Jet Propulsion Laboratory
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Eta-Earth from Kepler: A Progress Report

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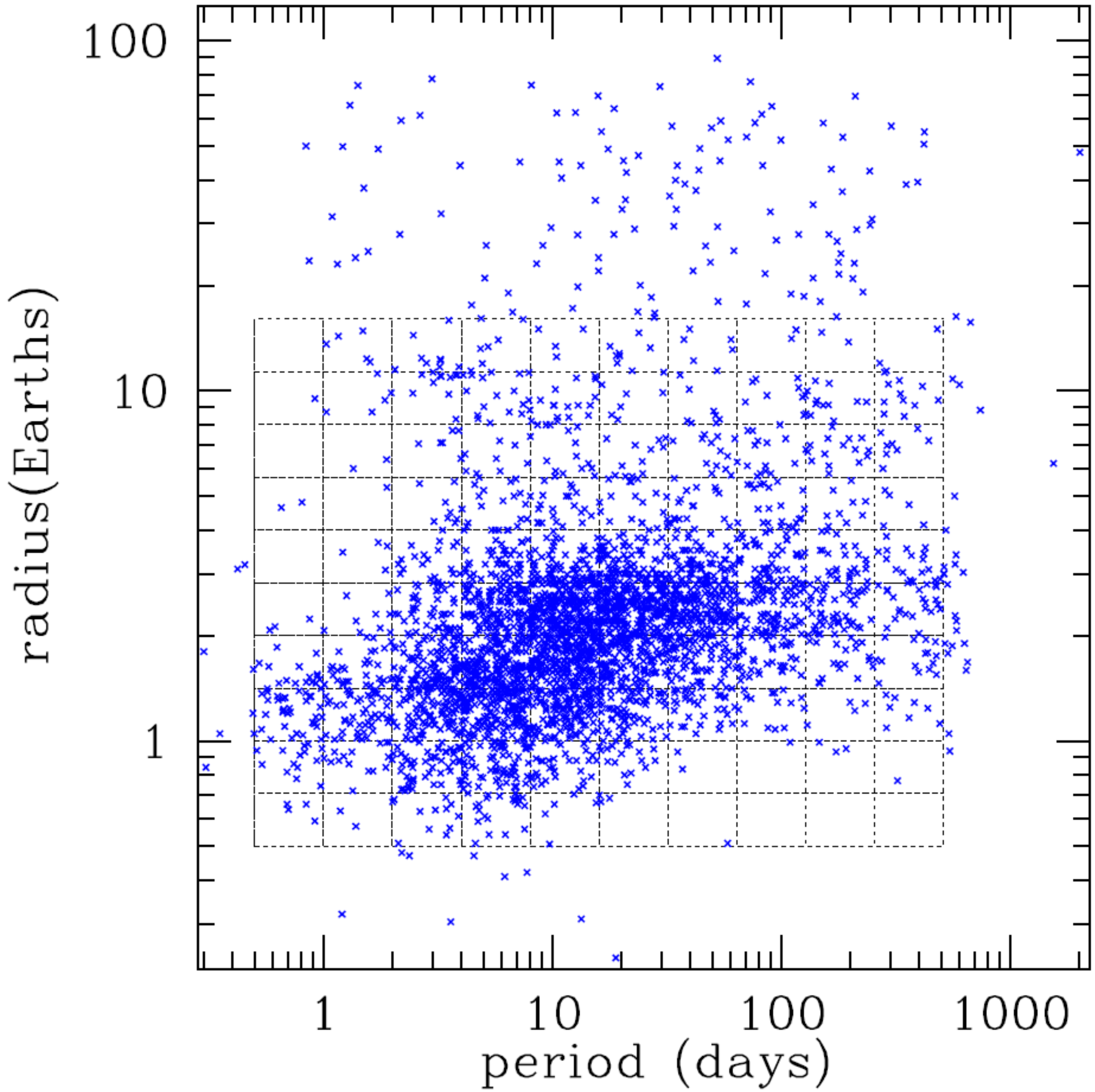
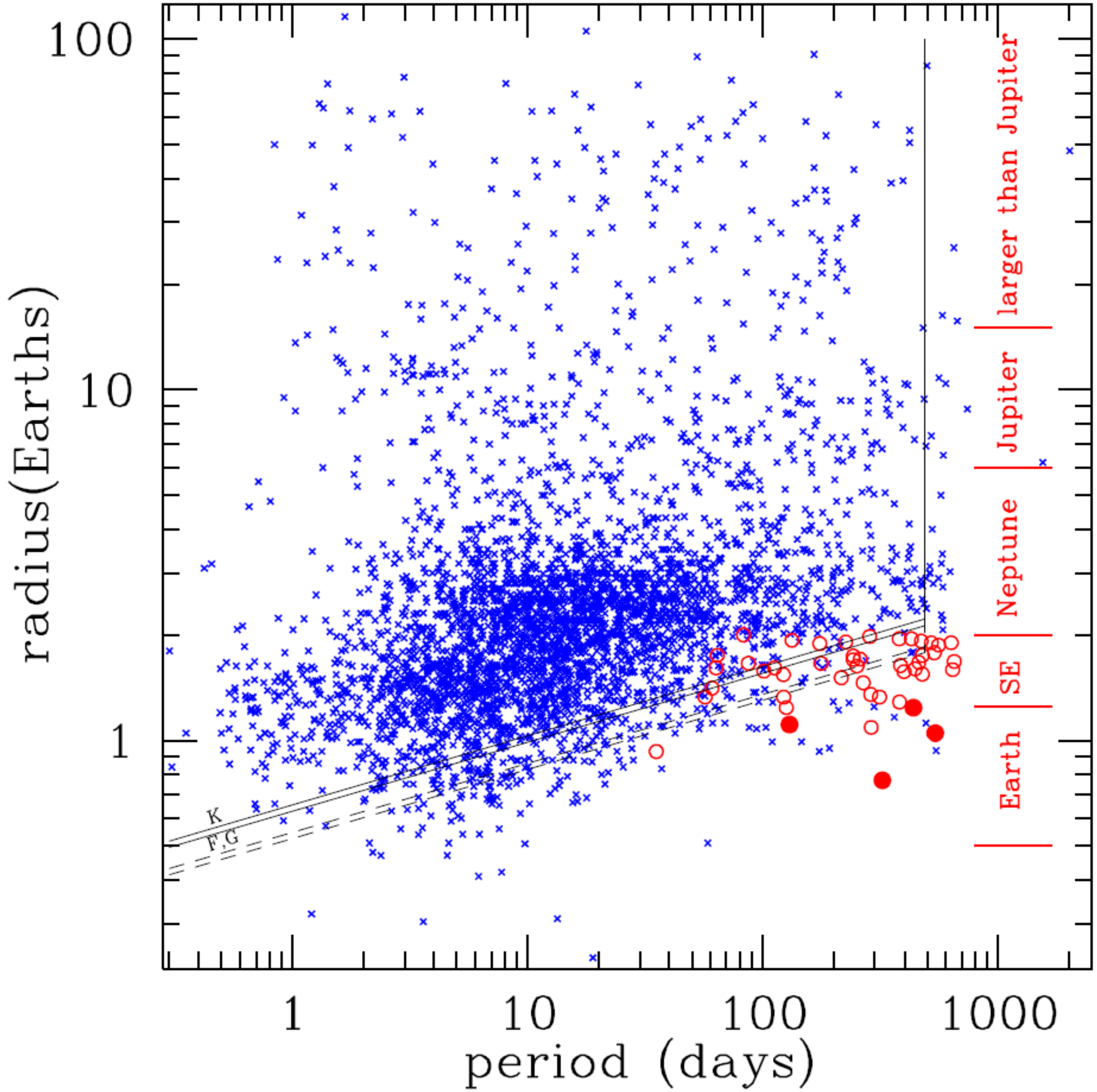
Kepler planets (incl. candidates) from May 2014



Kepler planets, annotated

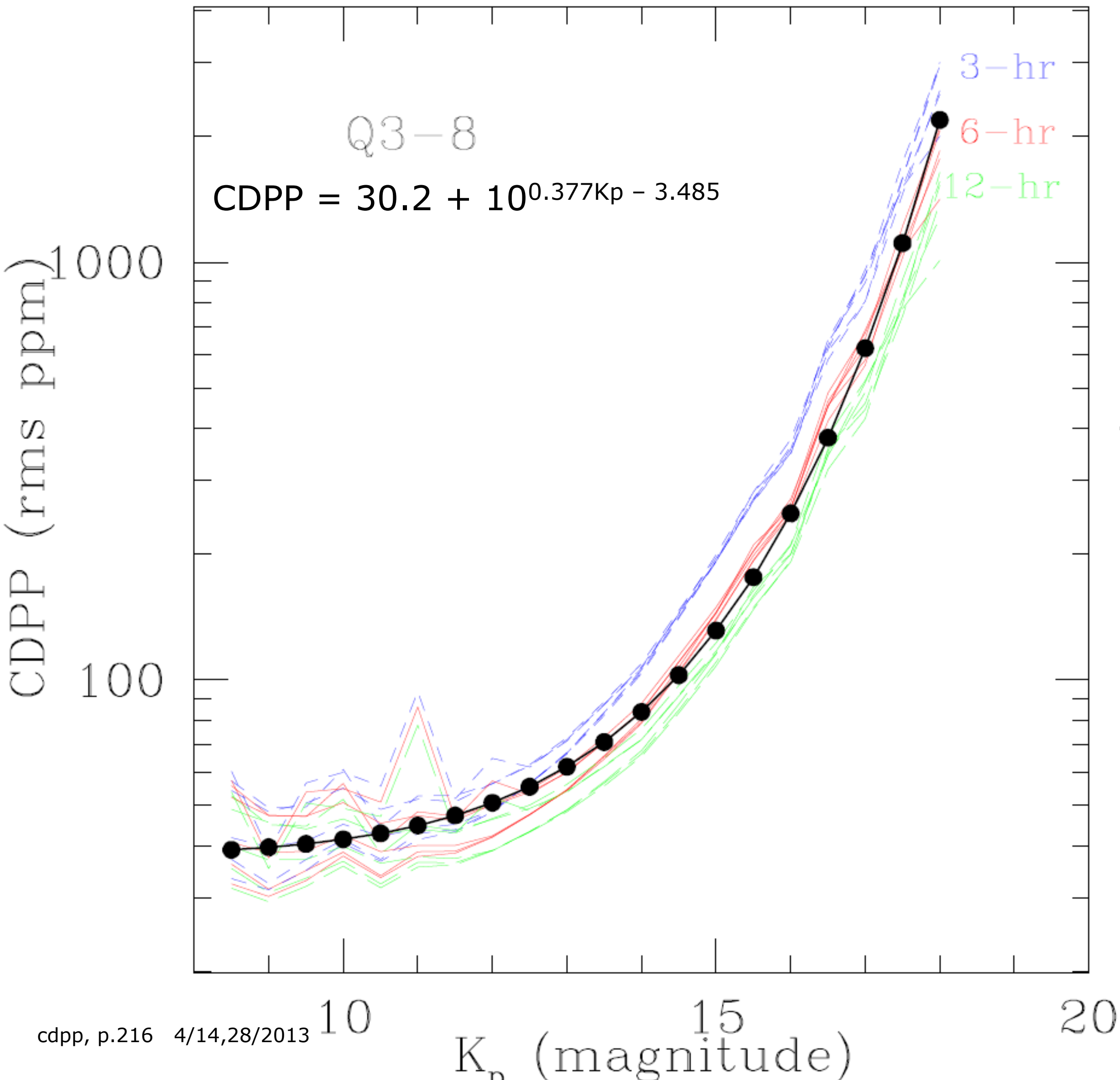


Method

- Select targets by T_{eff}(K), d(pc), K_p(mag)
- Select observed planets to match, also by range of (r,p)
- Assume planet occurrence model: $f(r,p) = f_0\,(r/r_{01})^a\,(p/p_{01})^b$
- Broken power law: $a=(a_0, a_1)$ for $(r<r_{01}, r>r_{01})$,
  and $b=(b_0,b_1)$ for $(p<p_{01}, p>p_{01})$
- Assume random (r,p) per distribution law
- Assign 1 planet per star, at the fractional rate $f(r,p) \times$ transit probability
- Add all fractional planets per star, for all target stars, in 10x10 bins
- Do least-squares fit of model to observations
- Adjust r(cutoff) empirically
- Repeat entire process to build fitting statistics
- Extrapolate model to (r,p) = (terrestrial, HZ) to give $\eta_\oplus$

Median noise (CDPP) vs magnitude

ExoPlanet Exploration Program



cdpp, p.216 4/14,28/2013

CDPP is RMS noise per 6-hour observation, in units of ppm

The middle curve is the median CDPP for all stars averaged over quarters 1 – 8

The best-fit curve is a simple function of Kepler magnitude

Minimum detectable planet

SNR = 7 detection criterion

$T_{mission}$ = 2 yr

duty cycle = 92%

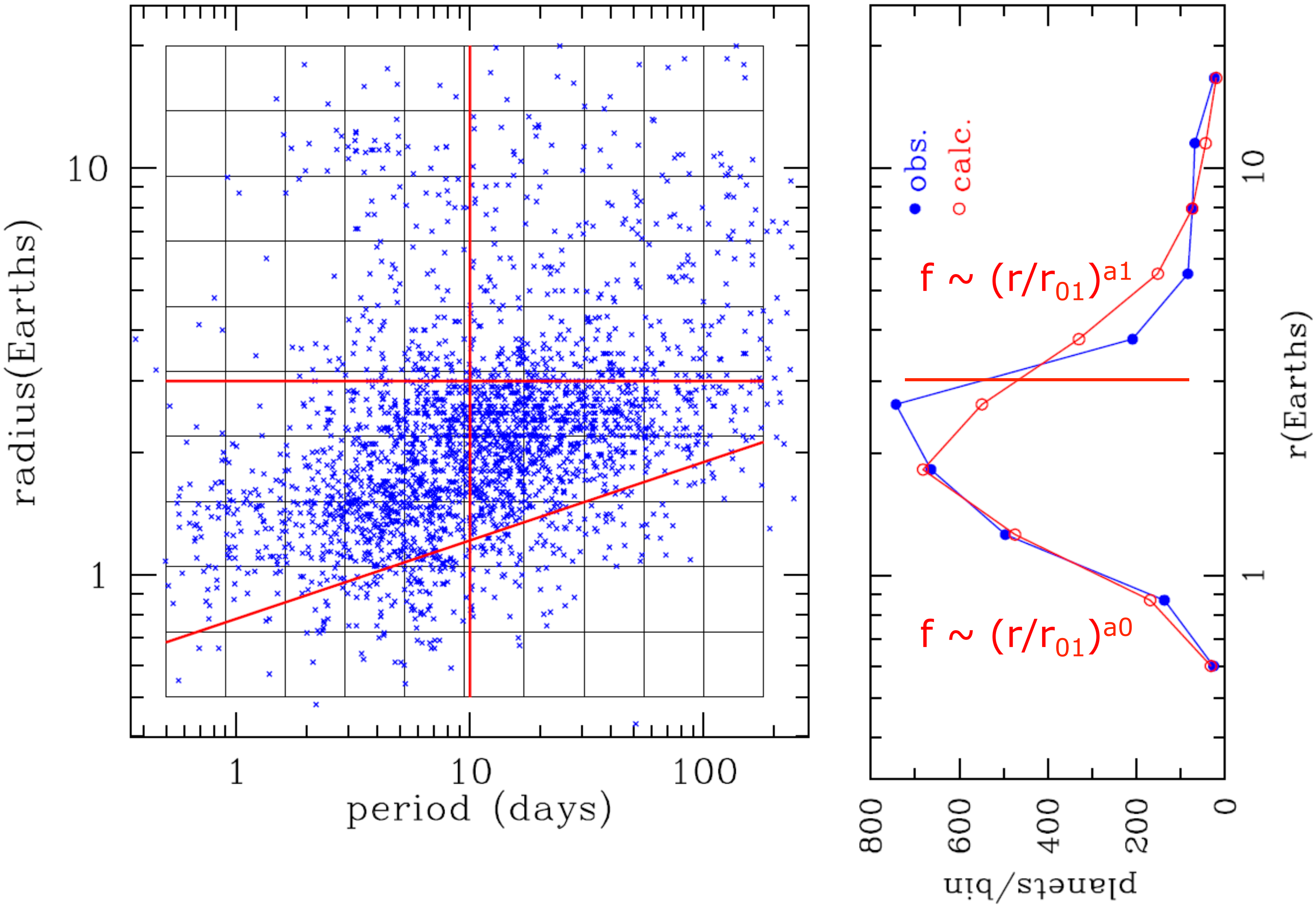
S/N ~ $1/t^{0.32}$ (not $1/t^{0.50}$)

minimum detectable planet radius is r_{min}

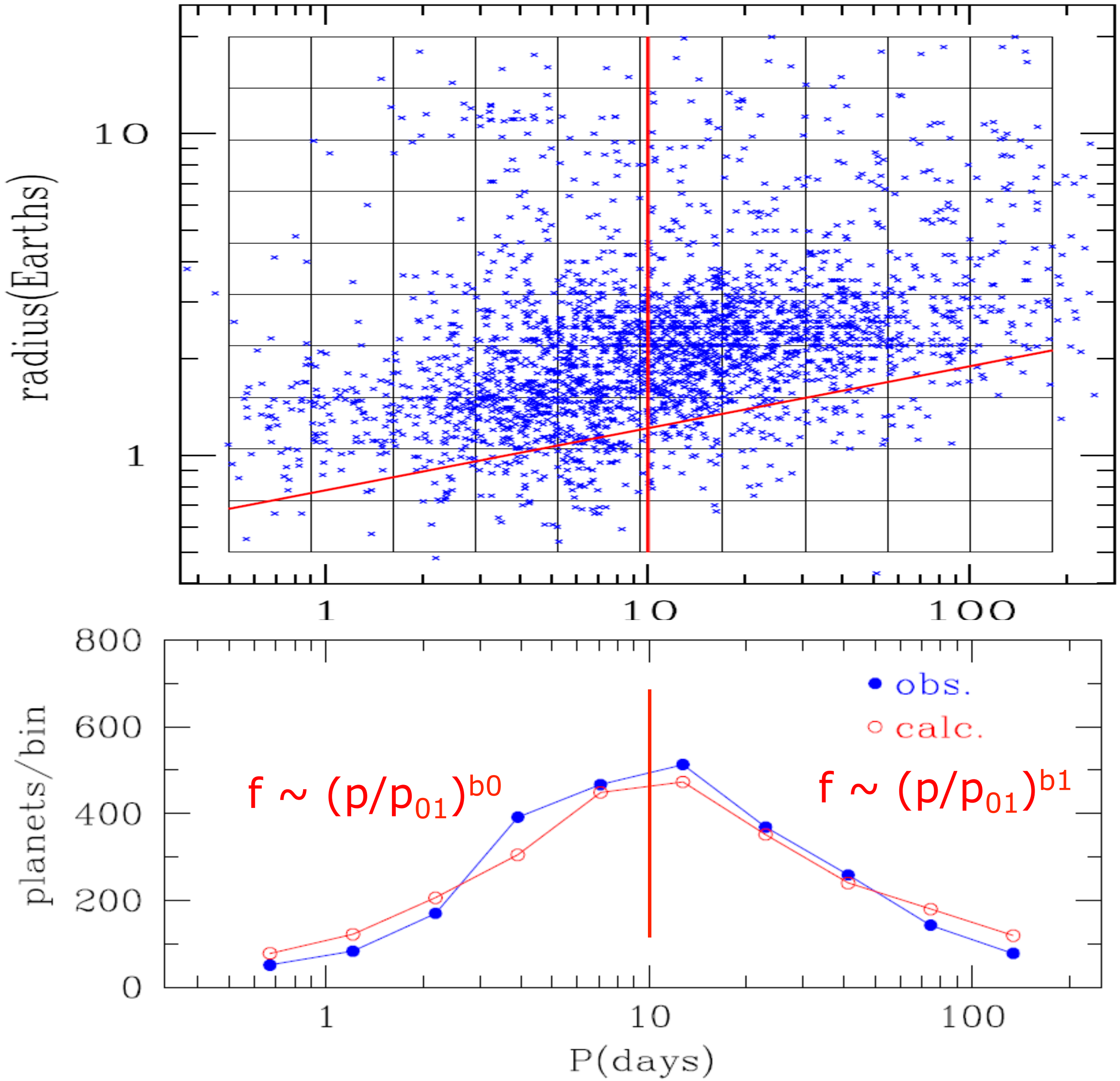
$$r_{min}/r_{\oplus} = 0.0389 \times (cdpp6_{ppm})^{1/2} \times (r_{star}/r_{sun})^{0.947} \times (P_{days})^{0.197} \times 10^{0.0533 \log(g)}$$

Empirically, scale this minimum radius by 1.8 for best fit

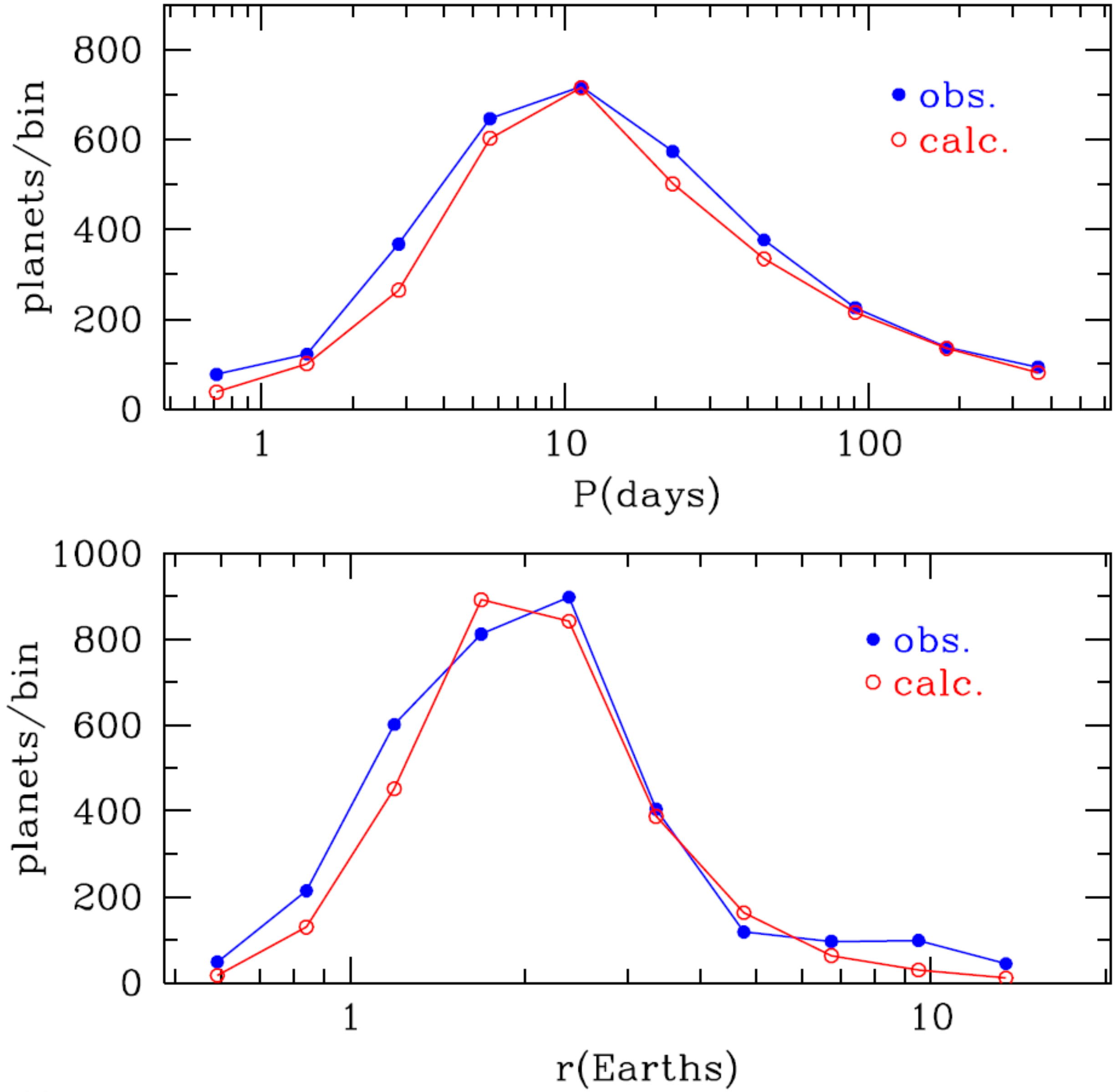
Radius: broken power law in the population



Period: broken power law in the population



Fit results for period and radius



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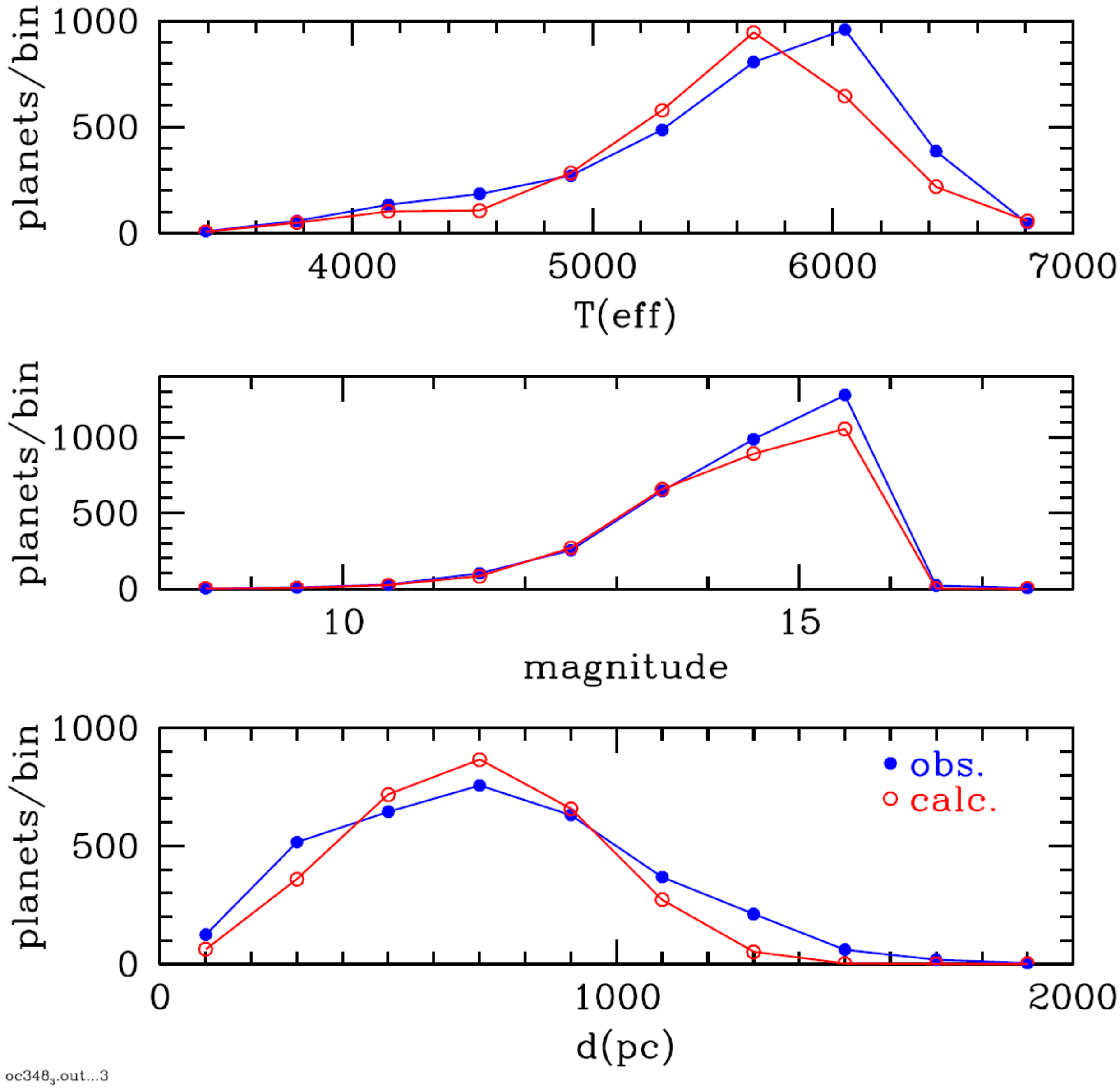
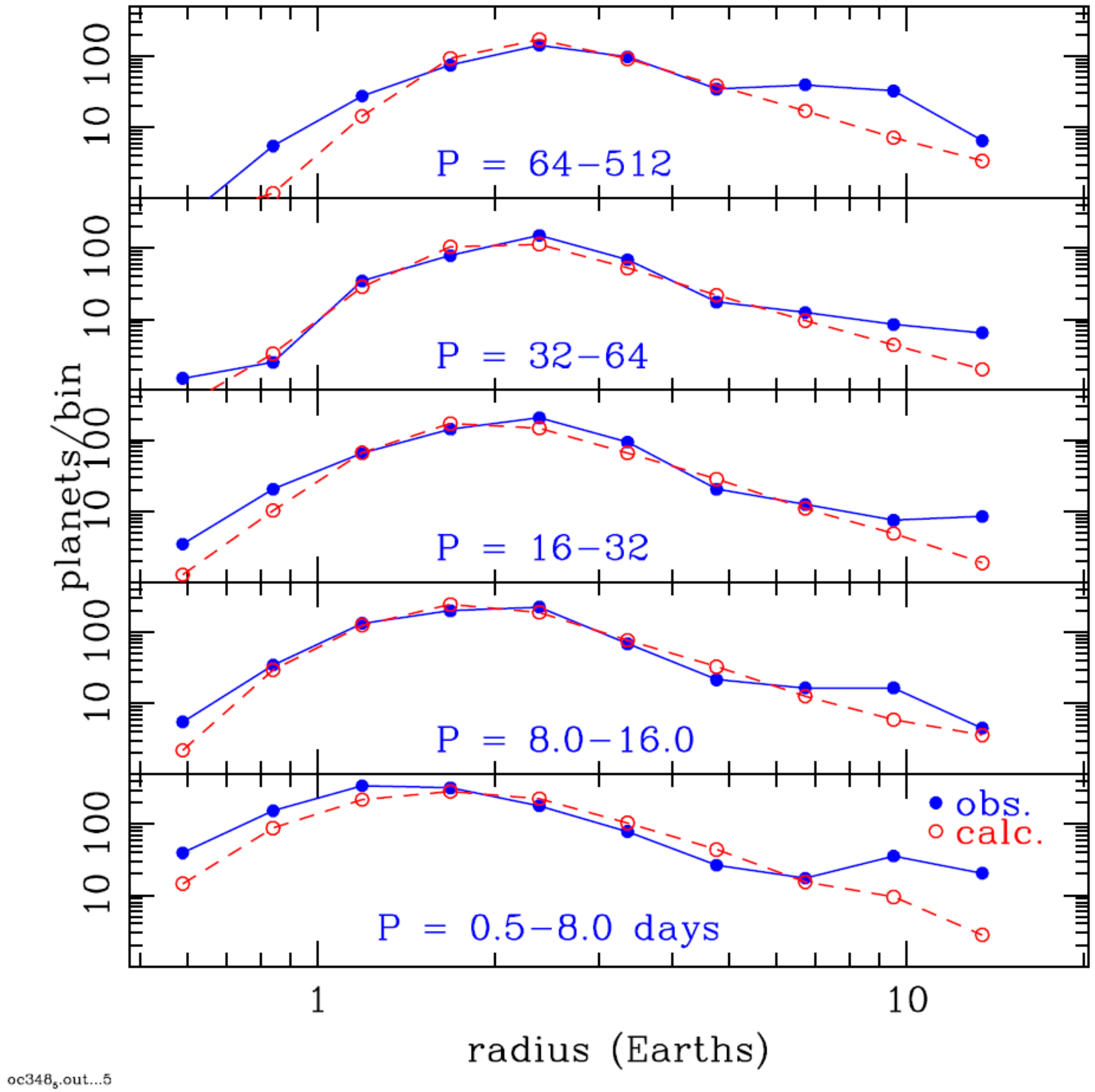
The overall fit is
χ^2/dof ~ 2.1

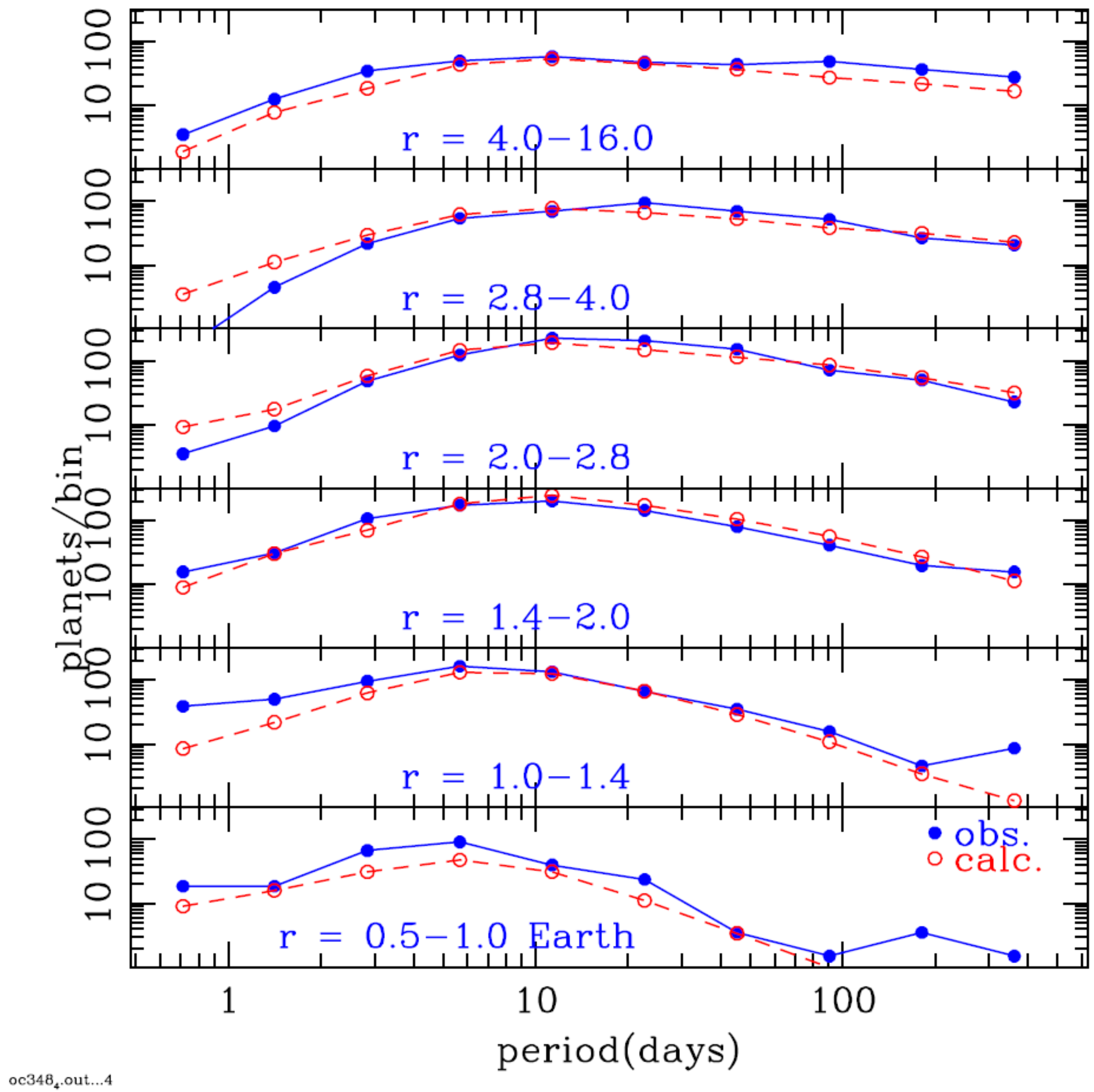
Magnitude, distance, & T(eff) distributions



Radius distributions



Period distributions



Tentative Eta-Earth values

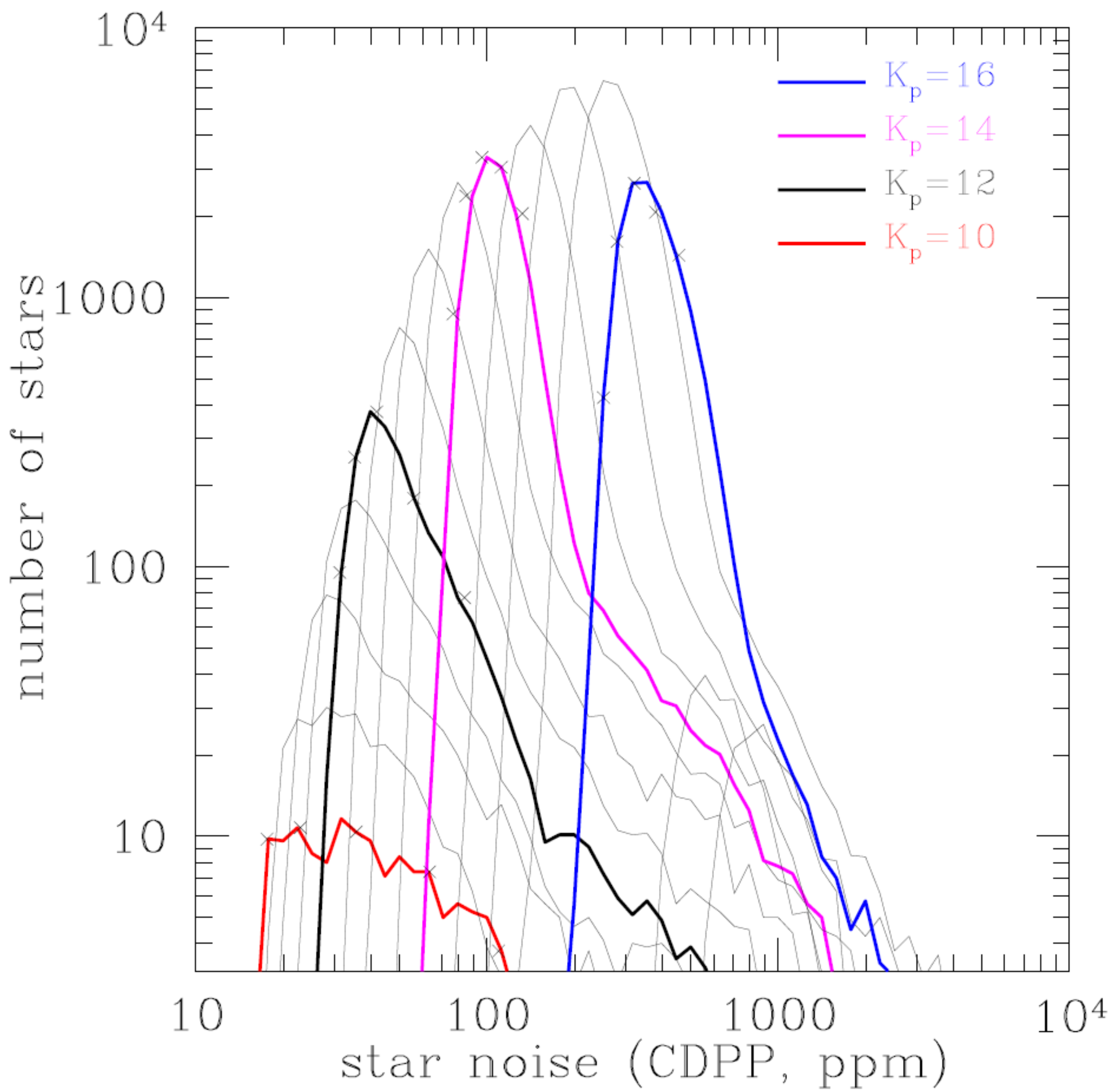
period (narrow)	radius	eta_Earth
Kopparapu: 338-793	Kepler Earth: 0.5-1.25	36%
Kopparapu: 338-793	Kepler Earth-SE: 0.5-2.0	57%
Petigura: 129-365	Petigura Earth: 1.0-2.0	29%

period (wide)	radius	eta_Earth
Kopparapu: 237-858	Kepler Earth: 0.5-1.25	52%
Kopparapu: 237-858	Kepler Earth-SE: 0.5-2.0	82%
Petigura: 129-1033	Petigura Earth: 1.0-2.0	69%

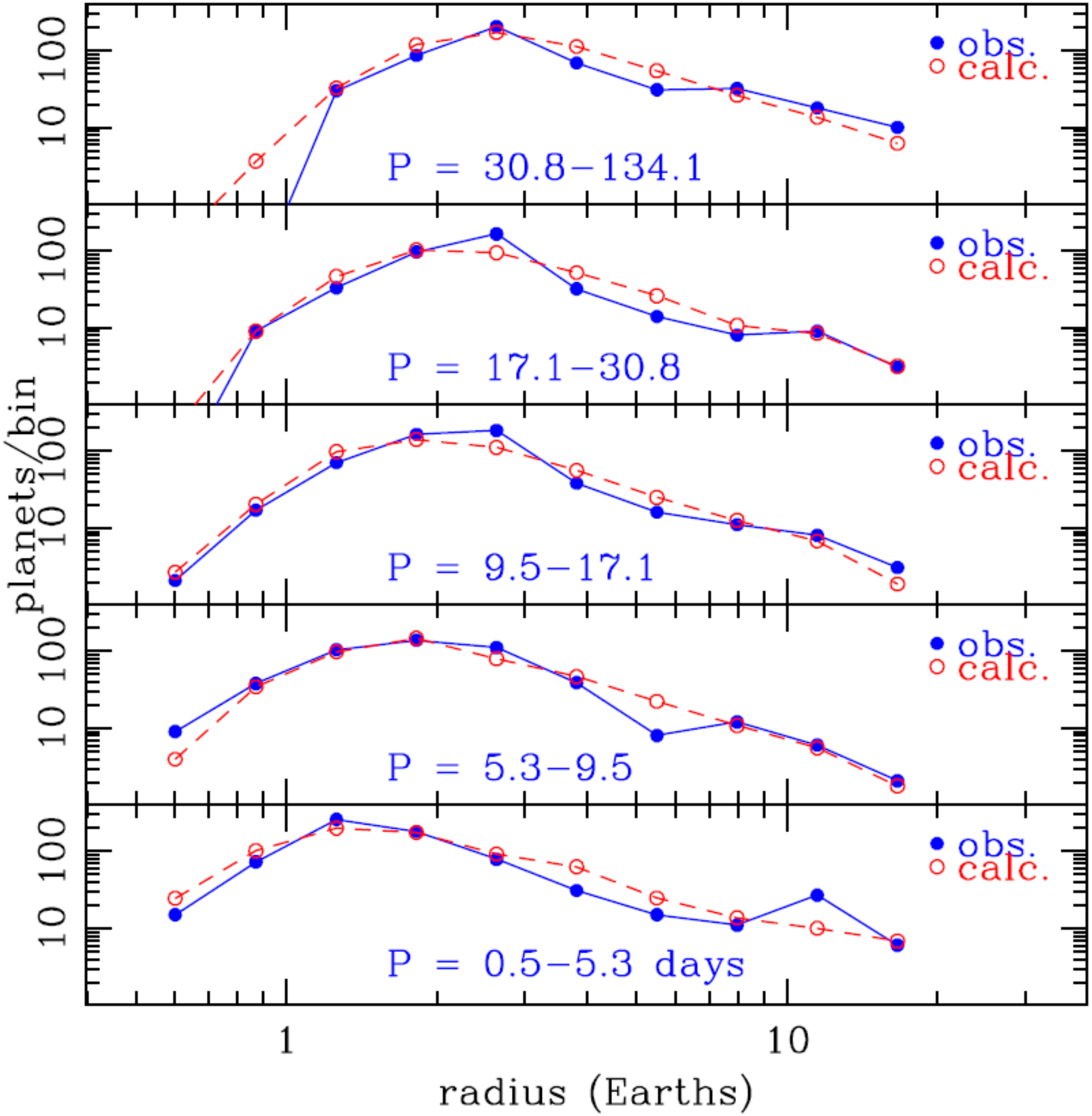
Based on all Kepler stars (FGK), not just G

Backup charts

Faint stars have more noise



cdistn3 7/4/2013



with broken power laws & r(min) cutoff, get model fit with reduced chi-square ~0.9

Goal

- The goal of this talk is to outline a method of simulating Kepler's planet distribution in terms of power laws in radius and period.

- The method is complimentary to that of Petigura, Howard, and Marcy who simulated the efficiency of the planet recovery process.

- Each method has its own biases.

- Allowing for differences in approach, our results are currently in the same ball park.

PHM's selection criteria

- T_{eff} = 4100 to 6100 K
- d = (5 to 4500 pc), guess
- K_p = 10 to 15 mag

- PHM find 42,557 target stars; I find 57,831 targets

- PHM find 603 observed planets; I find 1102 planets

Ref.: Petigura, Howard, and Marcy, Proc. Nat. Acad. Sci., submitted, 2013