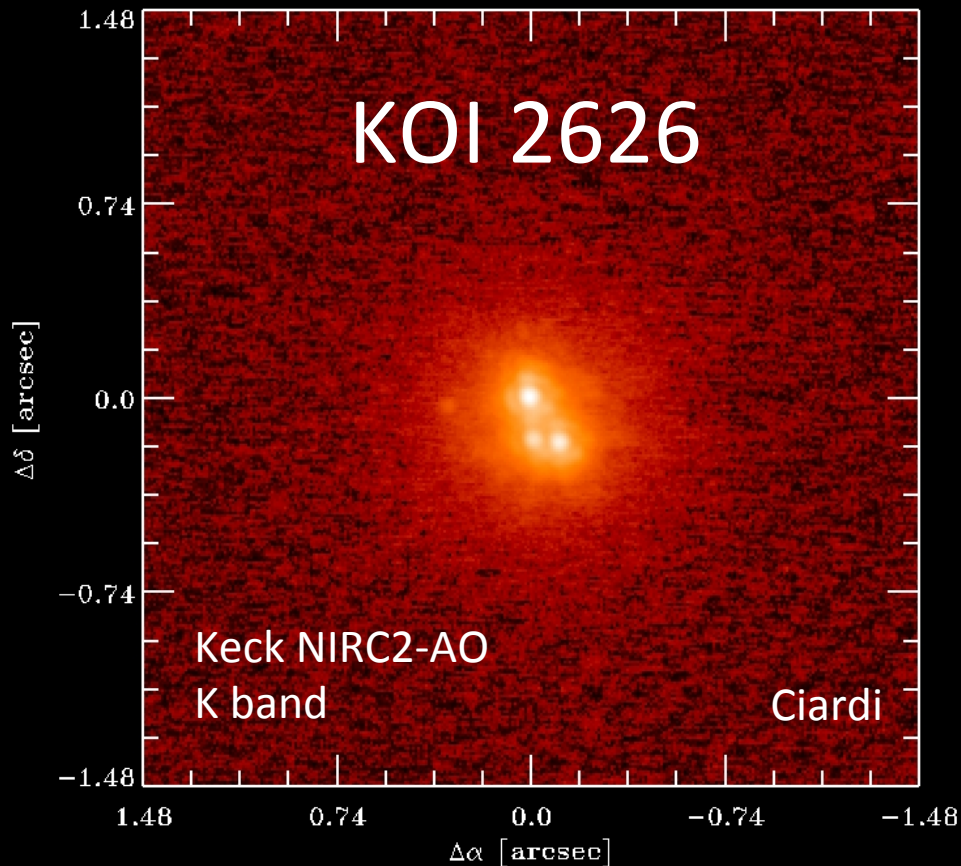
Updating the M Dwarf Planet Occurrence Rate

- Updates made:
 - Use Q1-Q12 KOI list → 125 KOIs around 84 stars
 - Use Q1-Q12 CDPP
 - Adopt SNR ramp instead of sharp 7.1σ threshold
 - Use revised HZ boundaries (Kopparapu et al. 2013)

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- Planned updates:
 - Conduct more thorough vetting of planet candidates
 - Incorporate false positive correction
 - Measure detection threshold for M dwarfs
 - Search for additional planets in Q1-Q16 data
 - Refit transits using Q1-Q16 data

Follow Up Images of Potentially Habitable KOIs

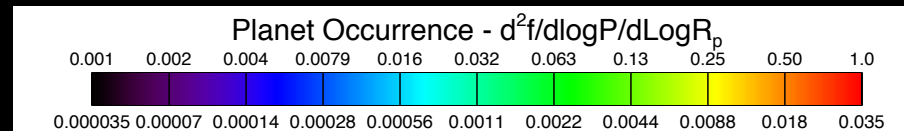


CFOP

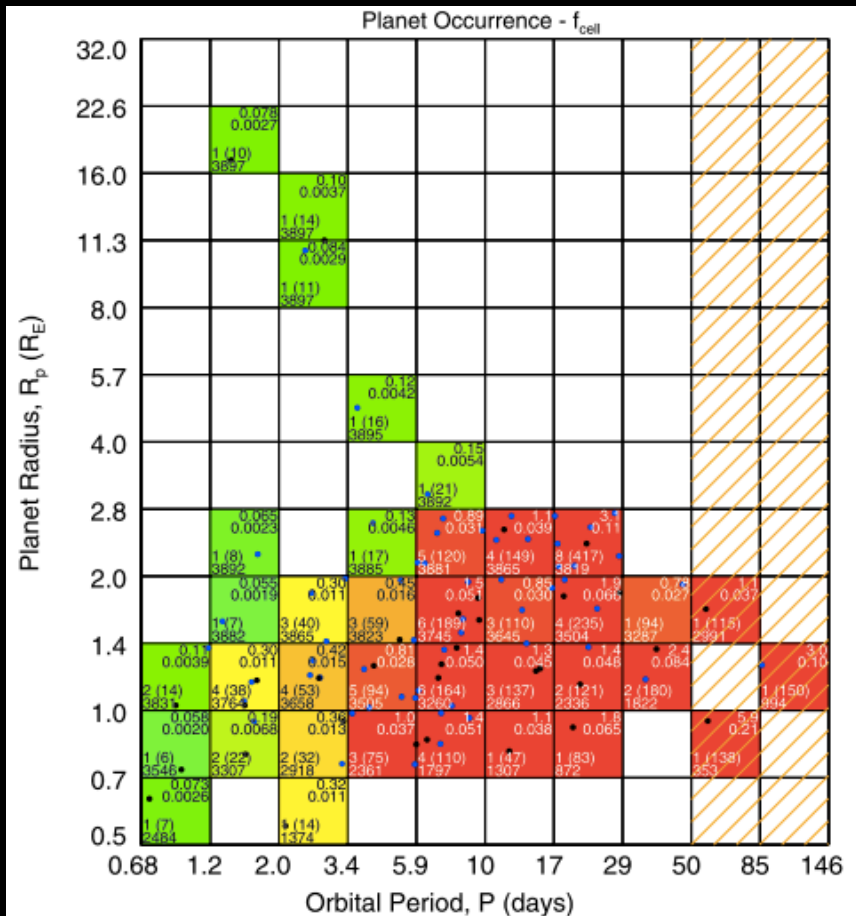
Kepler Community Follow-up Observing Program

M Dwarf Planet Occurrence Rate

Q1-Q6

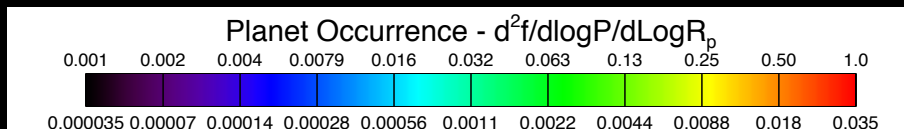


Q1-Q12

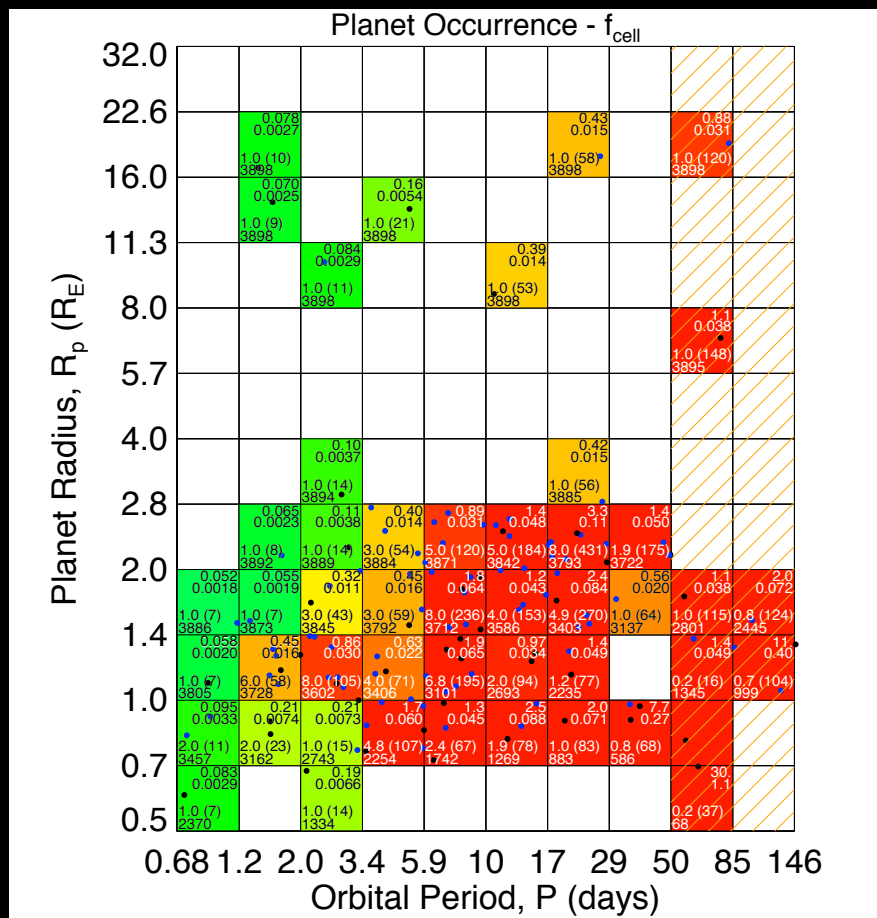
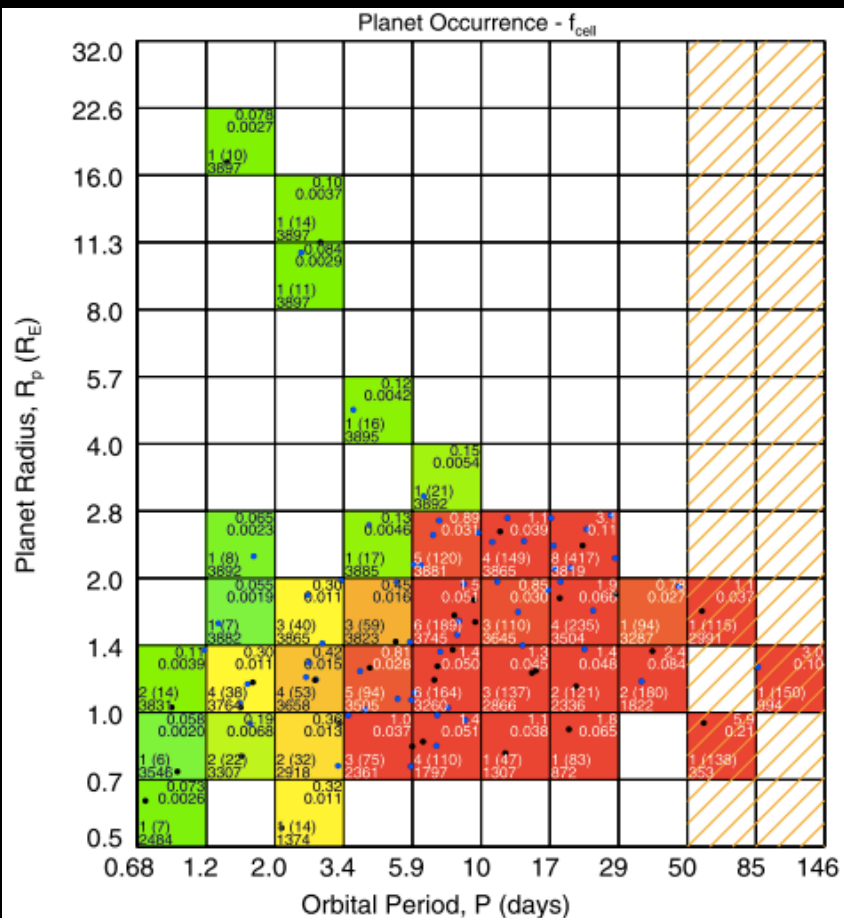


M Dwarf Planet Occurrence Rate

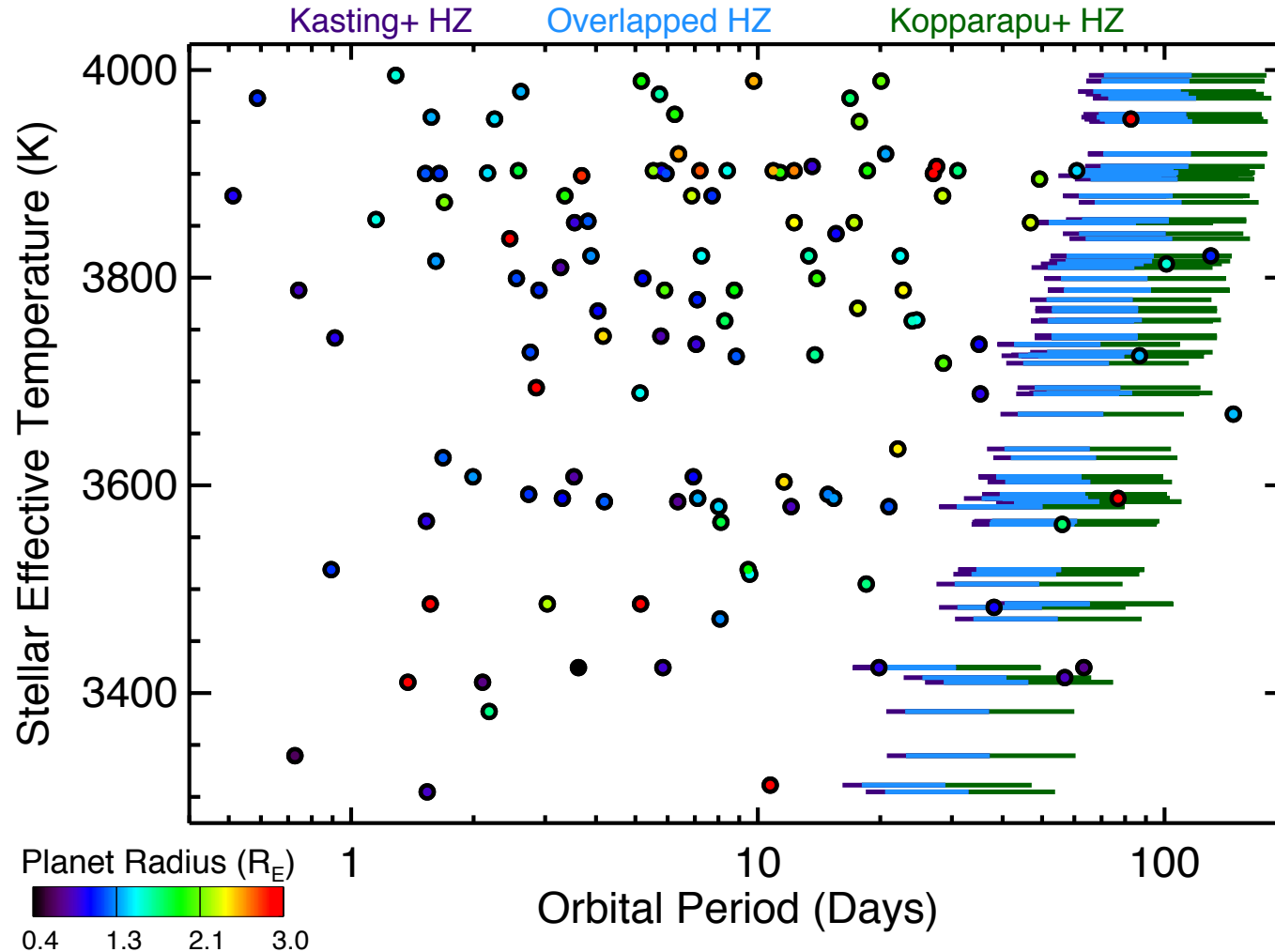
Q1-Q6



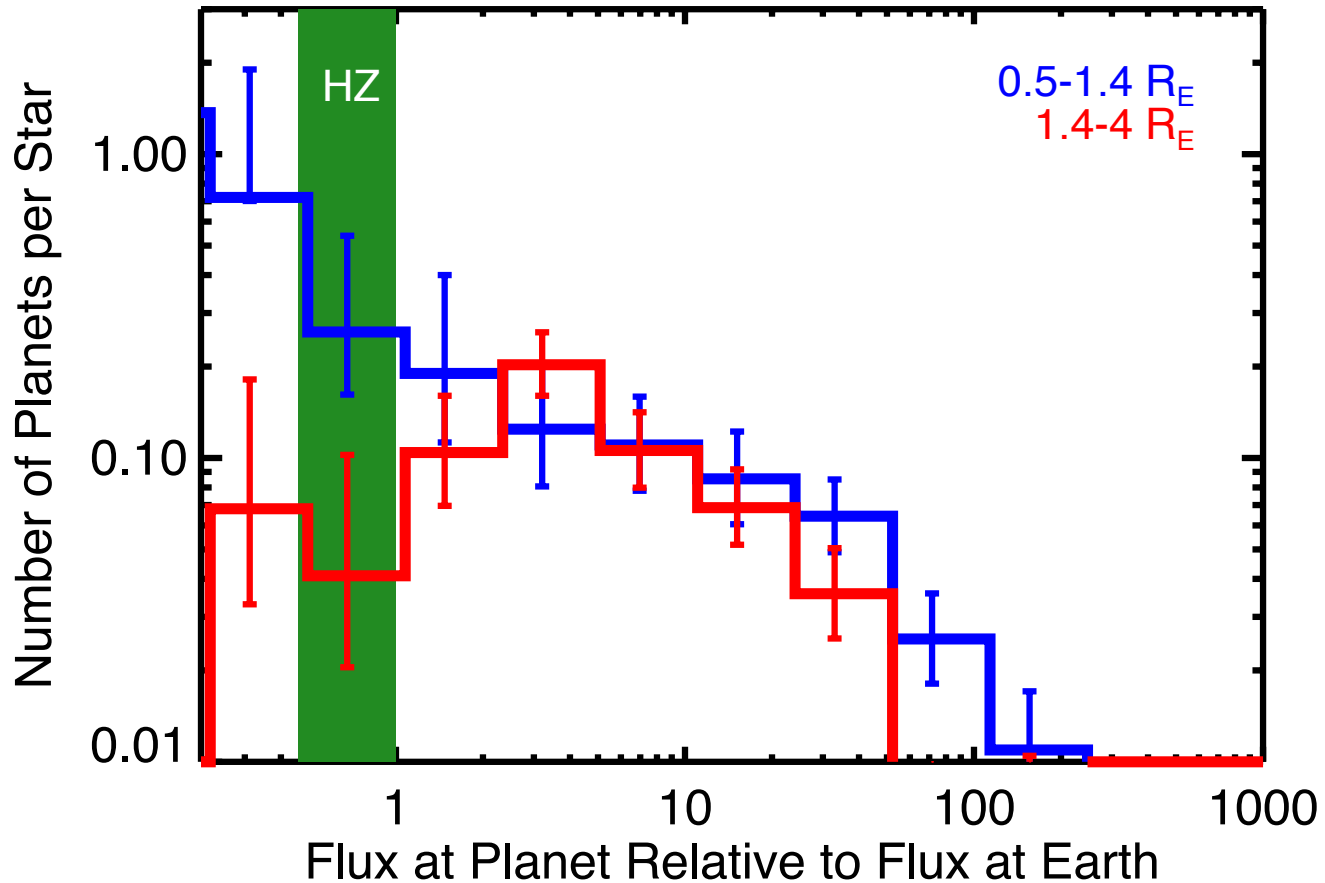
Q1-Q12



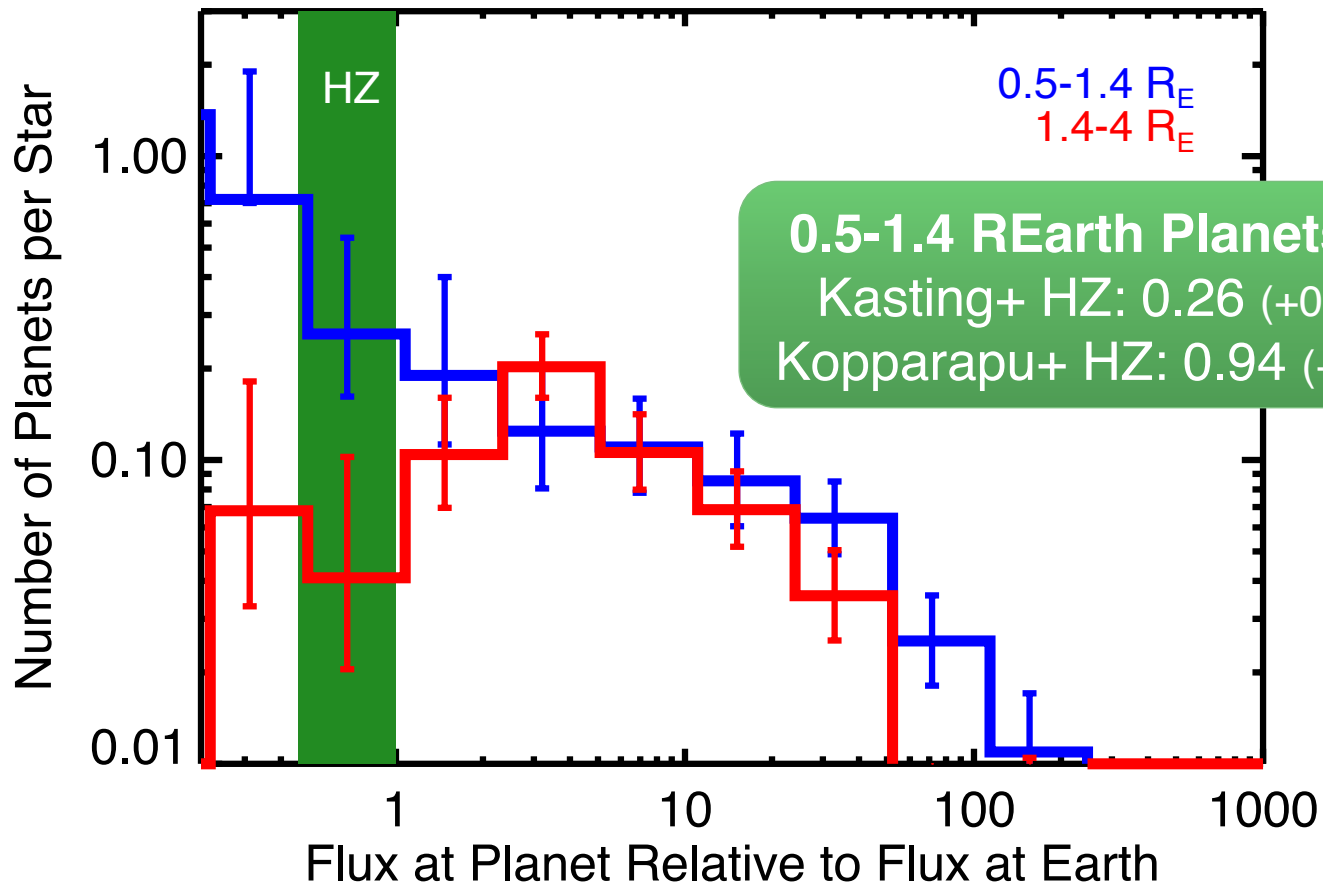
Candidates In & Near the HZ



Planet Occurrence in HZ



Planet Occurrence in HZ

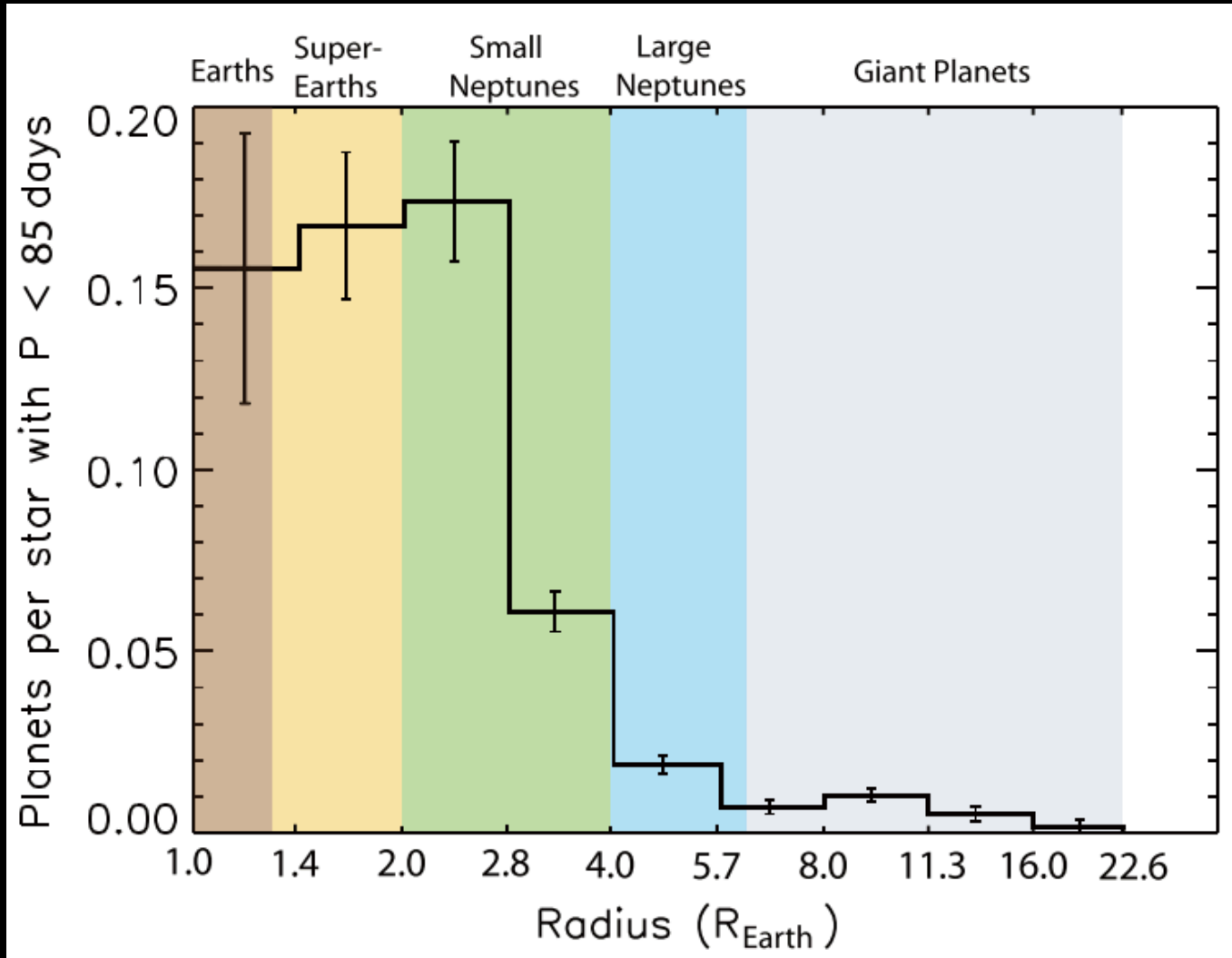




Estimating Planet Occurrence Rates for FGKM Stars

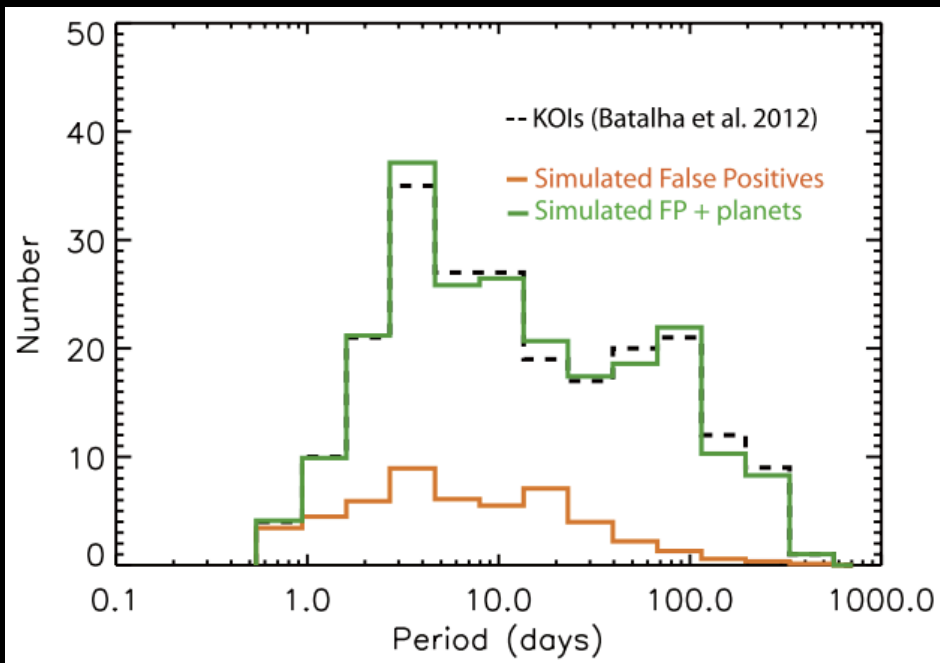
Fressin et al. 2013

Planet Occurrence Rate for FGKM Stars



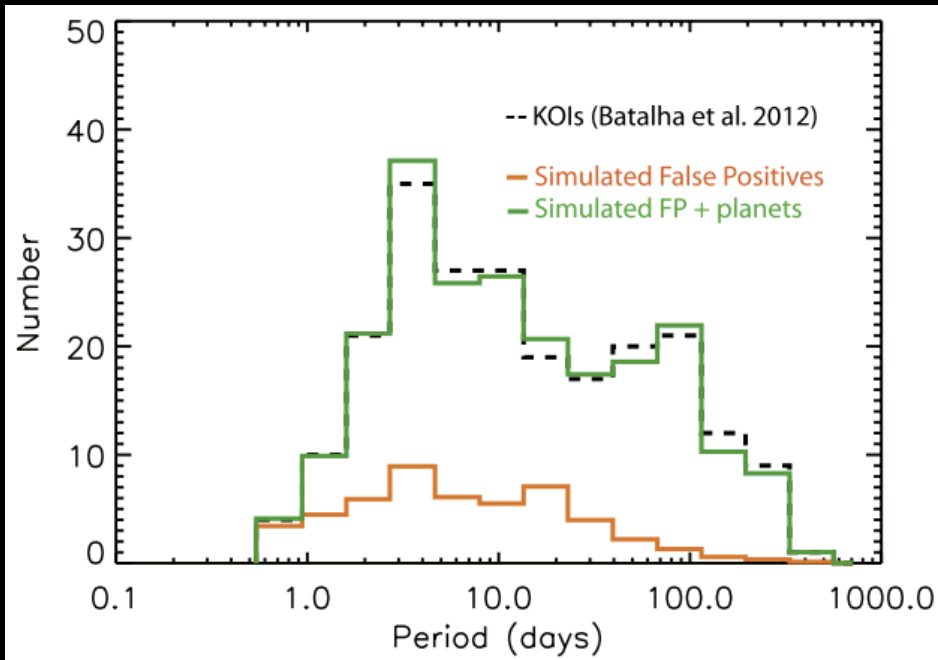
The False Positive Distribution

Modeling the Giant Planets

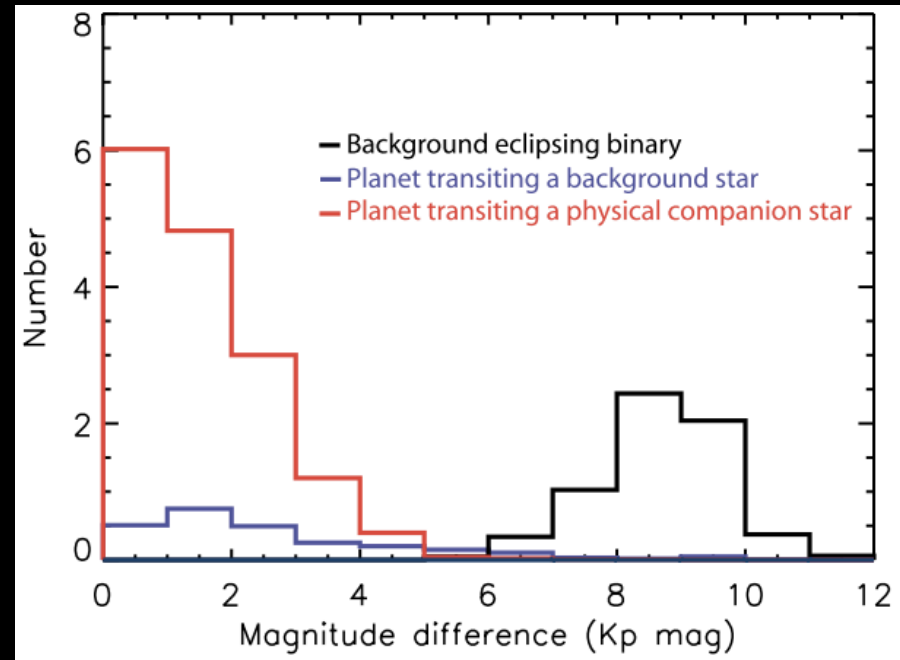


The False Positive Distribution

Modeling the Giant Planets



Sources of False Positives for Earth-size Planets



Summary of Planet Occurrence Rates (per Star)

- **M dwarfs:** $0.5\text{-}1.4 R_{\text{Earth}}$ with $P < 50$ days
 - Q1-Q6: $0.51 (+0.06/-0.06)$
 - Q1-Q12: $0.53 (+0.05/-0.04)$

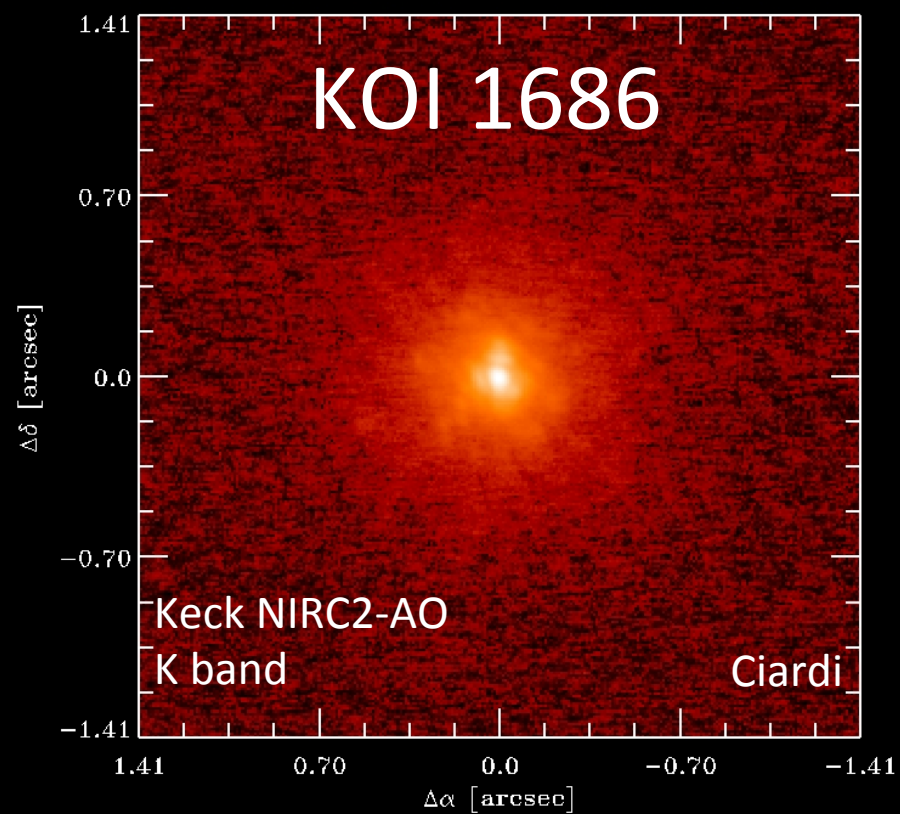
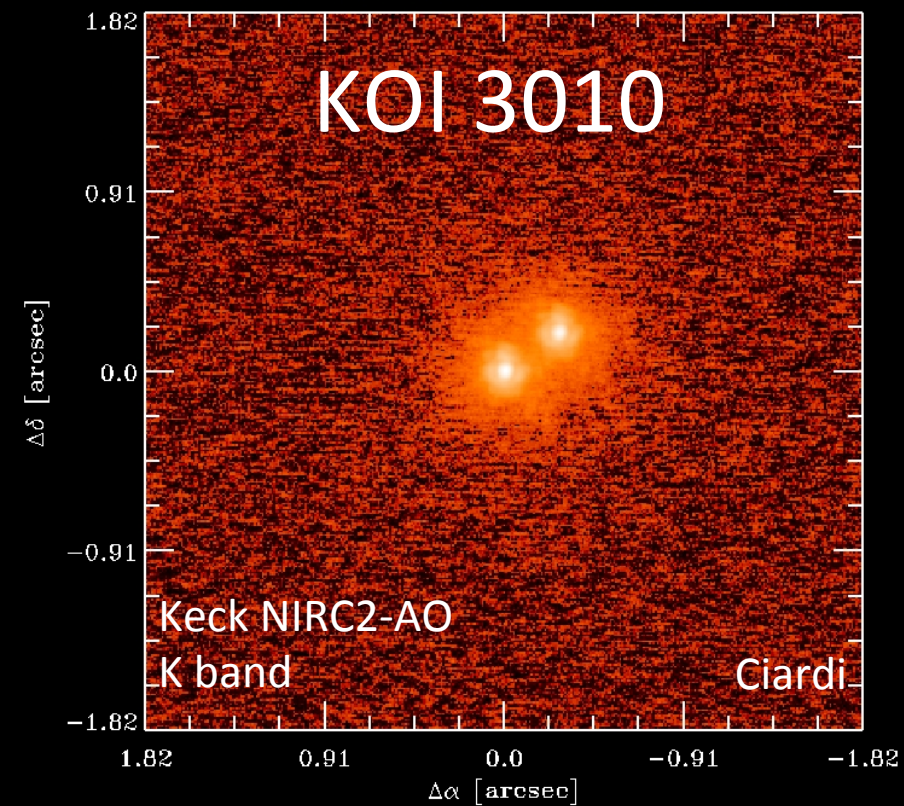
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- **M dwarfs: 0.5-1.4 R_{Earth} in HZ**
 - Q1-Q6: 0.15 (+0.13/-0.06)
 - Q1-Q12: 0.26-0.94 (depending on choice of HZ)

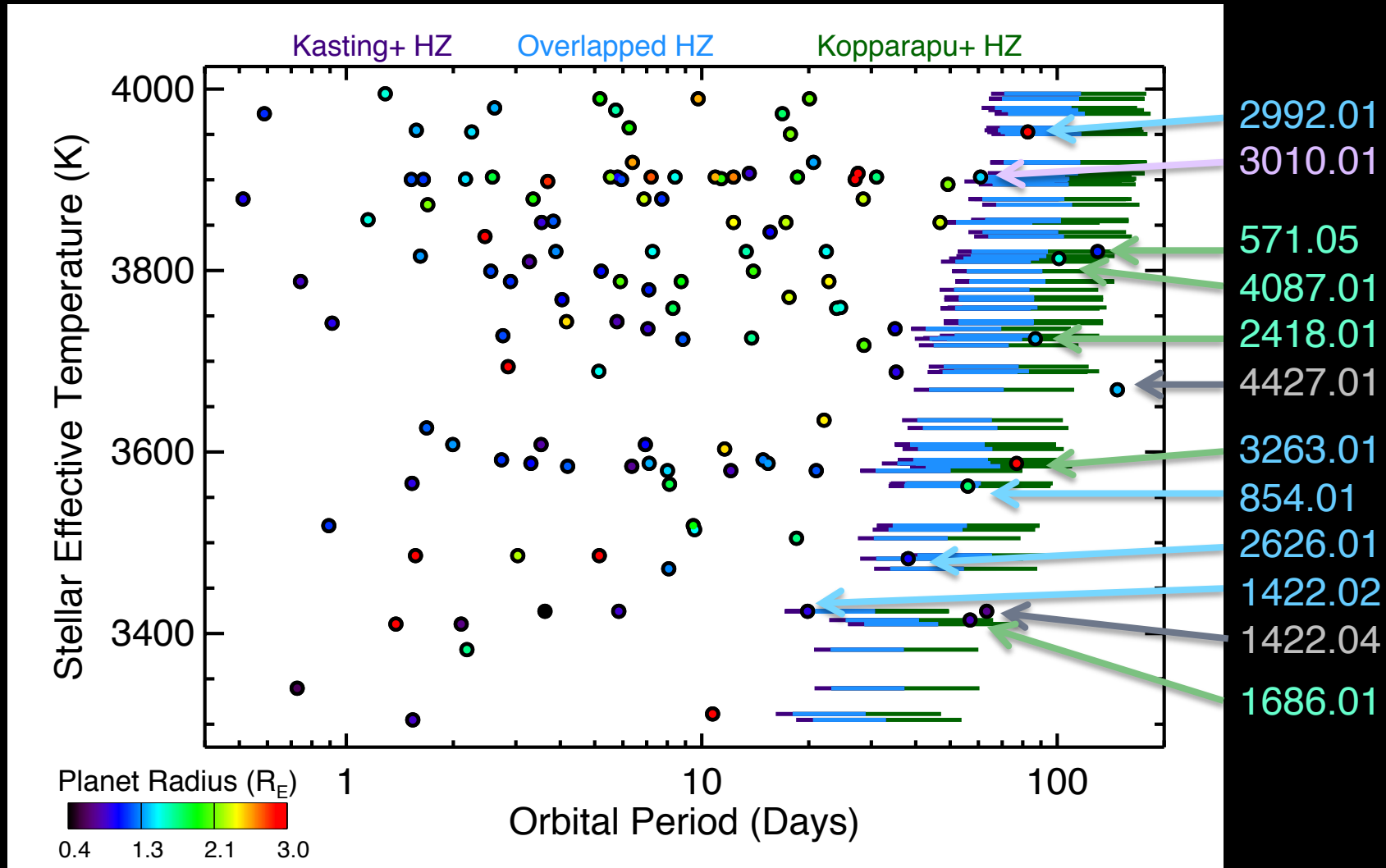
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 - Q1-Q6: 0.15 (+0.13/-0.06)
 - Q1-Q12: 0.26-0.94 (depending on choice of HZ)
- **FGKM dwarfs:** 0.8-1.25 R_{Earth} with $P < 85$ days
 - Q1-Q6: 0.165 (+/- 0.036) (Fressin+ 2013)

Additional Slides



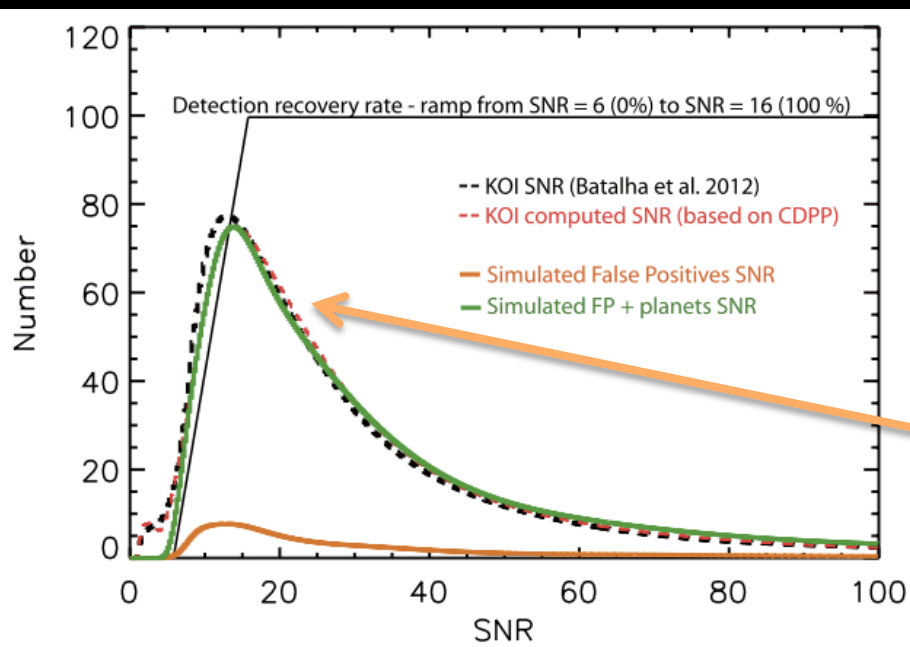
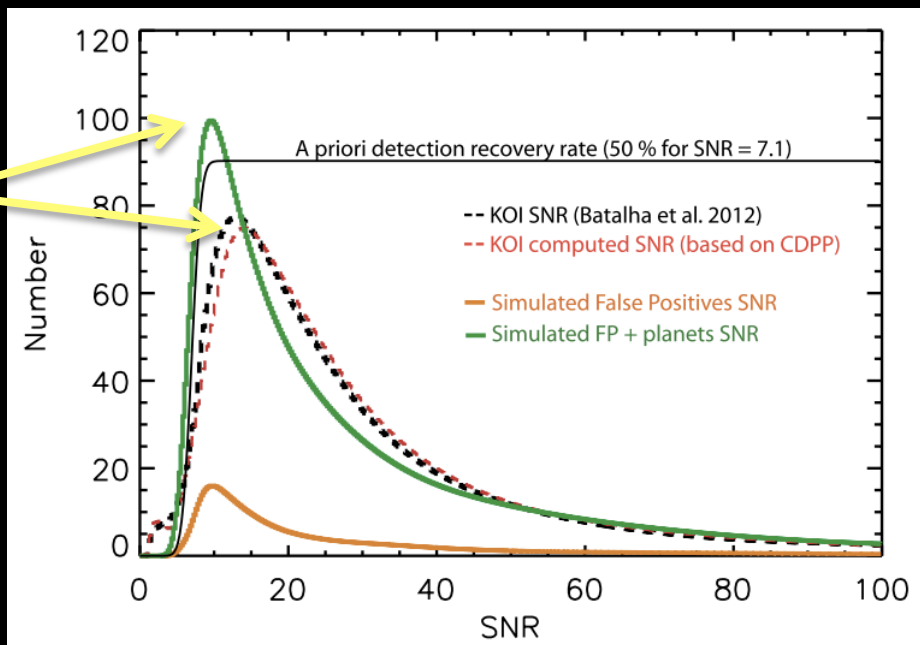
Candidates In & Near the HZ



[illegible]

Estimating the Detection Efficiency

A sharp transition at 7.1σ does not reproduce the KOI SNR distribution.



A ramp from 6σ - 16σ successfully reproduces the KOI SNR distribution.

SNR of M Dwarf Planet Candidates

