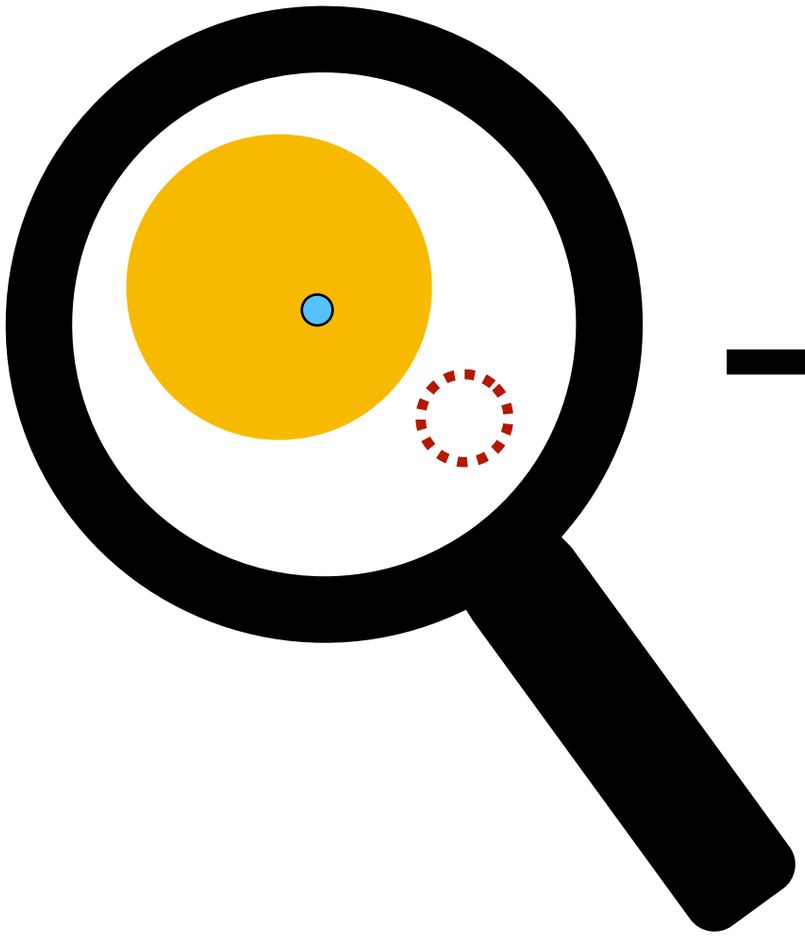
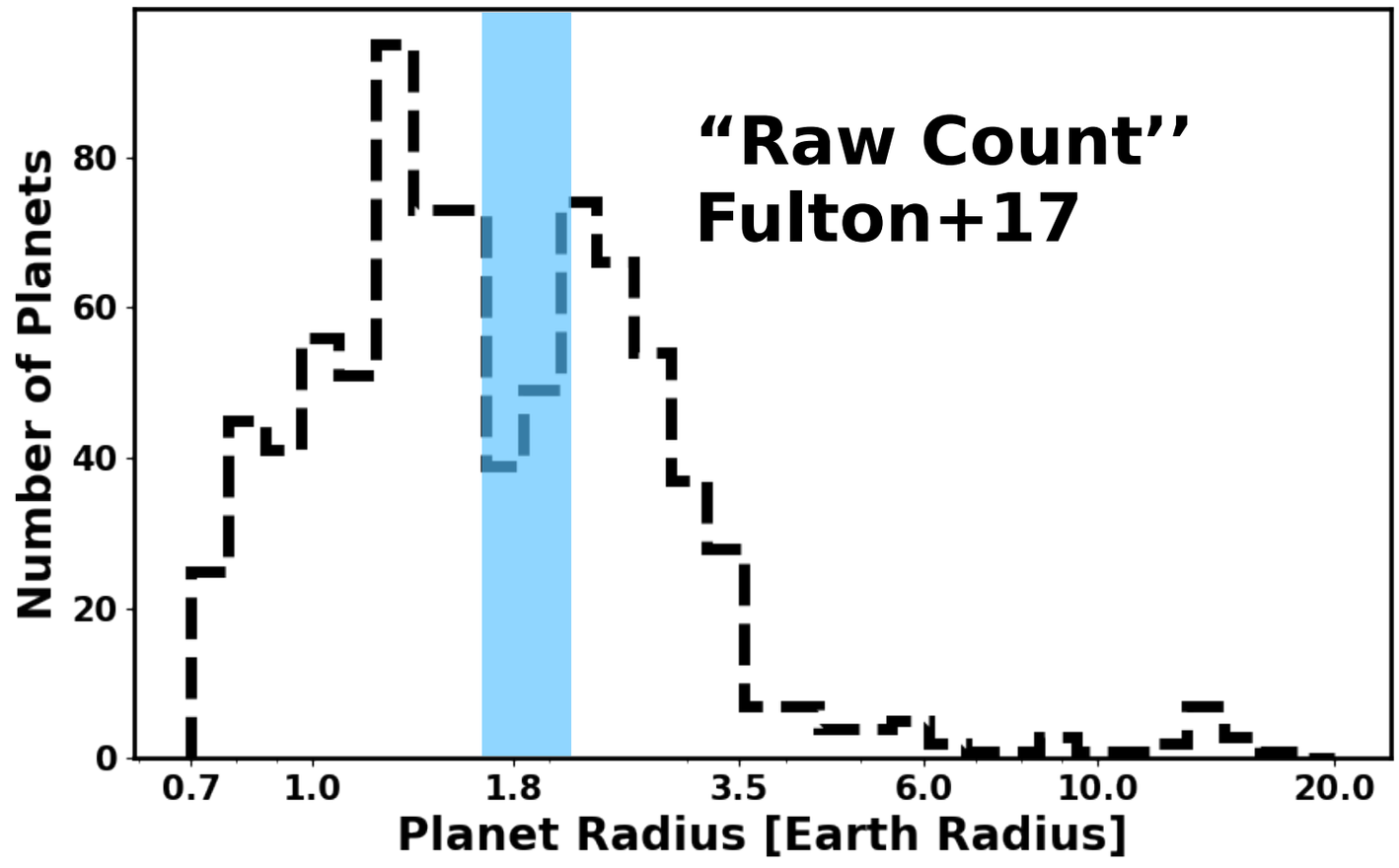
The Effects of Stellar Companions on the Observed Transiting Exoplanet Radius Distribution



?



Johanna Teske
Carnegie Observatories

planet mass & bulk composition

host star activity

host star parameters & abundances

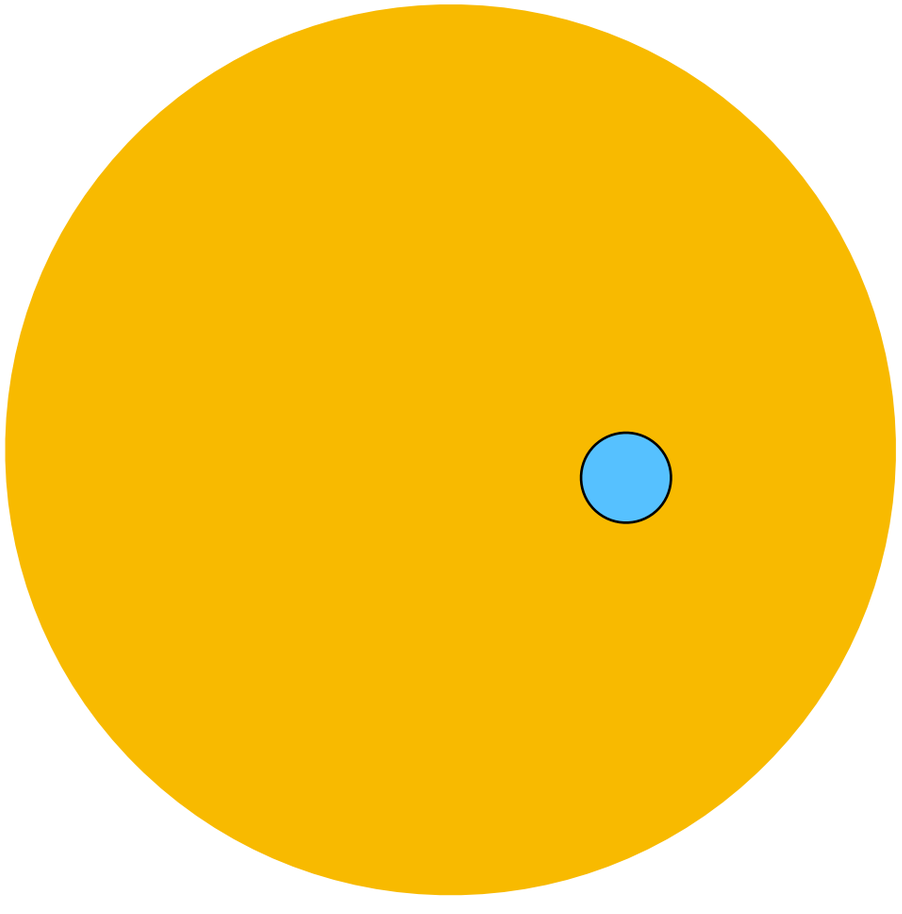
host star multiplicity

equity & inclusion in astronomy

formal and informal STEM education

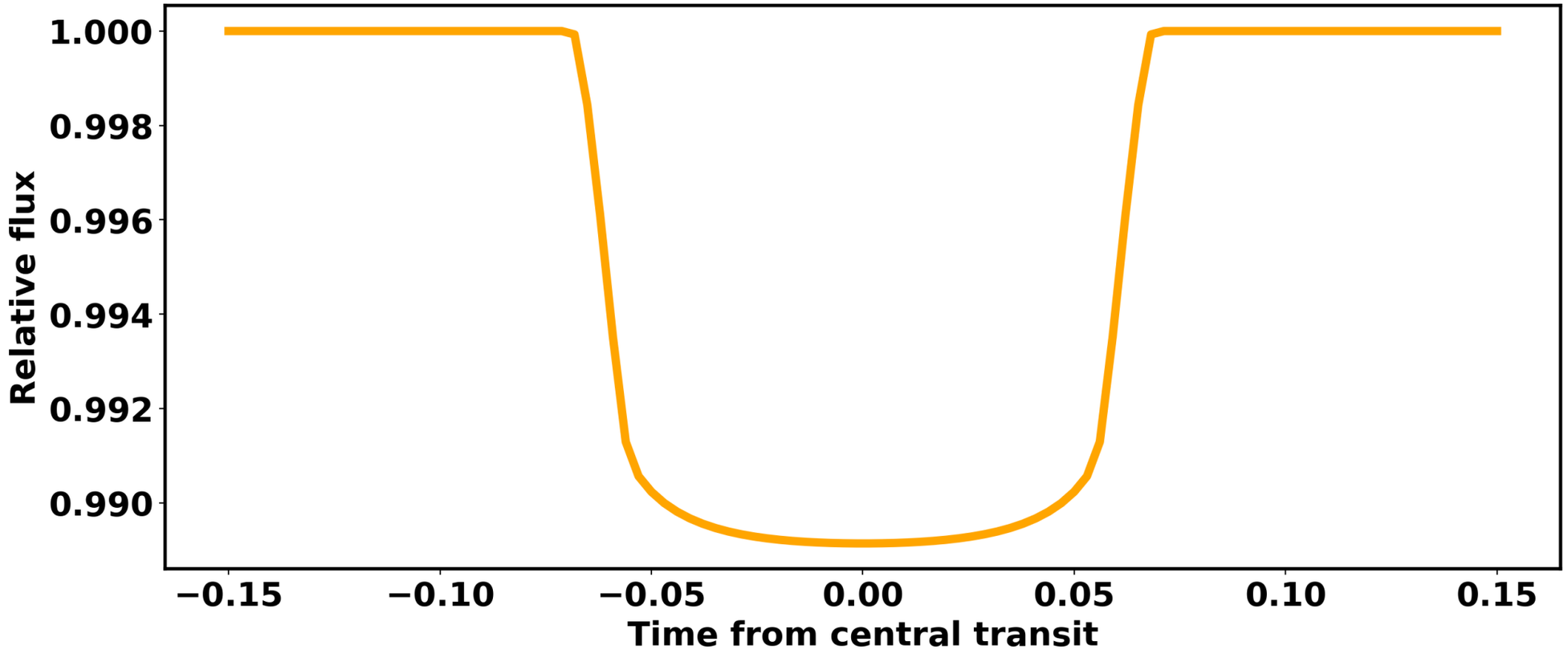
running

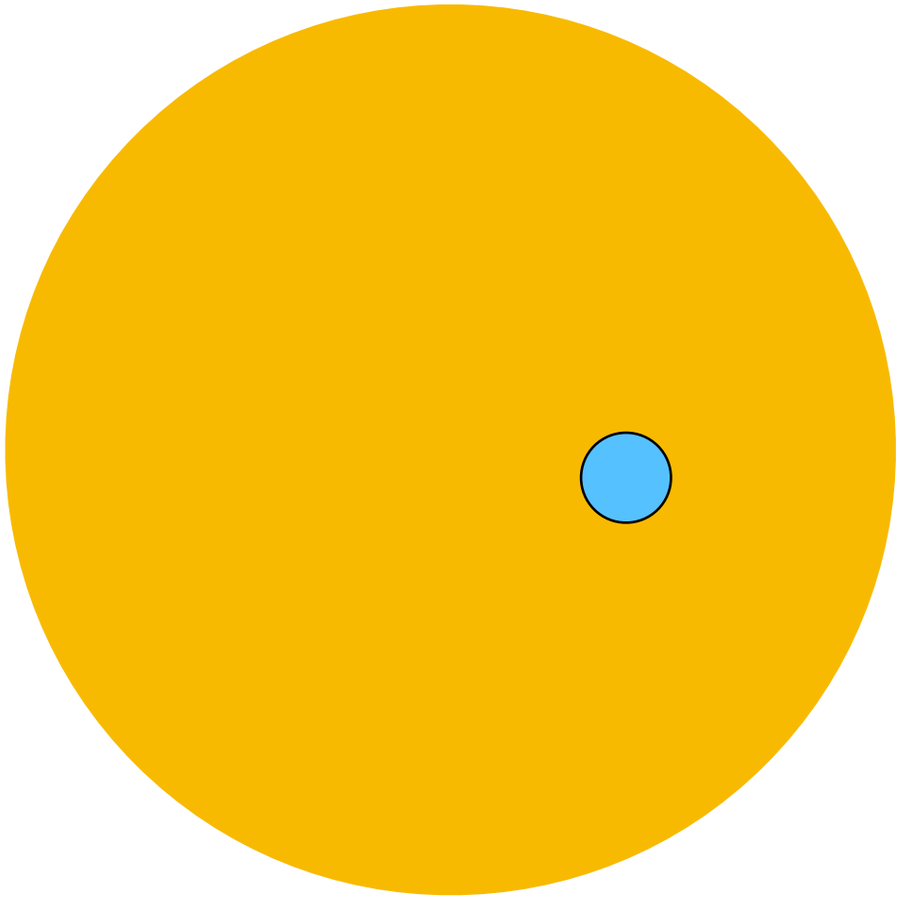
watching baseball



Primary Star is Single
Planet Orbits Primary Star

$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

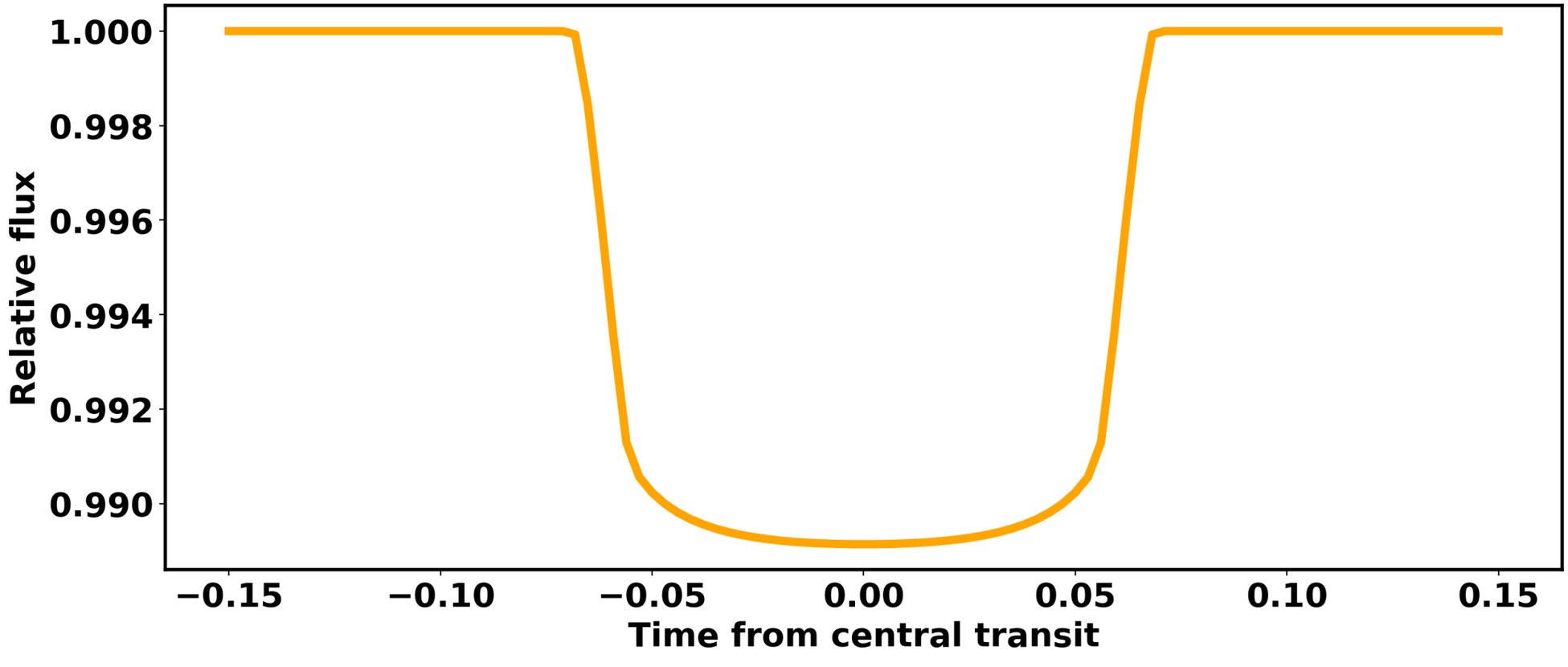




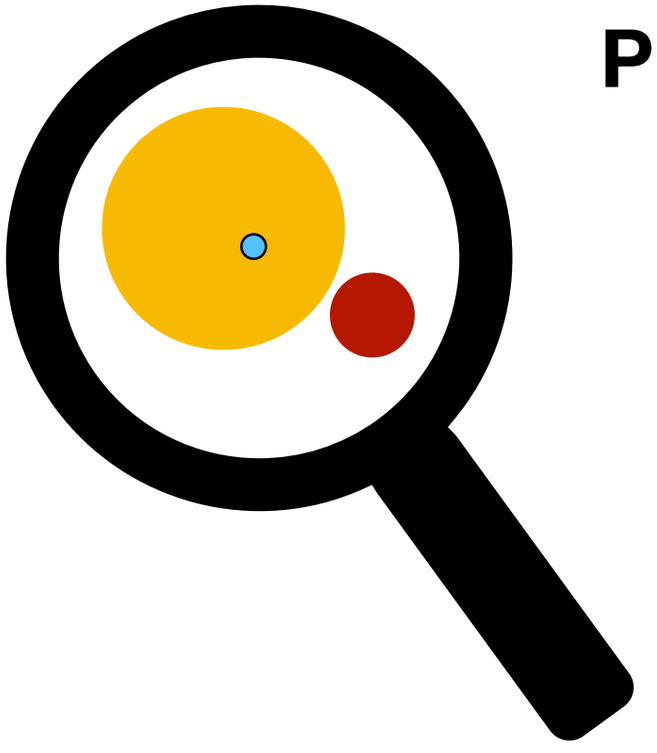
Primary Star is Single
Planet Orbits Primary Star

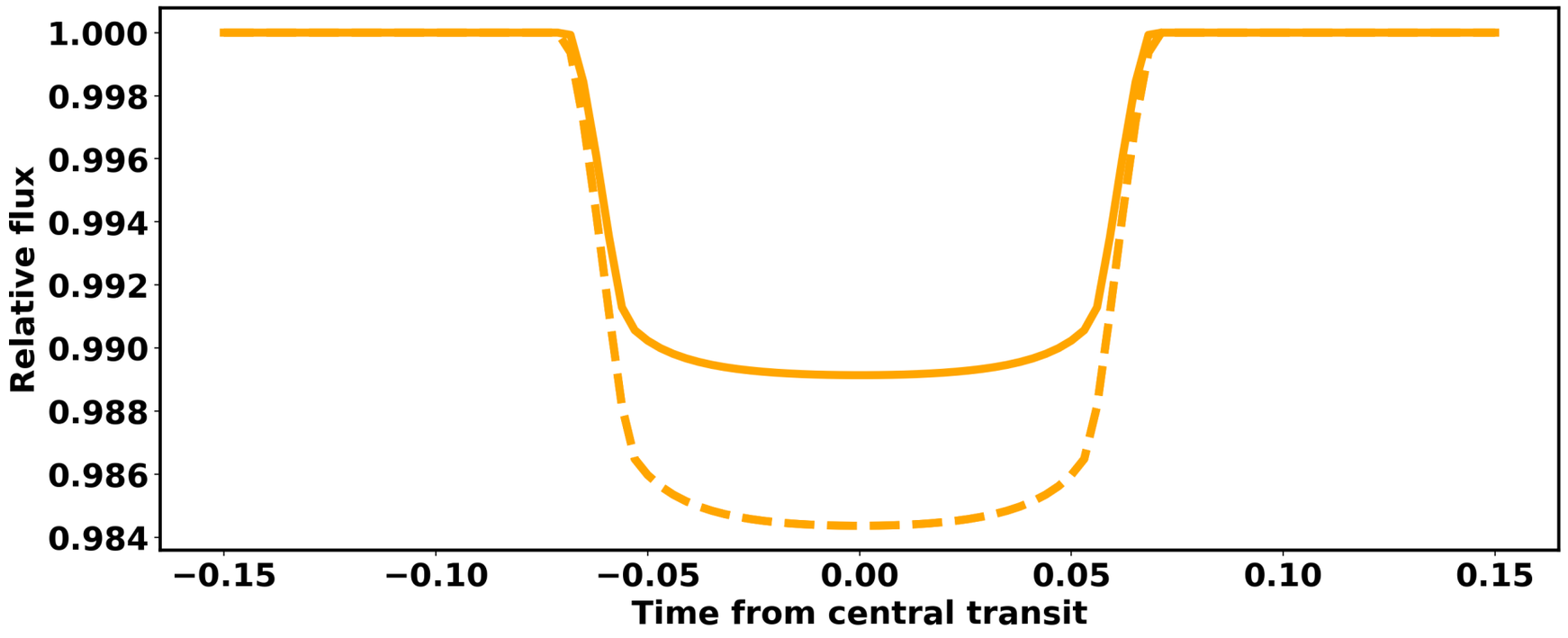
$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

=1 in this case

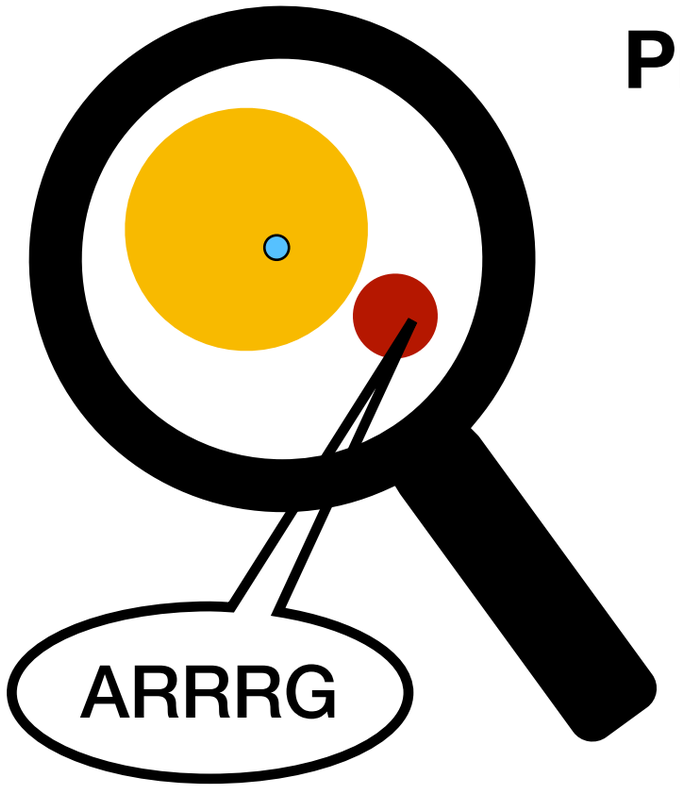


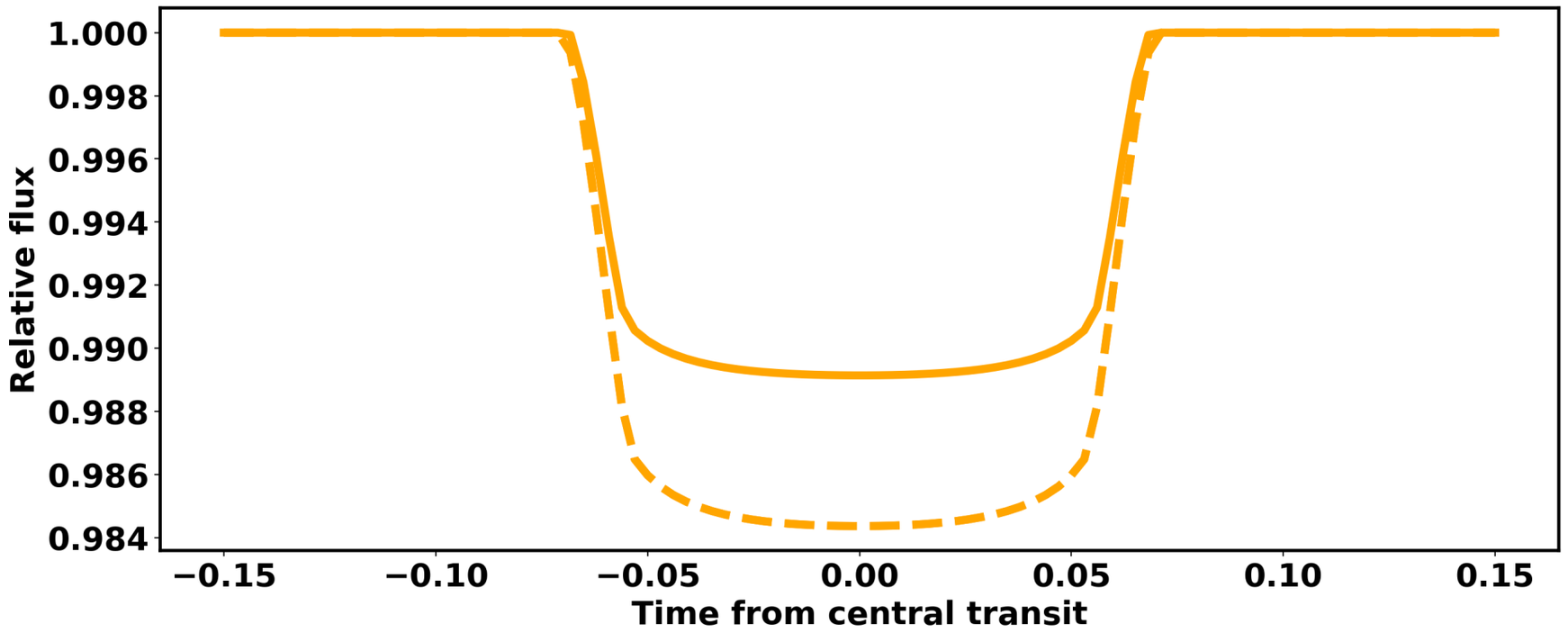
Primary Star is Double, Planet Orbits Primary Star





Primary Star is Double, Planet Orbits Primary Star





Primary Star is Double, Planet Orbits Primary Star

$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

Primary Star is Double, Planet Orbits Primary Star

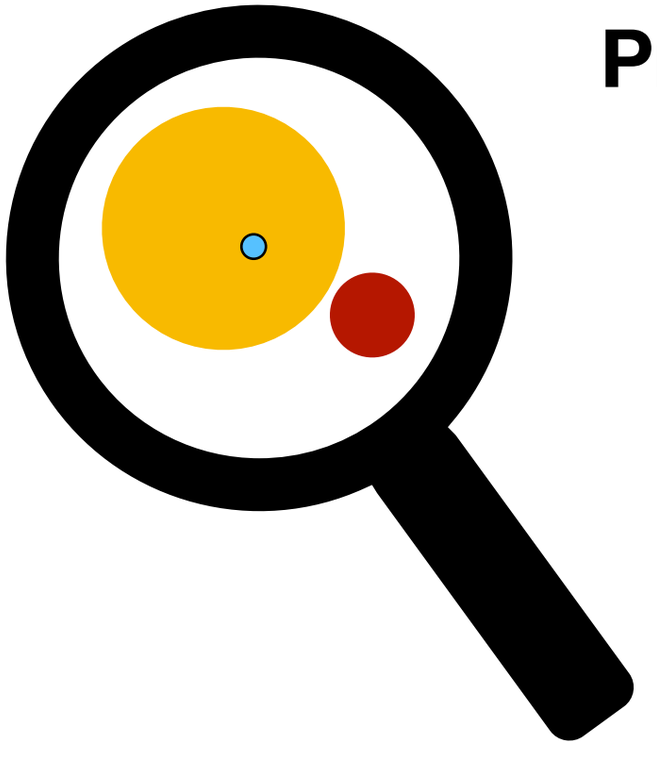
$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

Primary Star is Double, Planet Orbits Primary Star

$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

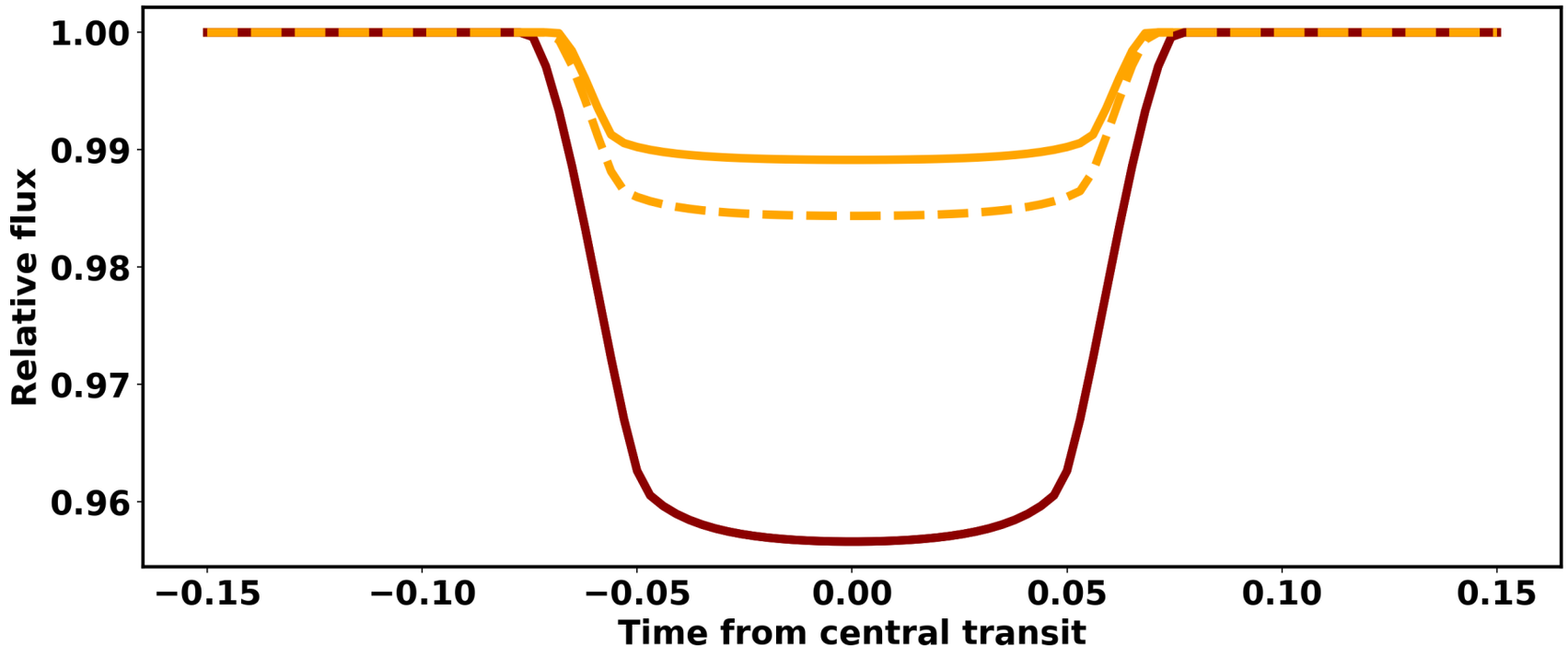


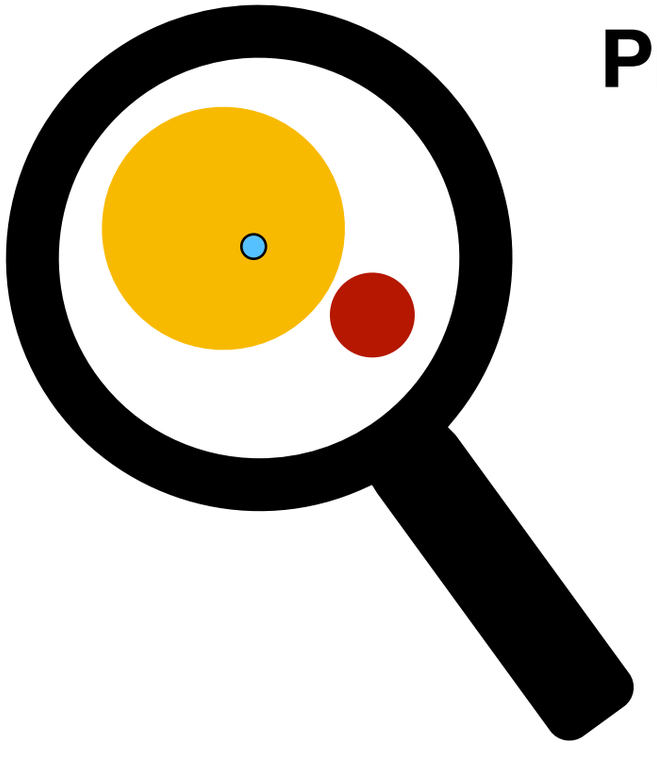
Primary Star is Double, Planet Orbits Primary Star

$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

Primary Star is Double, Planet Orbits Secondary Star





Primary Star is Double, Planet Orbits Primary Star

$$\delta_{\rm obs} = \frac{F_{\rm tot} - F_{\rm transit}}{F_{\rm tot}} = \left(\frac{F_*}{F_{\rm tot}}\right)\left(\frac{R_p}{R_*}\right)^2$$

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

Primary Star is Double, Planet Orbits Secondary Star

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \left(\frac{R_{t\star}}{R_{1\star}}\right)\sqrt{\frac{F_{total}}{F_t}}$$

Ciardi+15, Furlan+17

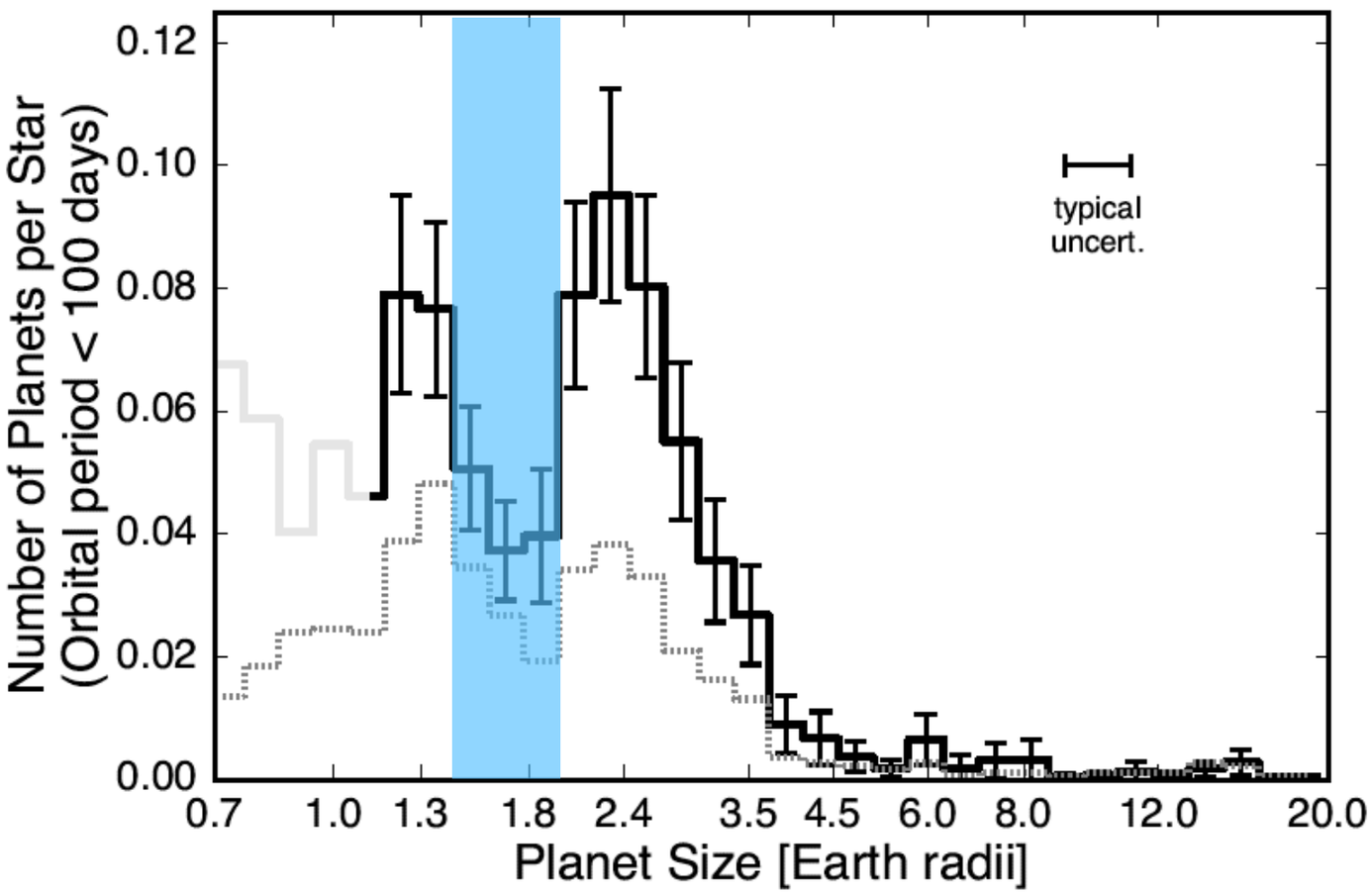
If the rate of stellar multiplicity is ~40-50%,

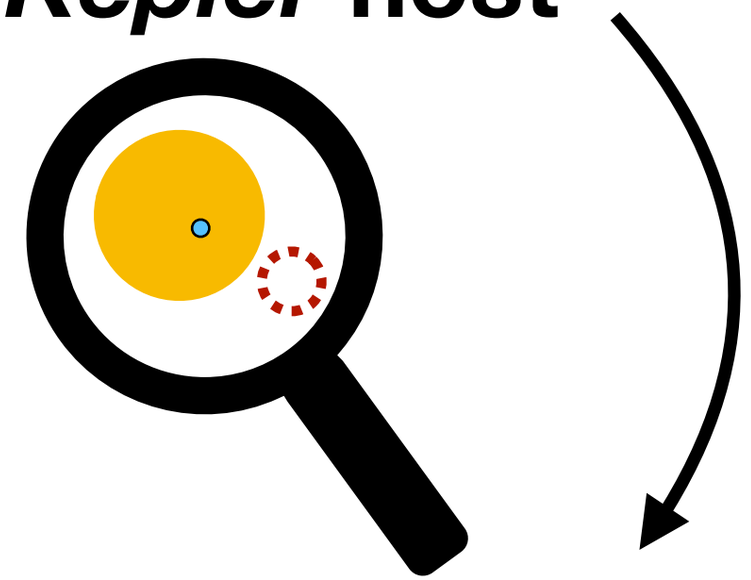
Raghavan+10, Horch+14, Matson+18

And we know that typical follow-up misses ~40% of companions to *Kepler* stars,

Ciardi+15

How will undetected companions to *Kepler* host stars affect inferred exoplanet radii?



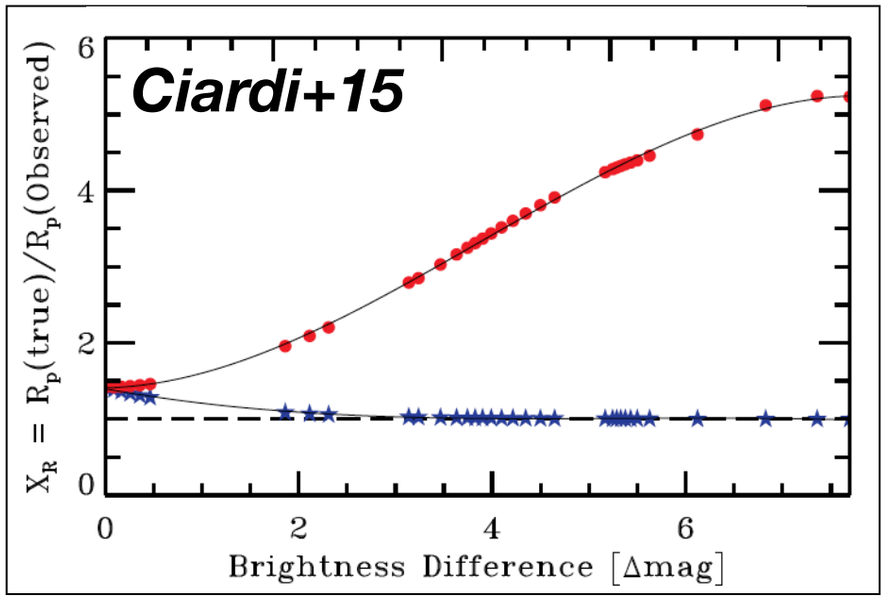


In particular, do they change the exoplanet radius gap?

Fulton+17,
Fulton & Petigura 18

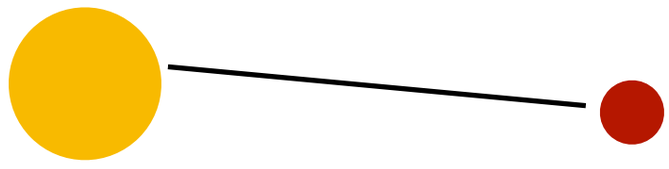
Steps to Correct for Companions to KOIs

1. Correct for detected companions within 1" using X_rs from Furlan+17 & Ziegler+18, accounting for both primary/secondary host possibility (o_{prob}). Assume these KOIs do not have more undetected companions.



2. Calculate Ciardi+15-esque X_r distributions ($dist_{xr}$; truncated at 1), accounting for both primary/secondary host possibility (o_{prob}).

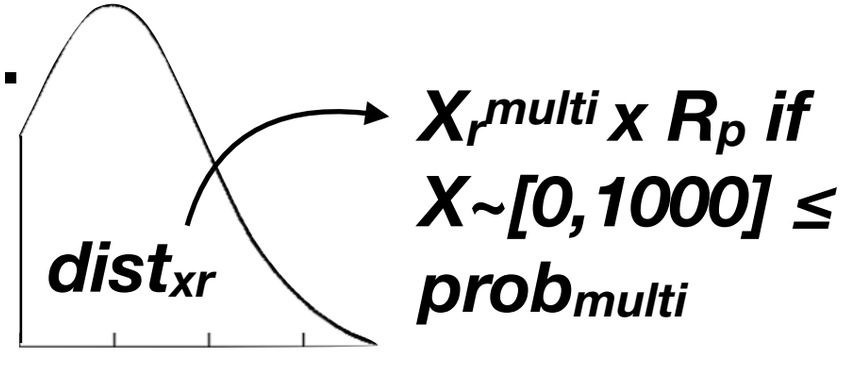
3. Adopt fraction of multiple stars *not* already removed from typical follow-up and multiply by 46% = $prob_{multi}$.

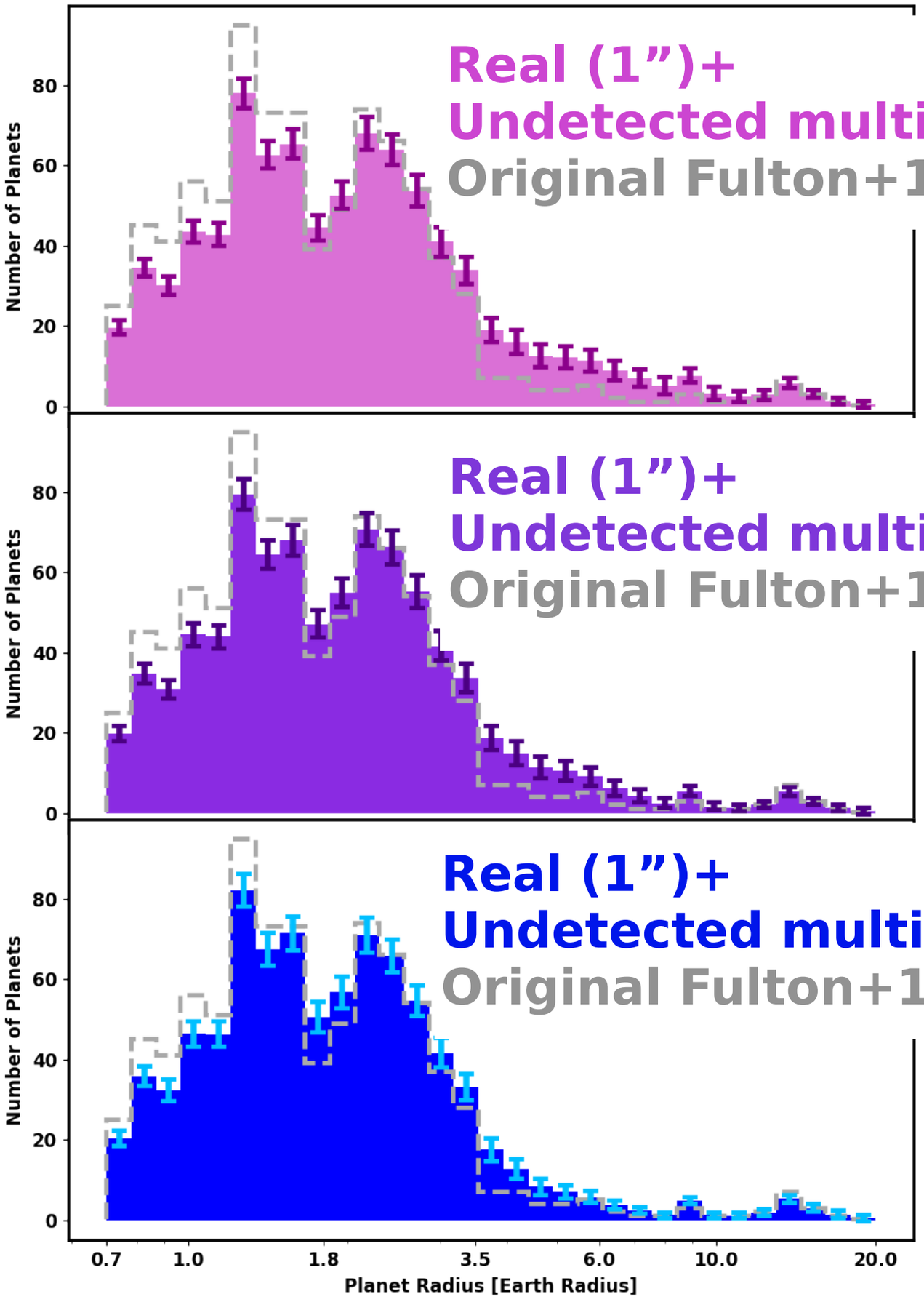


***P* > 2 years, *ρ* < 0.1"**

4. Calculate probabilistic X_r^{multi} and apply to R_p.

5. Repeat 1000x.

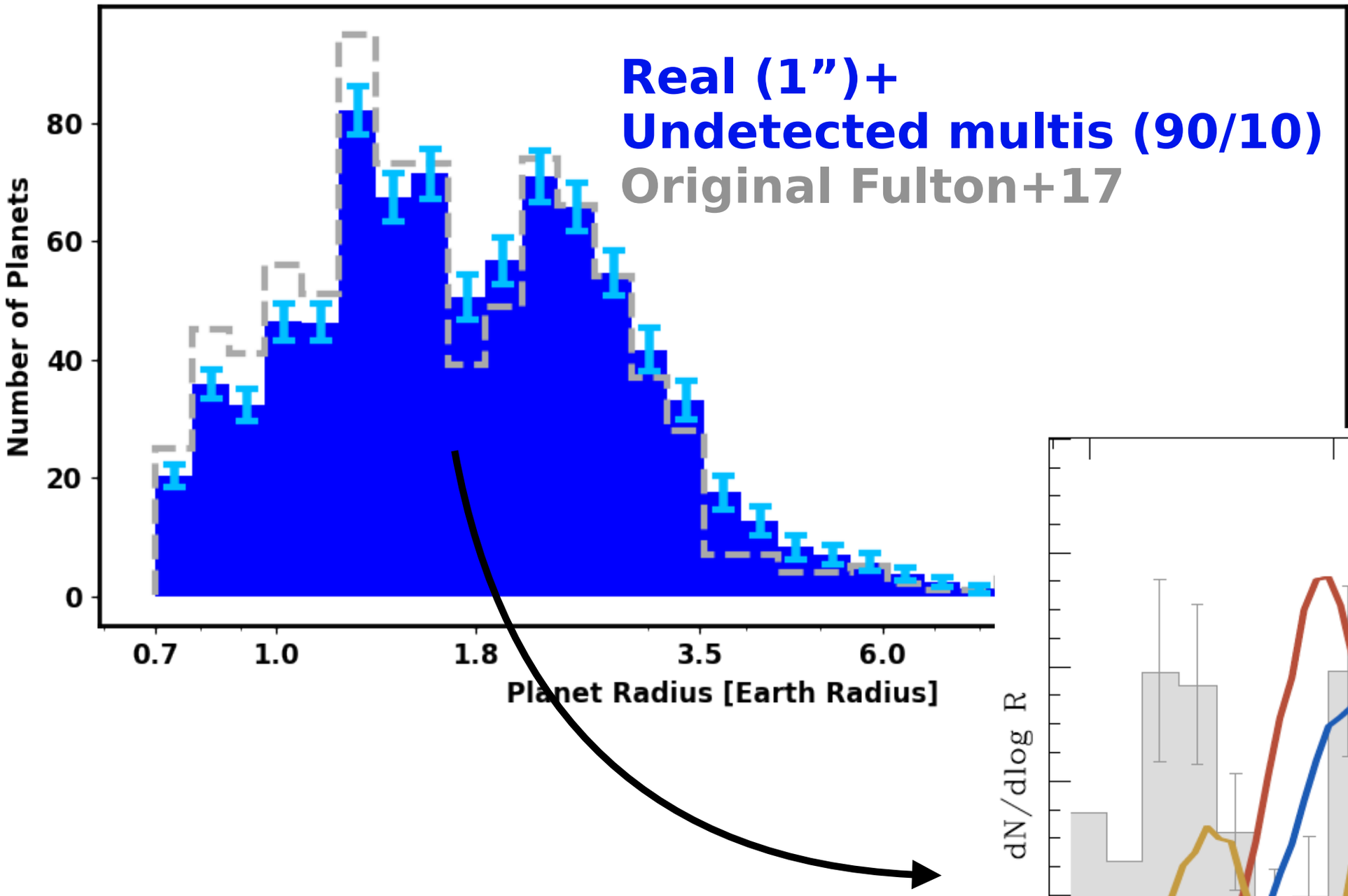


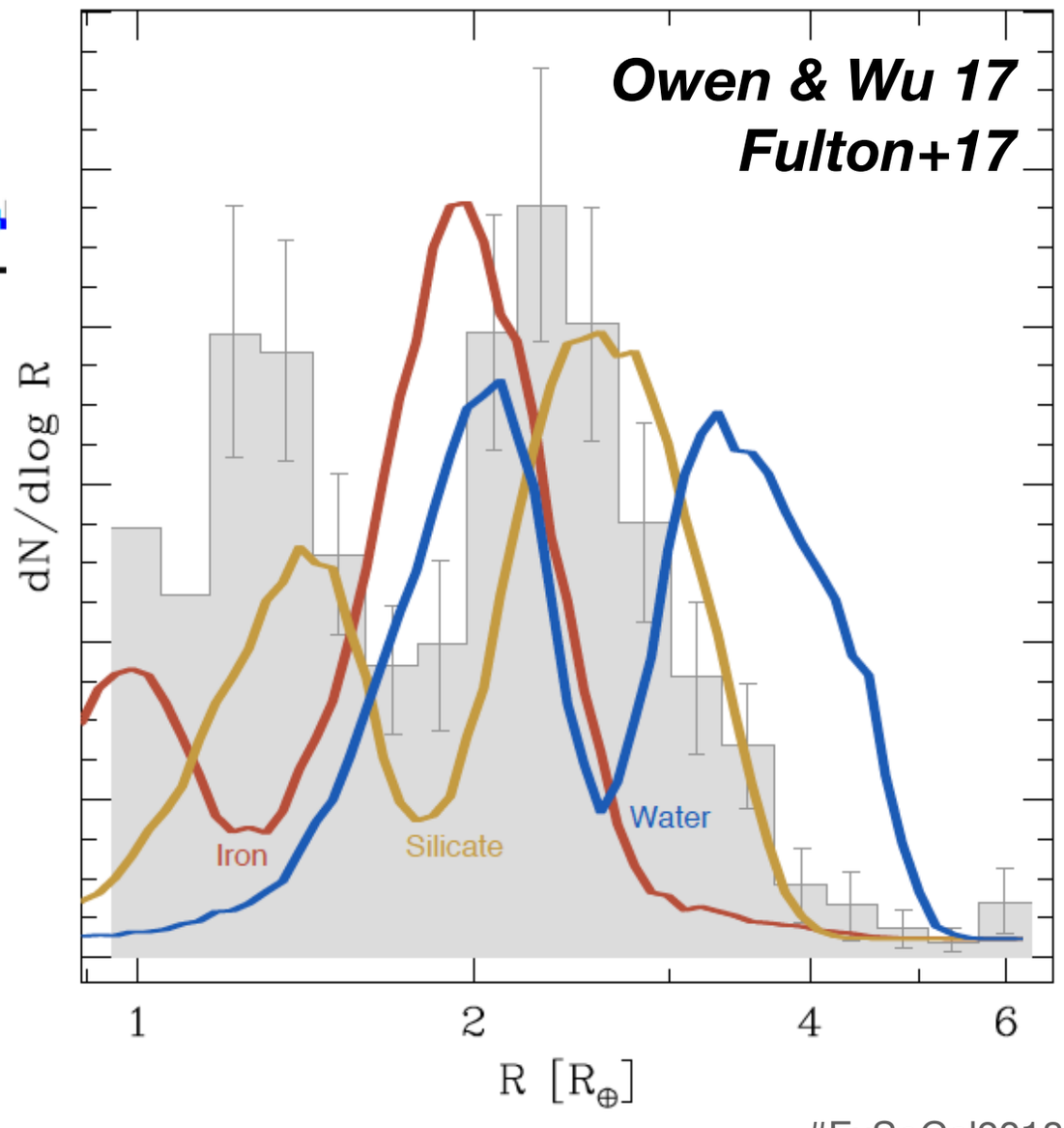


The gap in the observed ("raw count") exoplanet radius distribution is fairly robust to undetected (and detected) stellar companions.

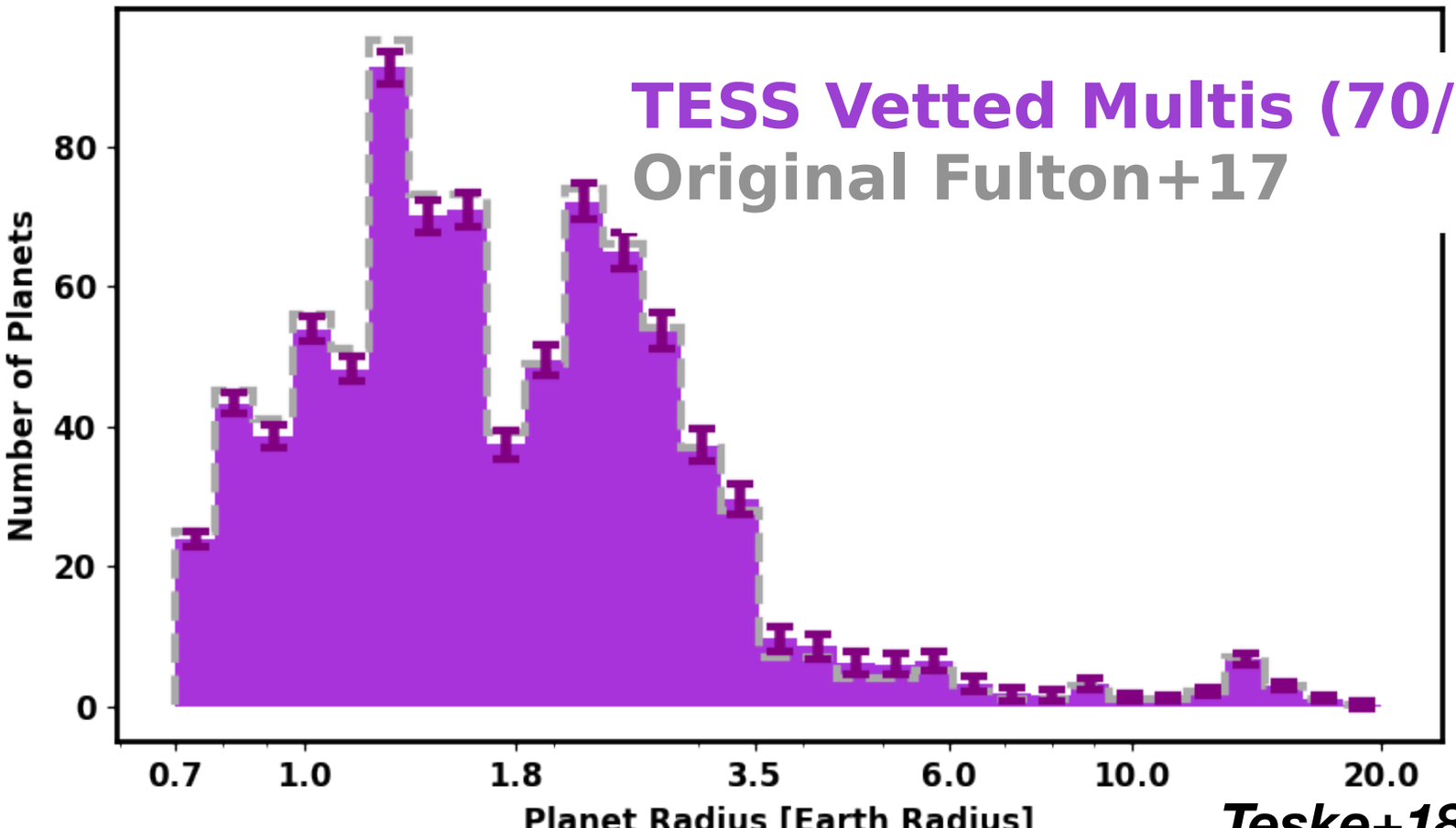
Teske+18 (in review)

Teske+18 (in review)



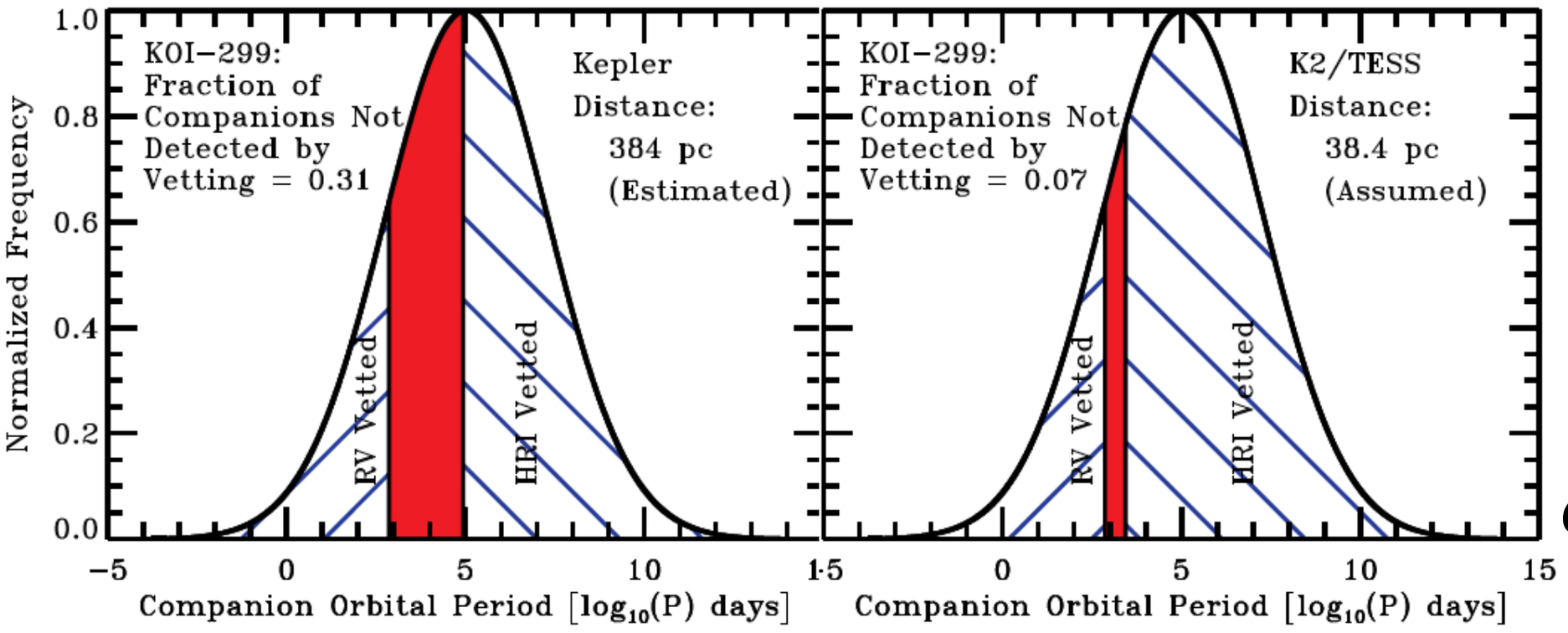


Hint of `smearing out” of radius distribution?

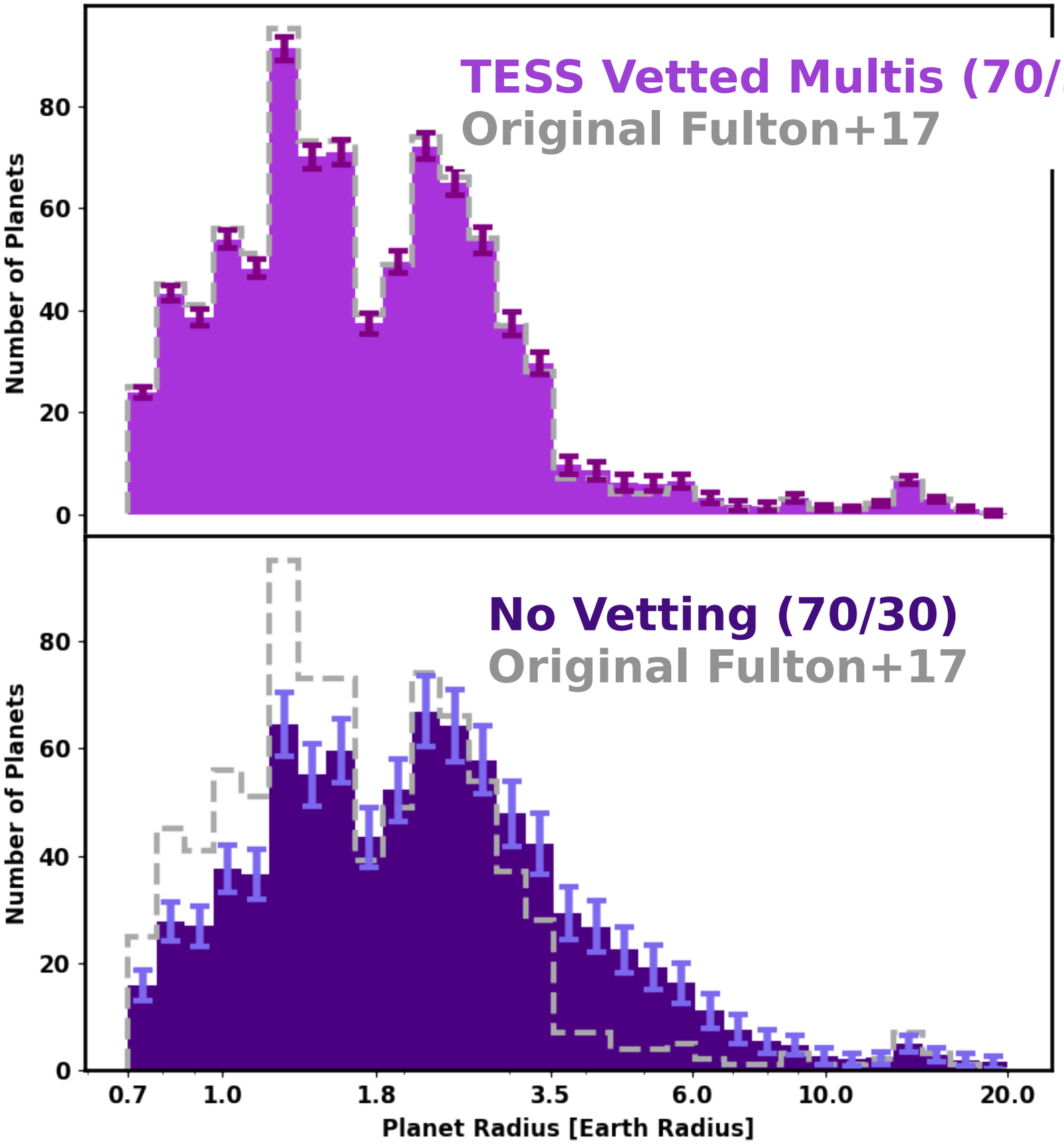


For closer TESS stars, HRI leaves many fewer companions missed. Reduced trapezoid of uncertainty!

Teske+18 (in review)



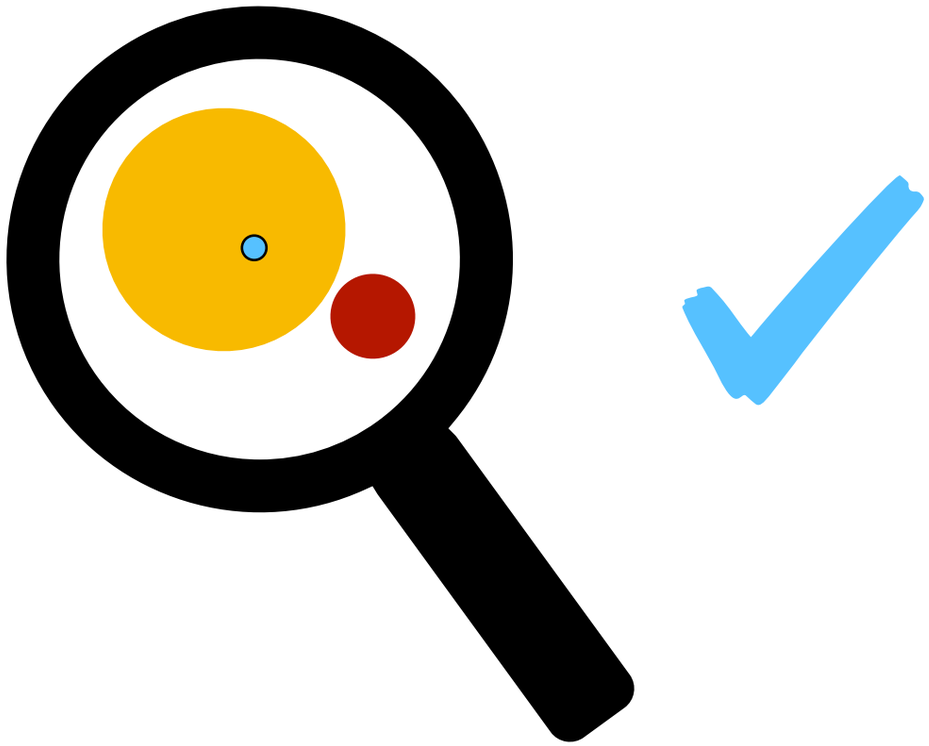
Ciardi+15



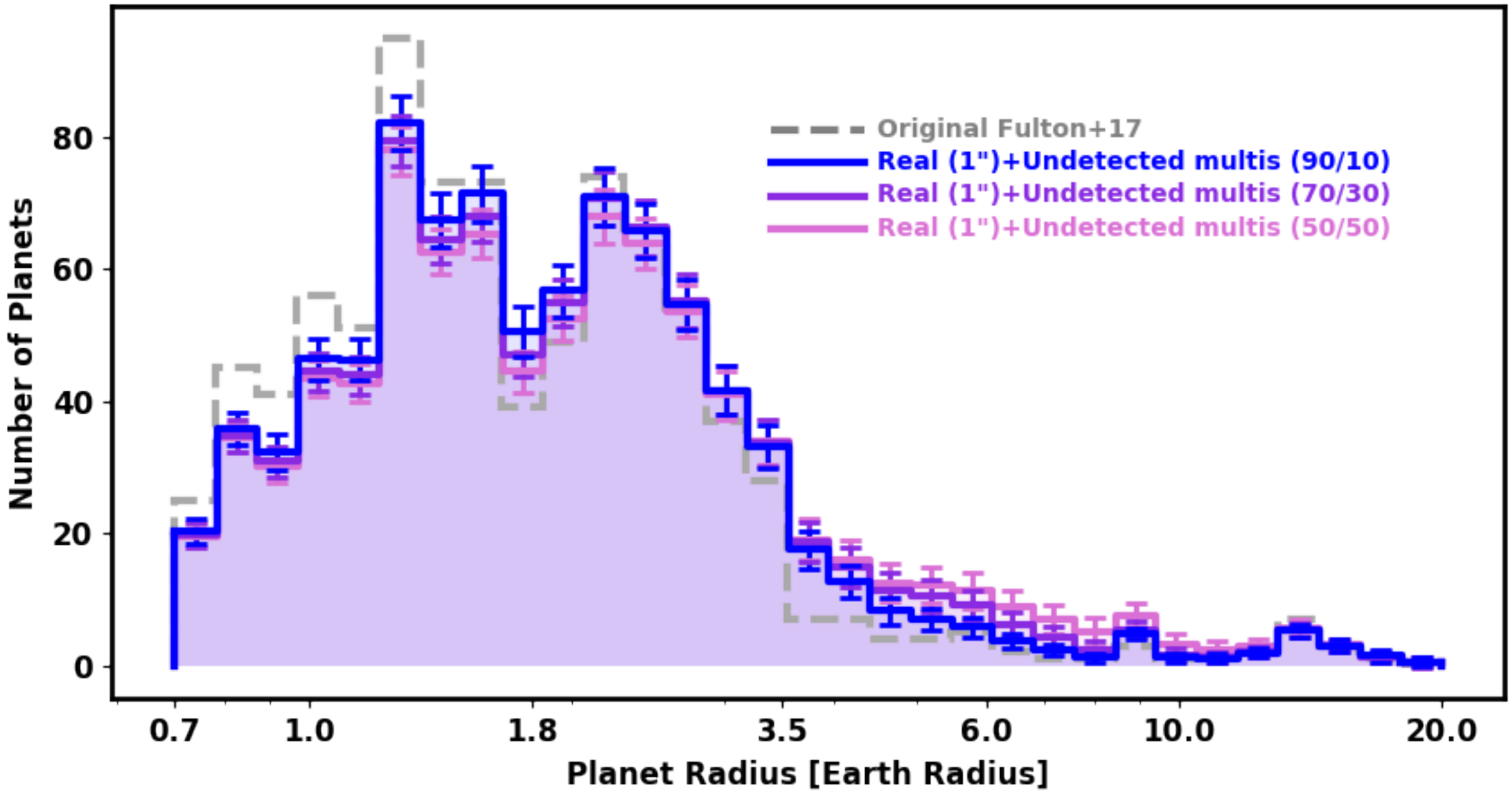
Without HRI of planet candidate hosts, the shape of the observed R_p distribution will be incorrectly inferred, for both *Kepler*- and *TESS*-detected systems.

Teske+18 (in review)

Do your due diligence and follow-up TESS targets with high-resolution imaging.



Backup


Original Fulton+17
Real (1")+Undetected multis (90/10)
Real (1")+Undetected multis (70/30)
Real (1")+Undetected multis (50/50)
Number of Planets
0
20
40
60
80
0.7
1.0
1.8
3.5
6.0
10.0
20.0
Planet Radius [Earth Radius]