Jet Propulsion Laboratory
California Institute of Technology

An Eta-Earth Projection, Based on a New Analysis of Kepler Completeness

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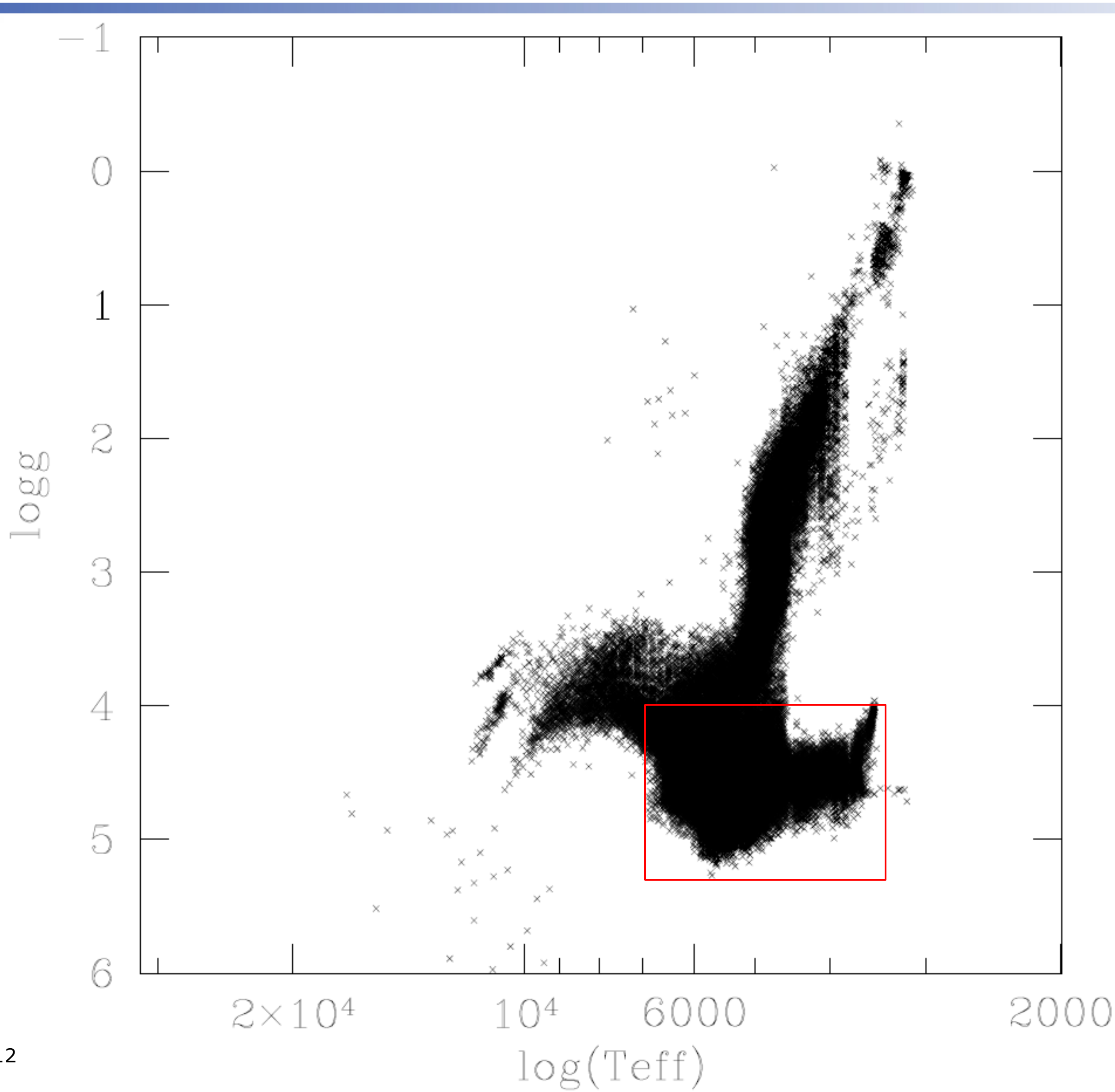
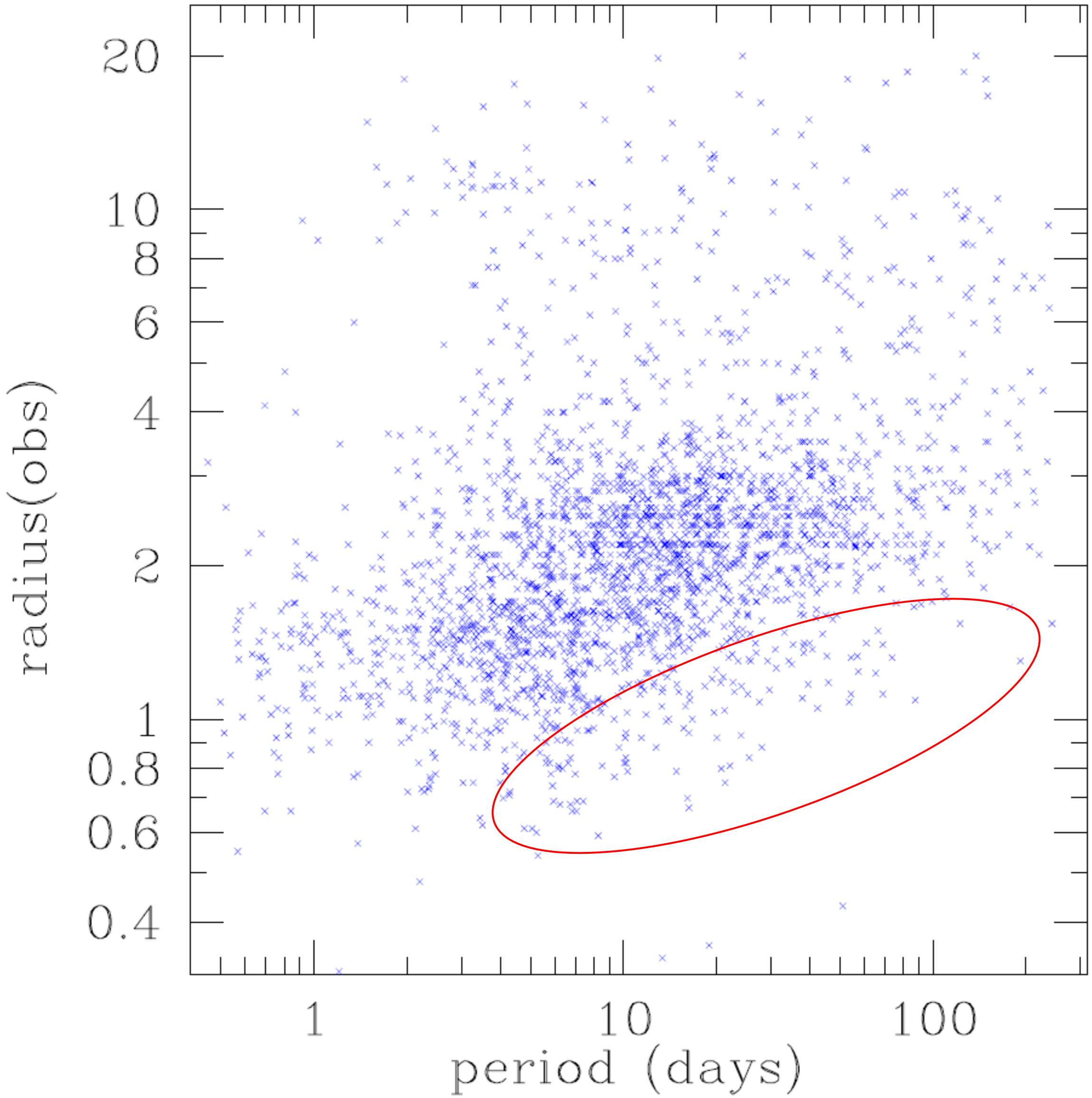
4-8 Nov. 2013

Select 3200-7000K, log g > 4.0



tgr_0_291 4/15/2012

Missing small planets at long periods

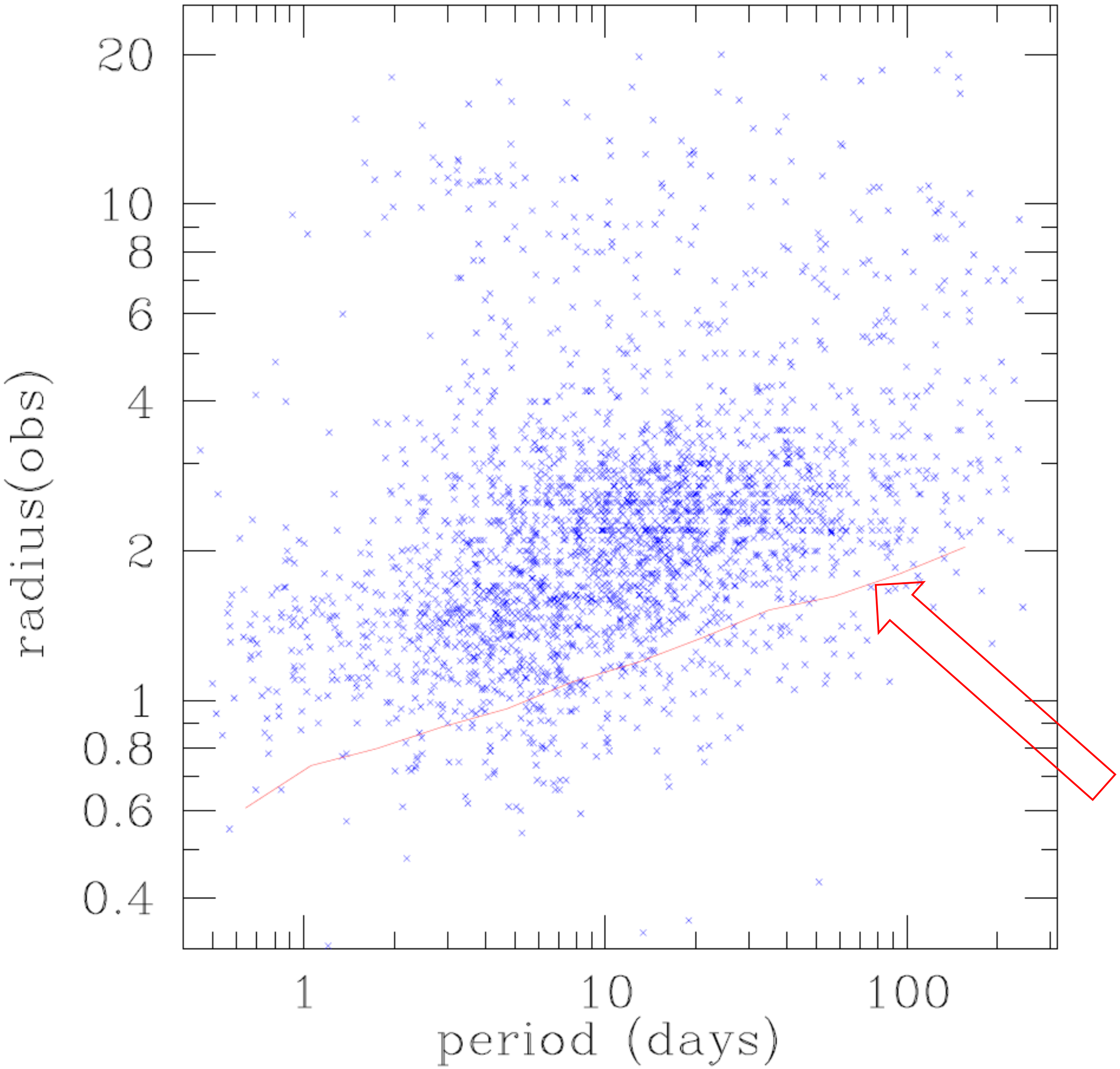


Very few small planets at longer periods:

Nature or Bias?

Missing small planets at long periods

ExoPlanet Exploration Program



Average noise-limited minimum radius
(scaled by 70%)

Must be a noise bias

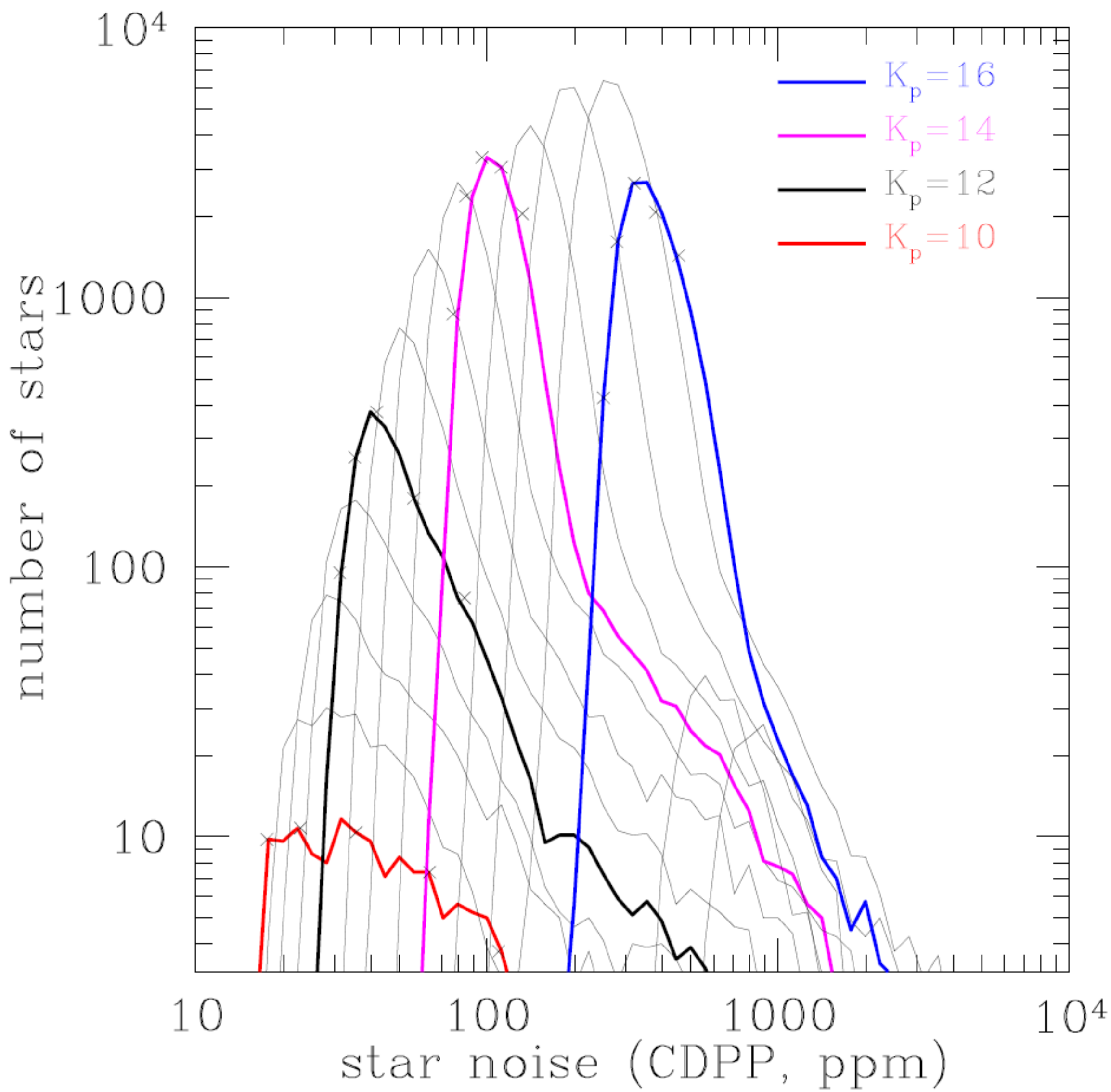
Minimum detectable plane

From first principles,
for SNR = 7 detection criterion,
for $T_{mission}$ = 2 yr & duty cycle = 92%,
& S/N ~ $1/t^{0.32}$ (not $1/t^{0.50}$),
the minimum detectable planet radius is r_{min}:

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

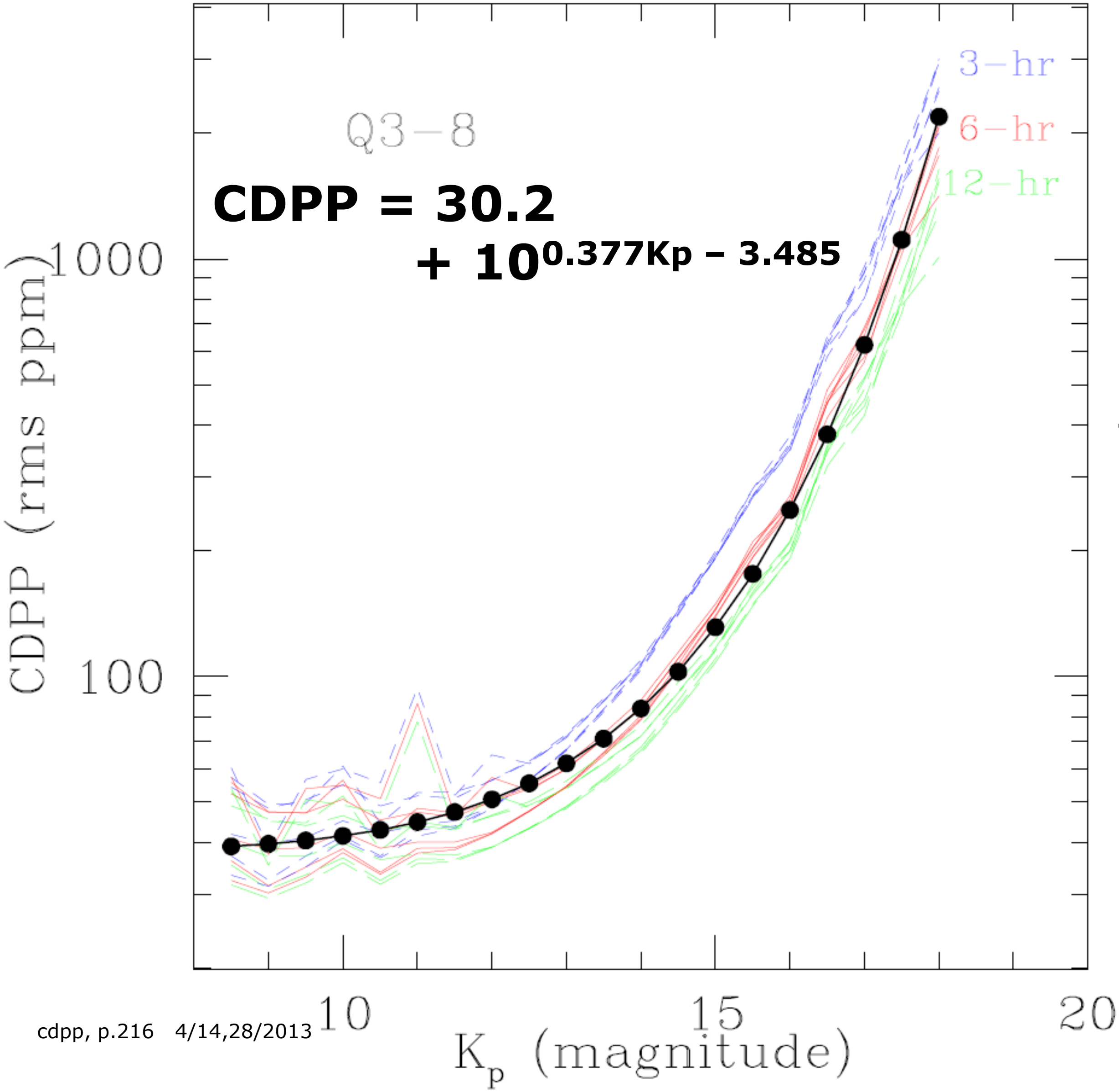
p.264-266, 6/5/2013

Faint stars have more noise



cdistn3 7/4/2013

Median noise (CDPP) vs magnitude

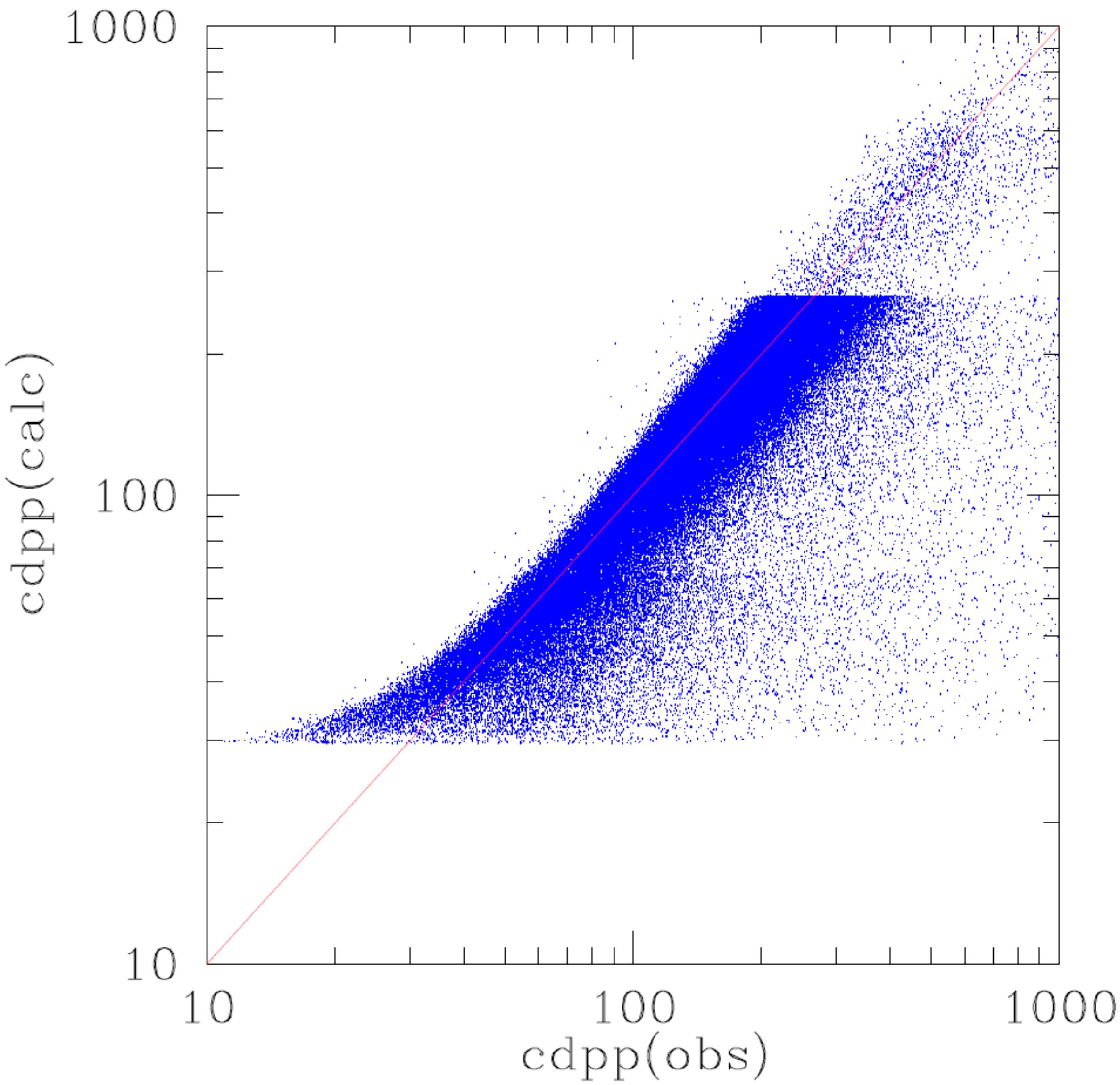


CDPP is RMS noise per 6-hour observation, in units of ppm

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

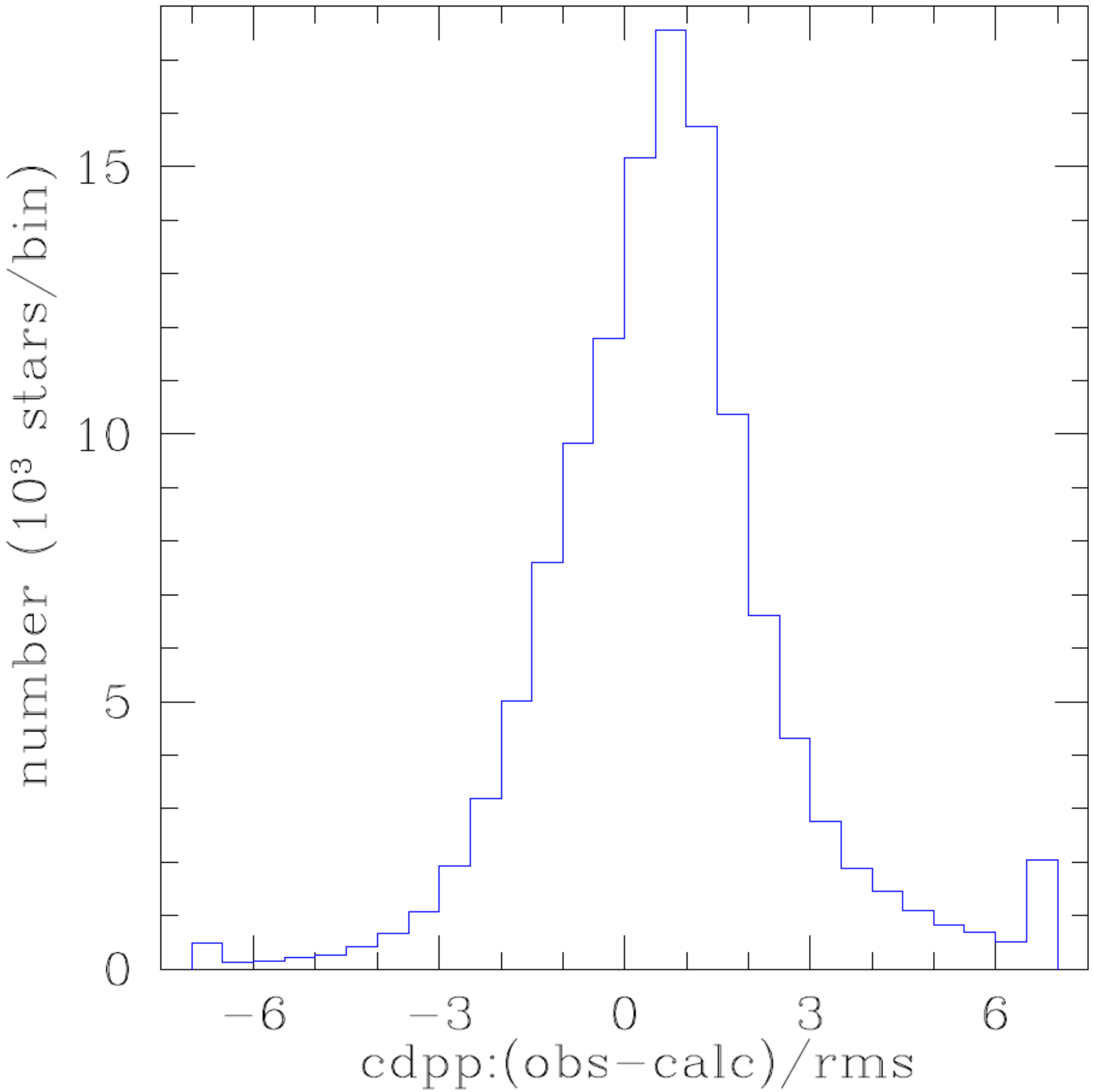
The best-fit curve is a simple function of Kepler magnitude

Calculated vs observed noise (CDPP)



crms1 7/15/2013

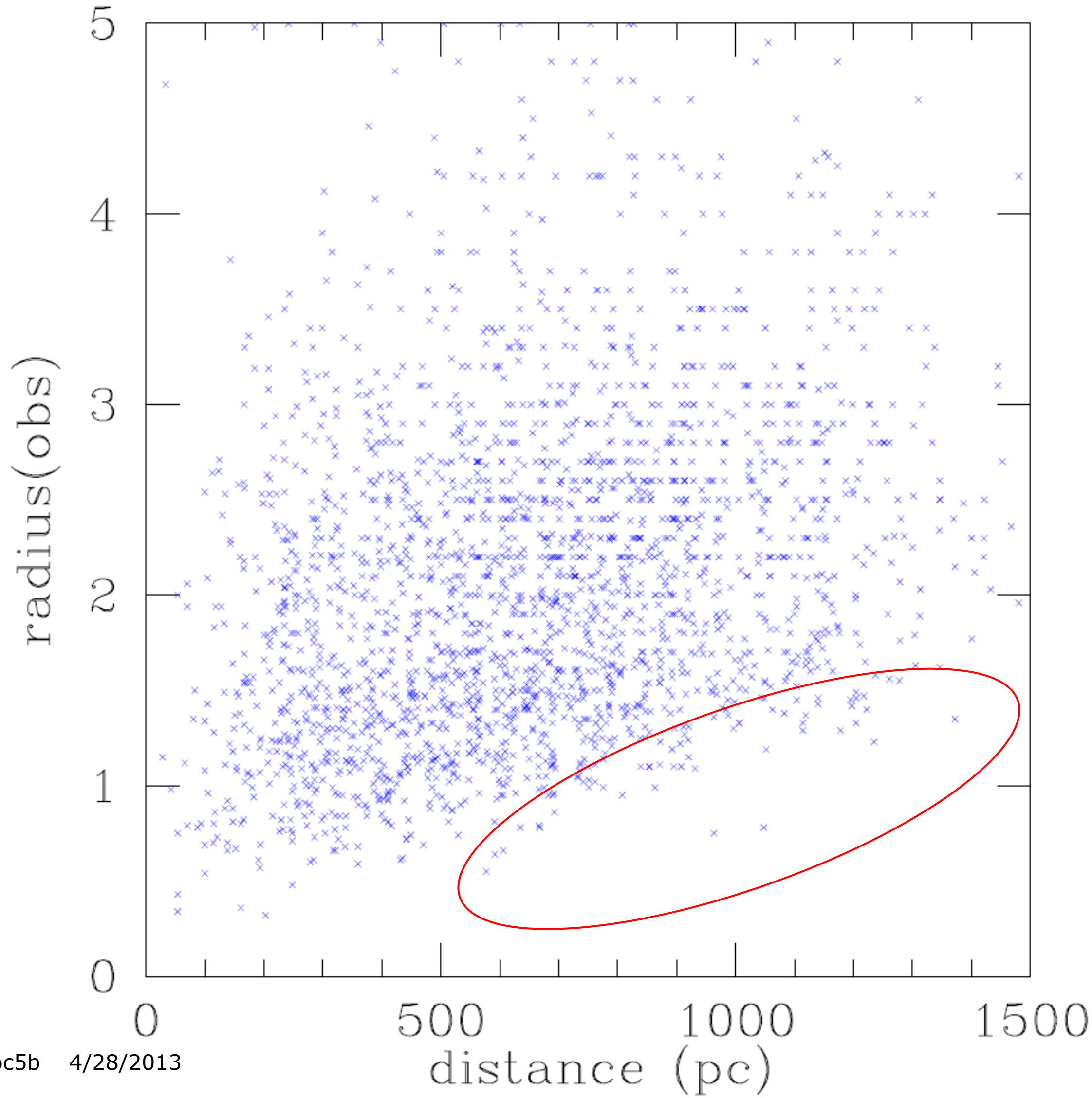
Relative scatter of observed – calculated noise



crmsoc 7/16/2013

Missing small planets at large distance

ExoPlanet Exploration Program

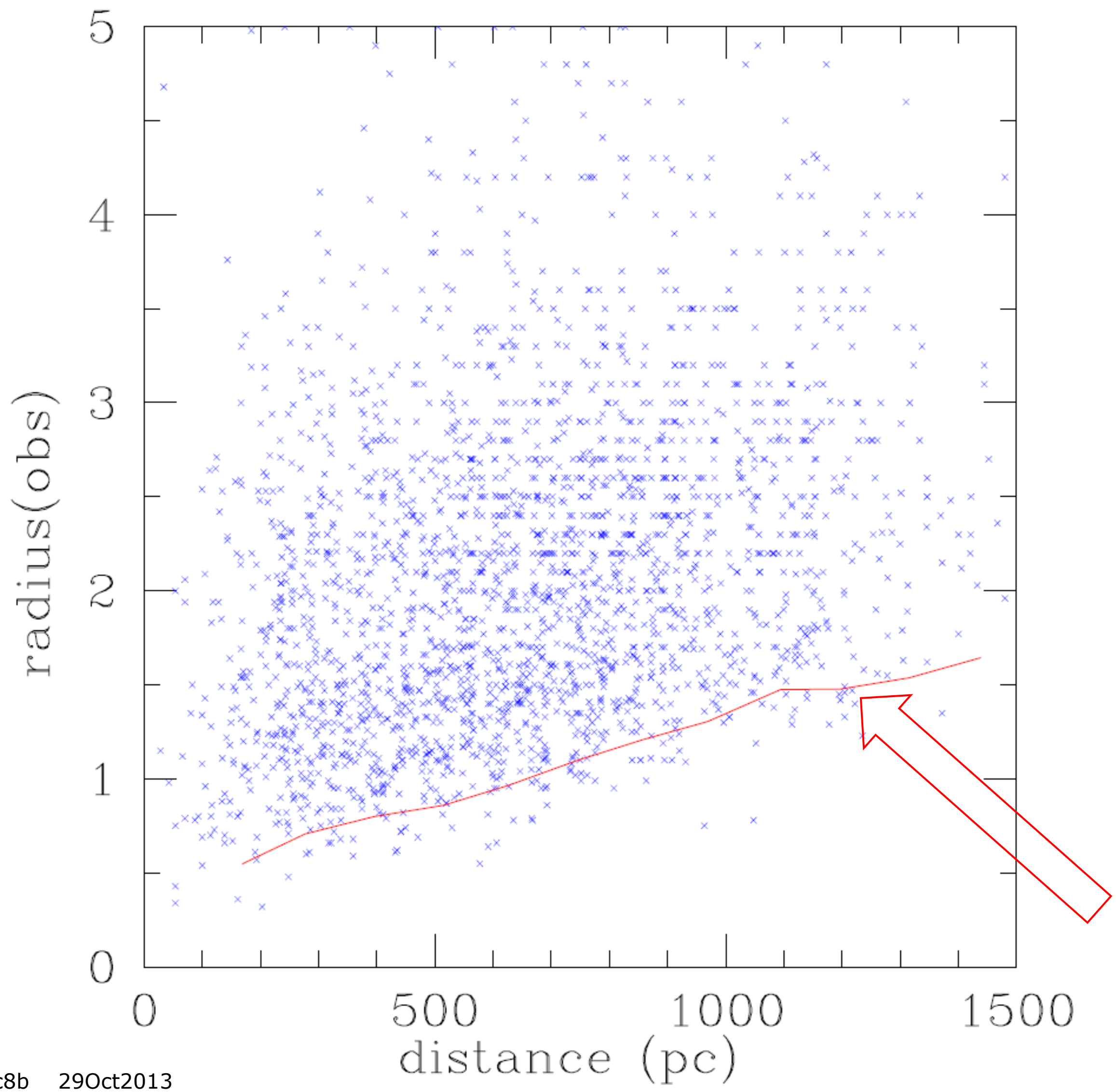


Very few small planets at large distances:

Nature or Bias?

roc5b 4/28/2013

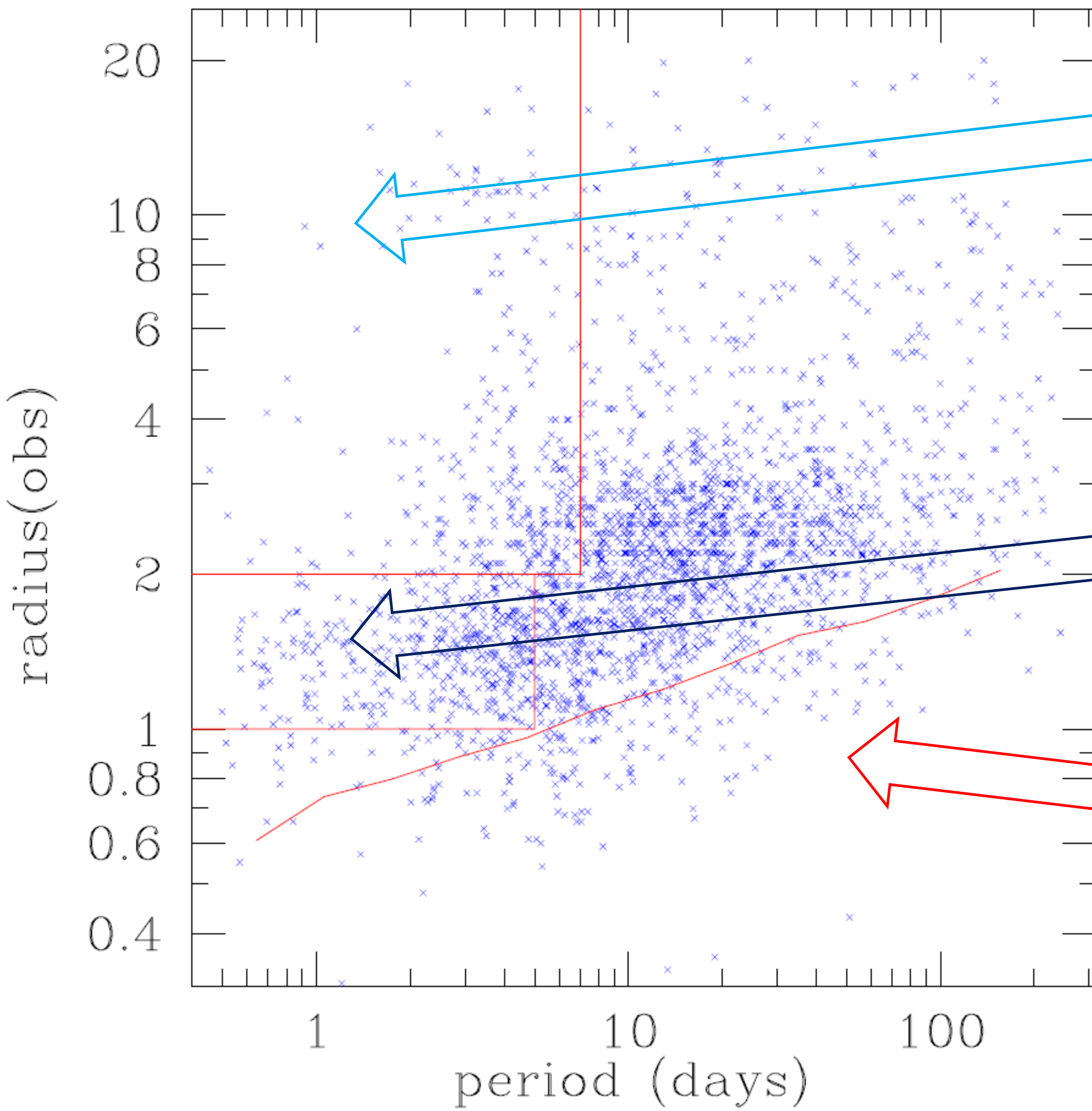
Missing small planets at large distance



Average noise-limited minimum radius
(scaled by 70%)

Must be a noise bias

Salient regions of the (P,r) diagram

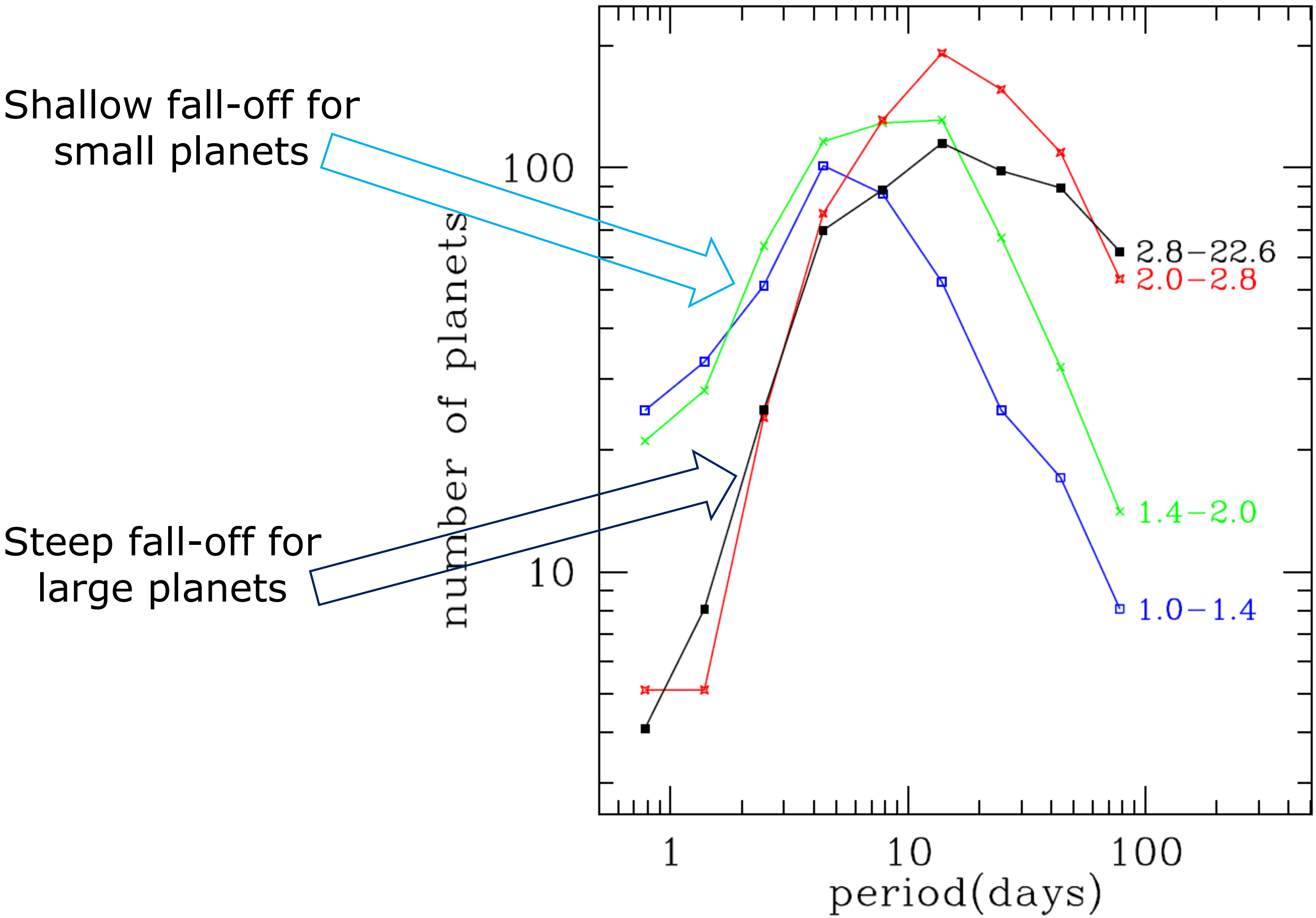


P < 7 days, r > 2 Earths
Nature bias against short periods

P < 5 days, r = 1-2 Earths
Nature bias against short periods

R < r(min)
Instrument bias against noisy signals

Short-period fall-off



Eta-Earth (tentative)

Tentative bottom line: Fitting all 3 areas of the (P,r) diagram, using random planets assigned to 134,000 Kepler target stars, & using power-law functions, I find a best fit

$$N(\text{planets})/N(\text{stars}) = A \times r^a \times P^b \times \Delta\ln(r) \times \Delta\ln(P)$$

where A = 0.168, a = -2.4, b = 0.4

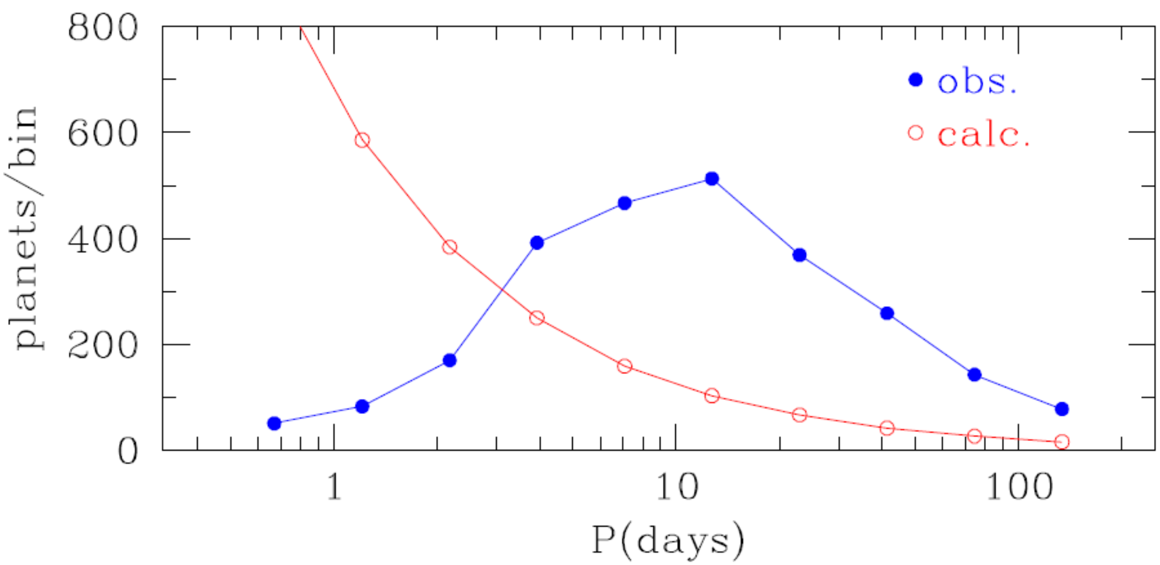
which gives $\eta_\oplus = 0.70$

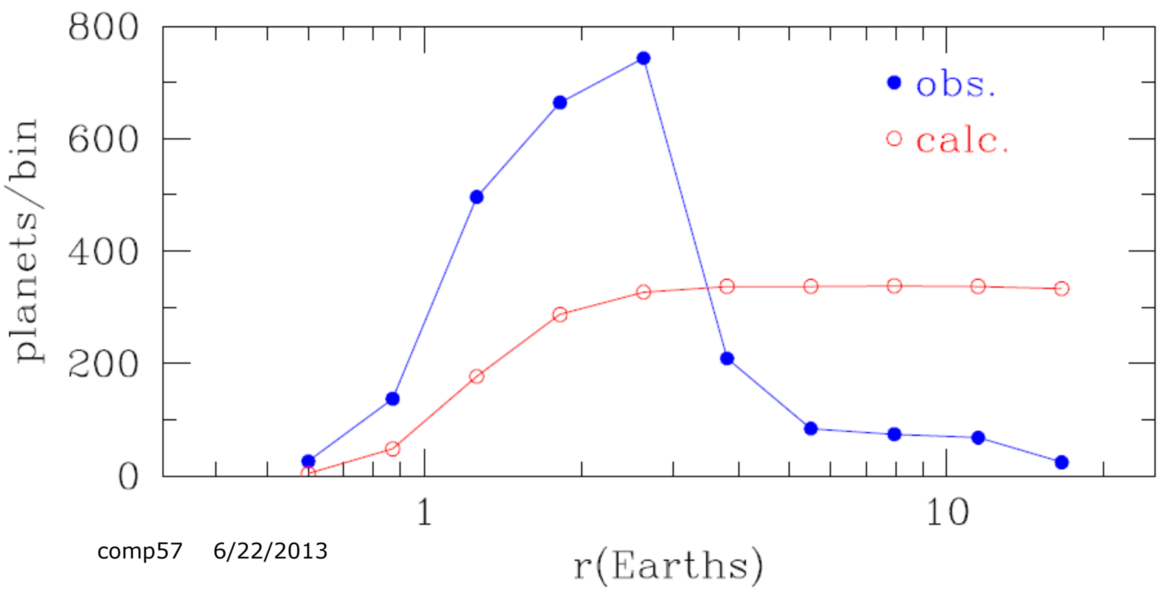
for r = 1-2 Earth radius
& P = 225-687 days (Venus to Mars around Sun-like star)

Backup charts

Example: O vs C: $f \sim r^0 P^0$ per bin, poor fit

ExoPlanet Exploration Program





Generate simulated data:

For each Kepler star, assign a random planet radius and period, using power laws in r & P

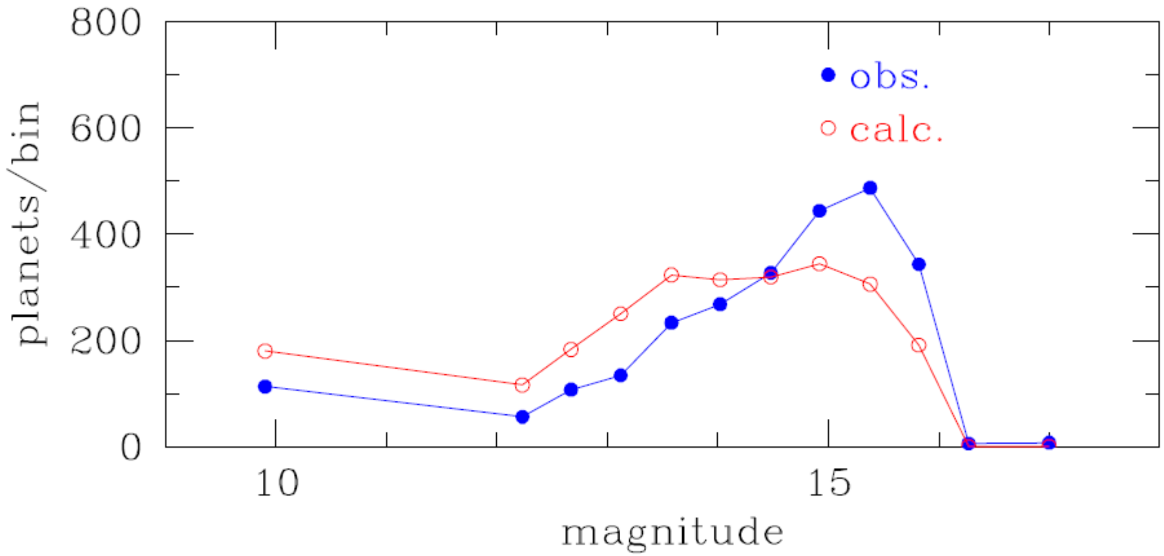
If radius is greater than the minimum, then "detect" the planet, otherwise reject it.

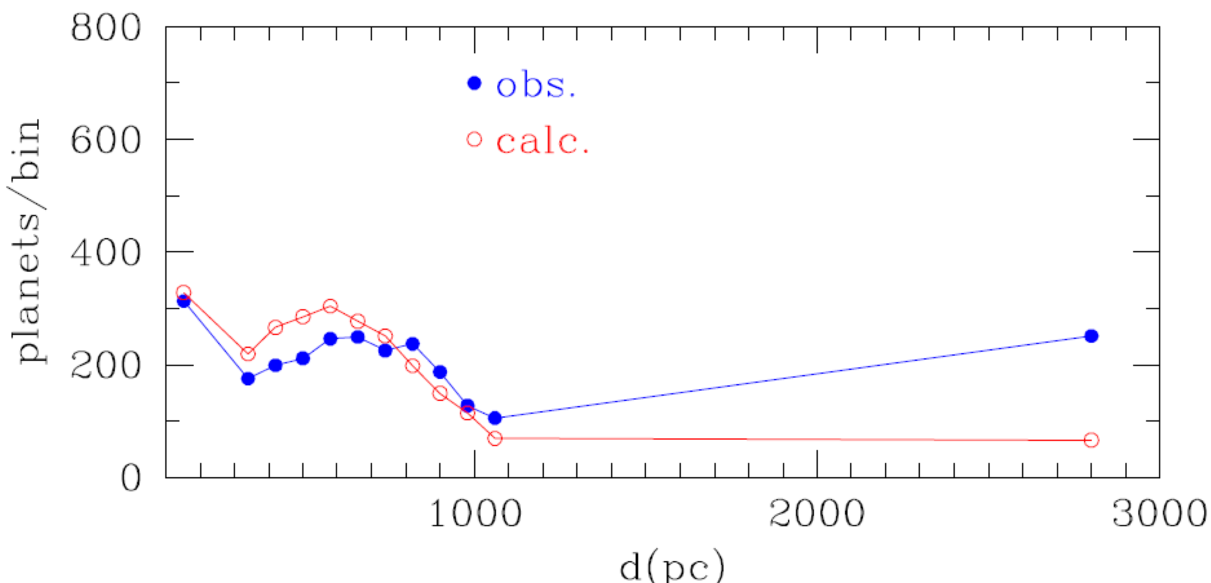
Compare observed data with simulated data.

In this case (flat power laws) the fits are not good.

Observed-calculated vs magnitude and distance: best (P,r) fit

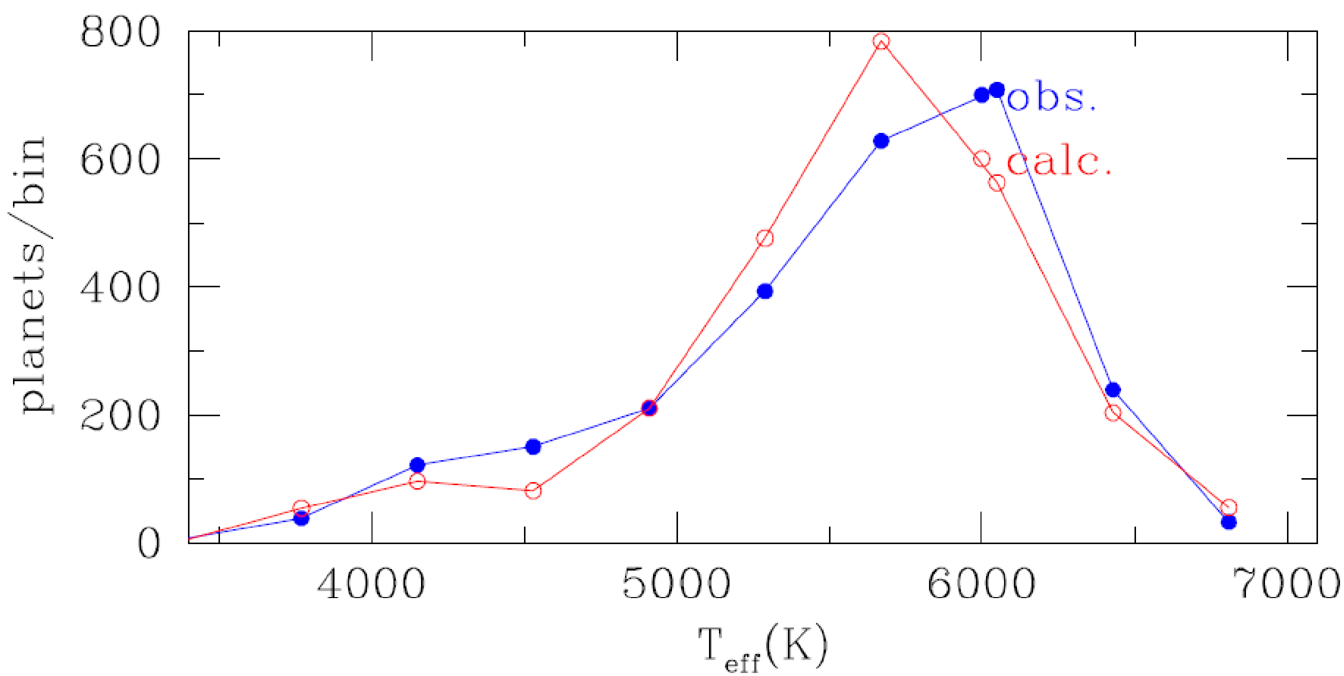
ExoPlanet Exploration Program





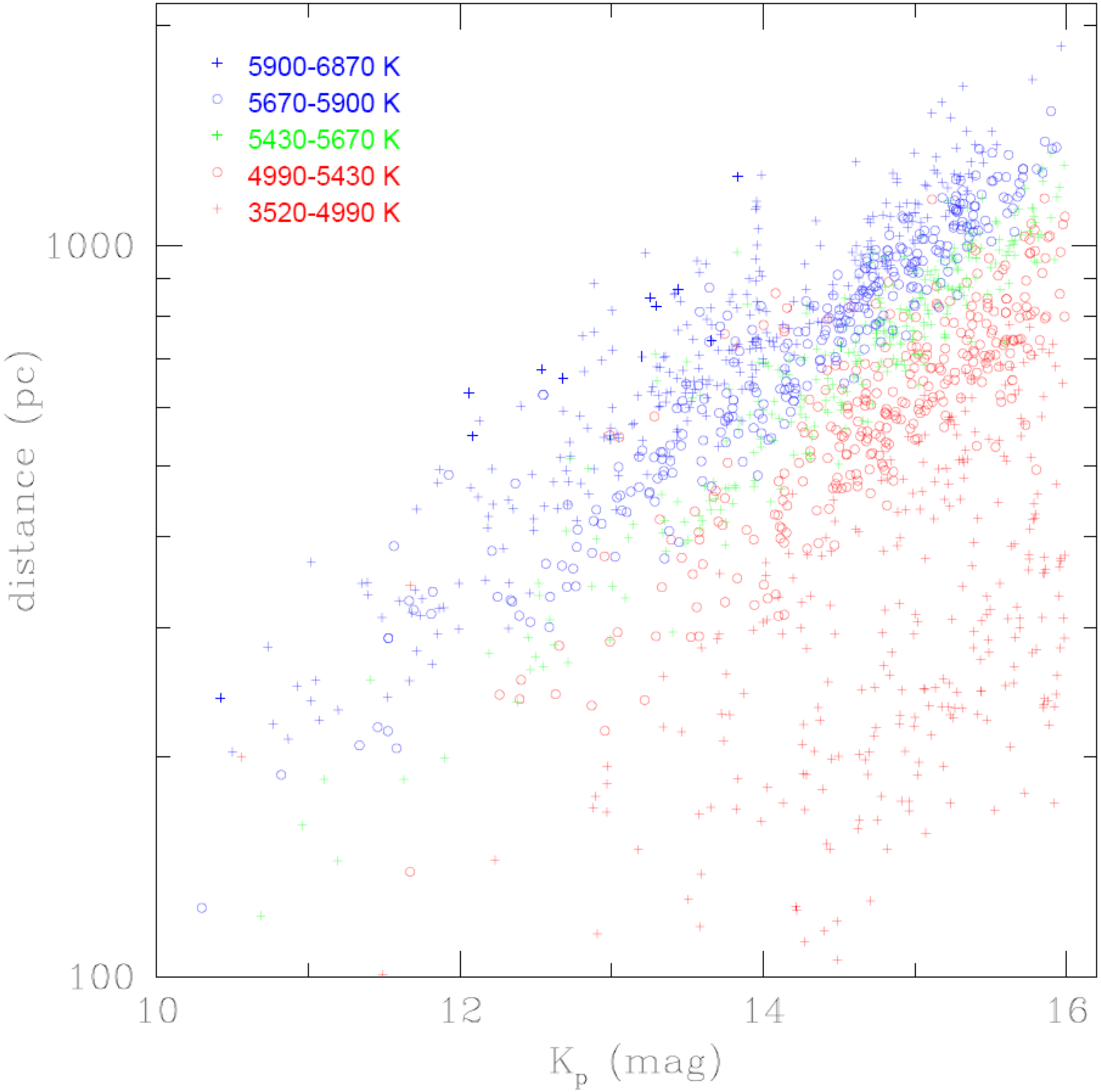
Comp78_2.pdf 29Oct2013

Observed-calculated vs T(eff): best (P,r) fit



Comp78_2.pdf 29Oct2013

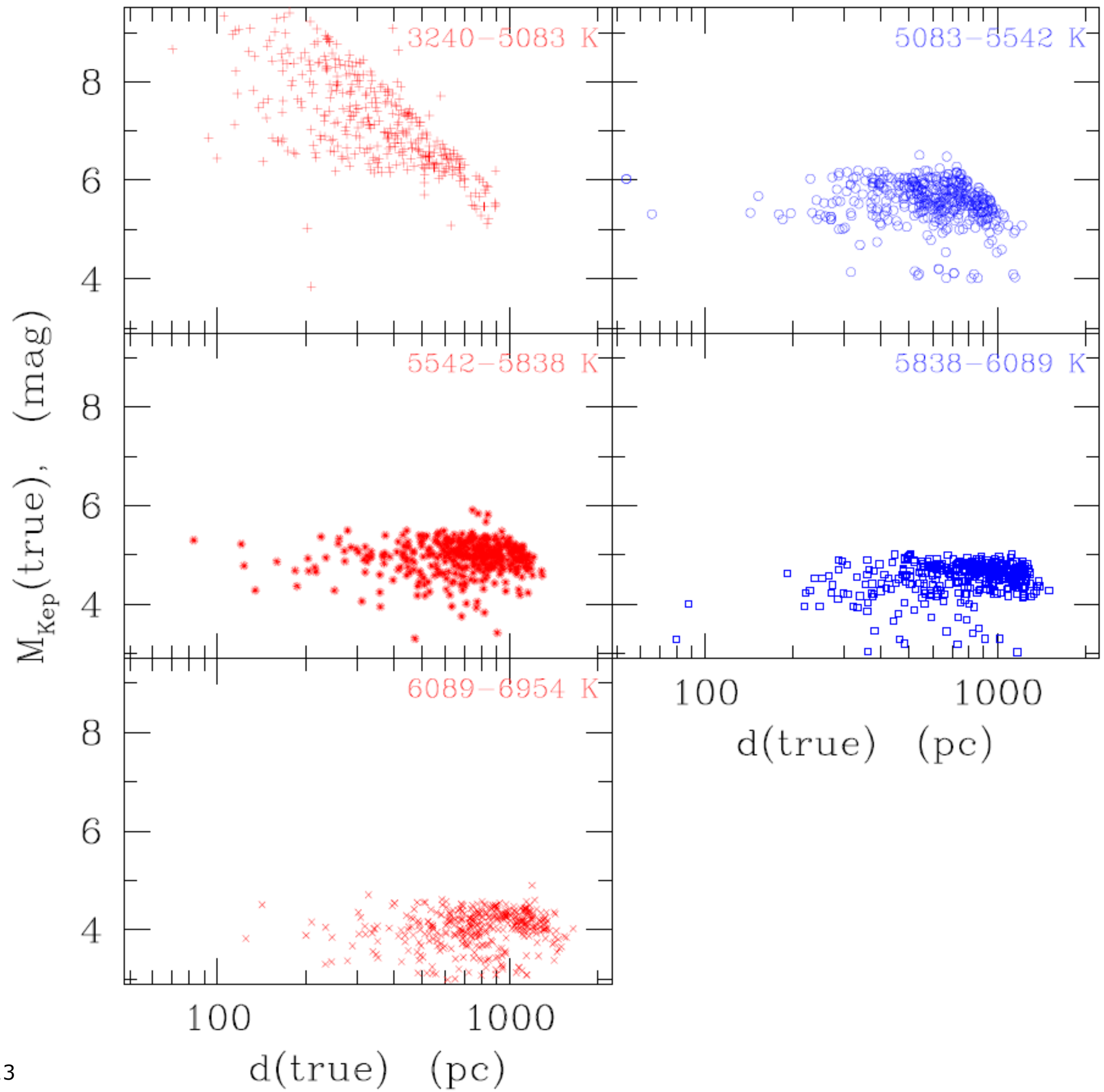
Distance vs magnitude



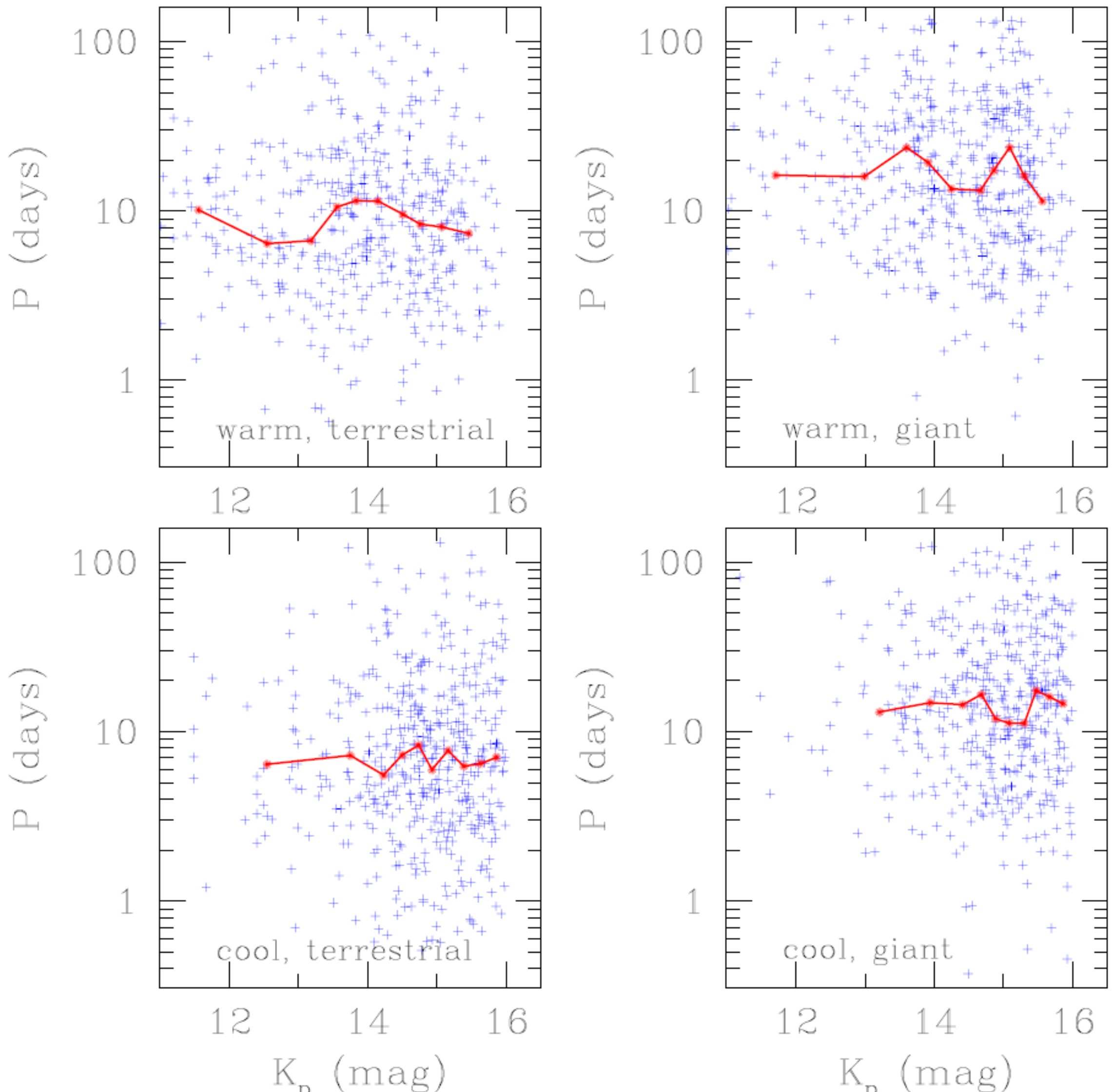
mag_dist_3 10/7/2012

Reasonable clustering in absolute magnitude vs distance

ExoPlanet Exploration Program

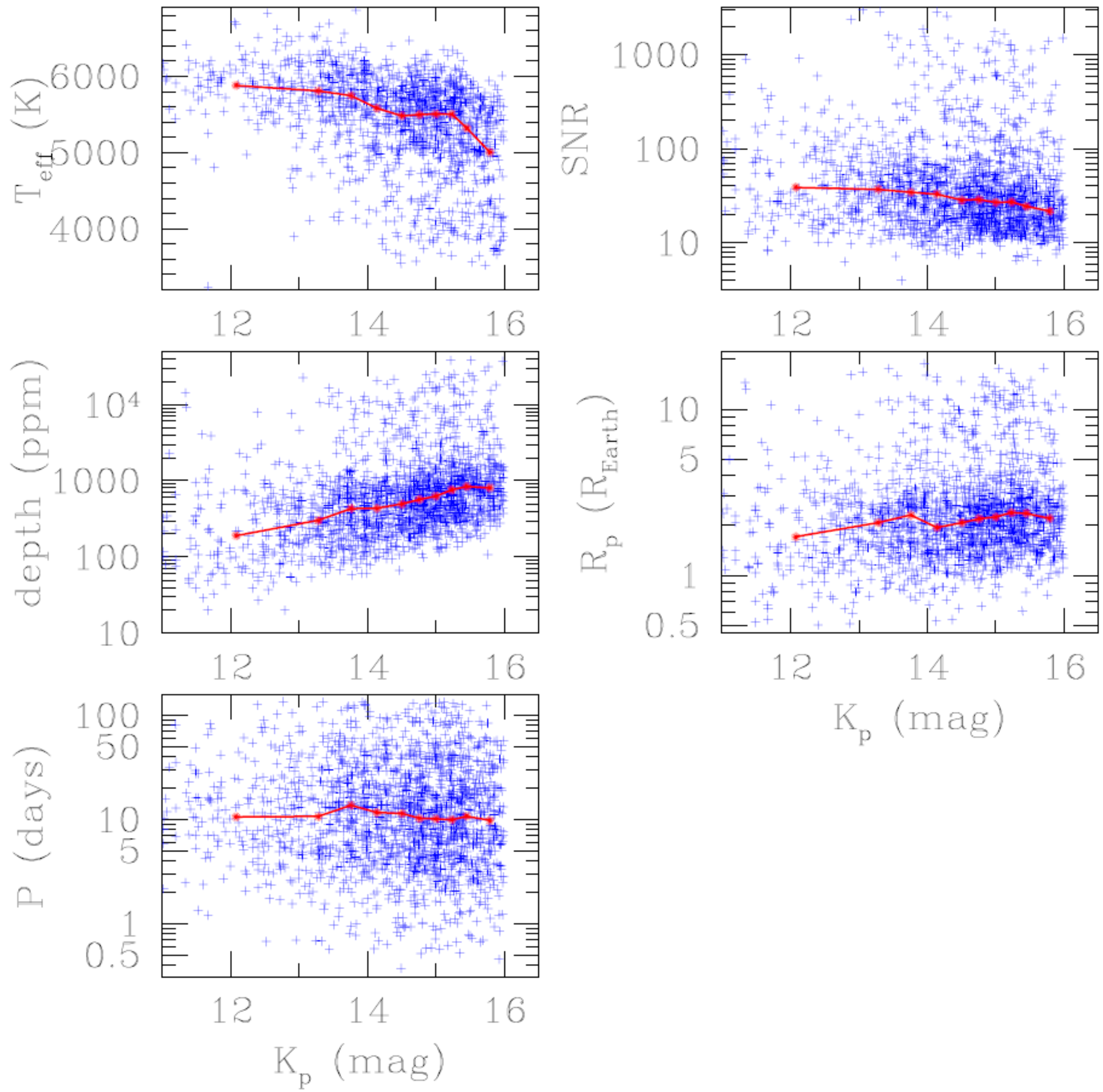


Reasonable scatter in period vs magnitude



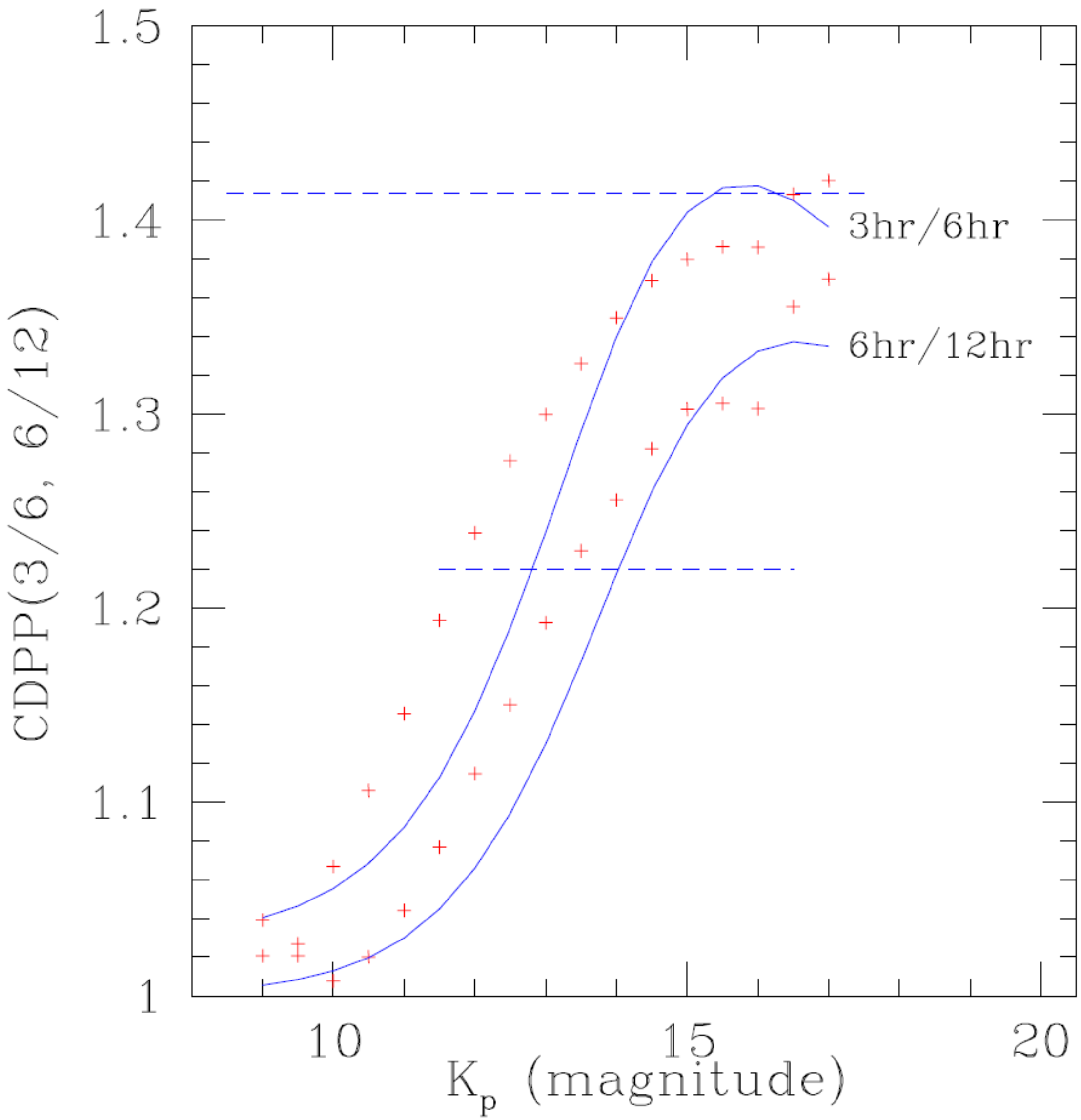
kpscatter_wctg 8/4/2012

Reasonable scatter with magnitude (except for depth vs mag)



Kpscatter2 8/4/2012

Ratio of 3/6 hr and 6/12 hr noise vs magnitude



cdpptimeorig 7/6/2013