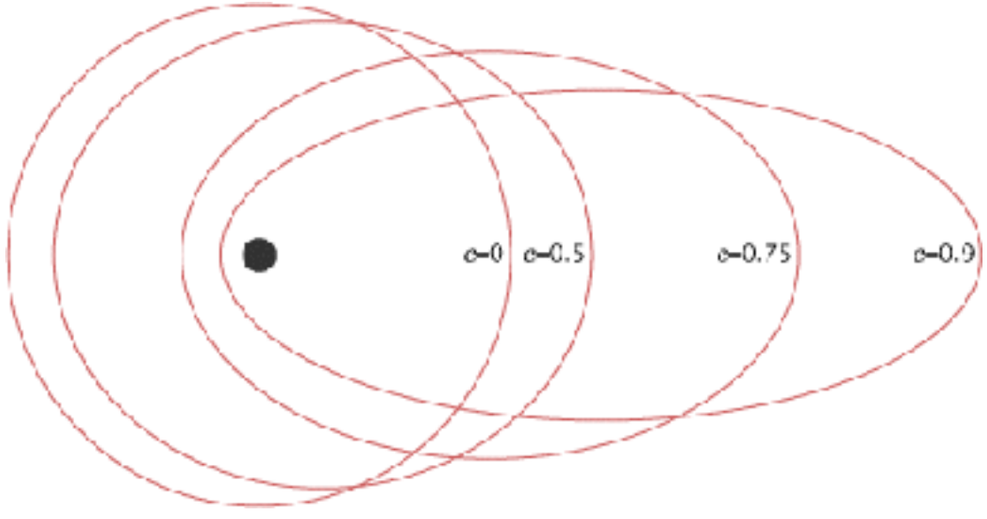
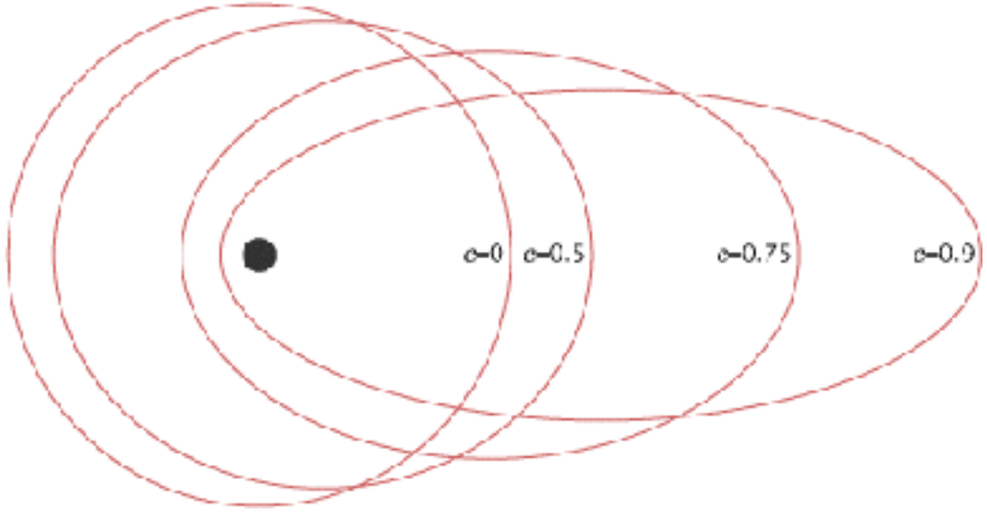
Eccentric Small Planets Prefer High Metallicity Stars



Sean Mills
Andrew Howard, Erik Petigura, BJ Fulton, CPS Team

Eccentric Small Planets Prefer High Metallicity Stars

Planetary Eccentricity Statistics with Kepler Durations and CKS-Gaia Stellar Properties



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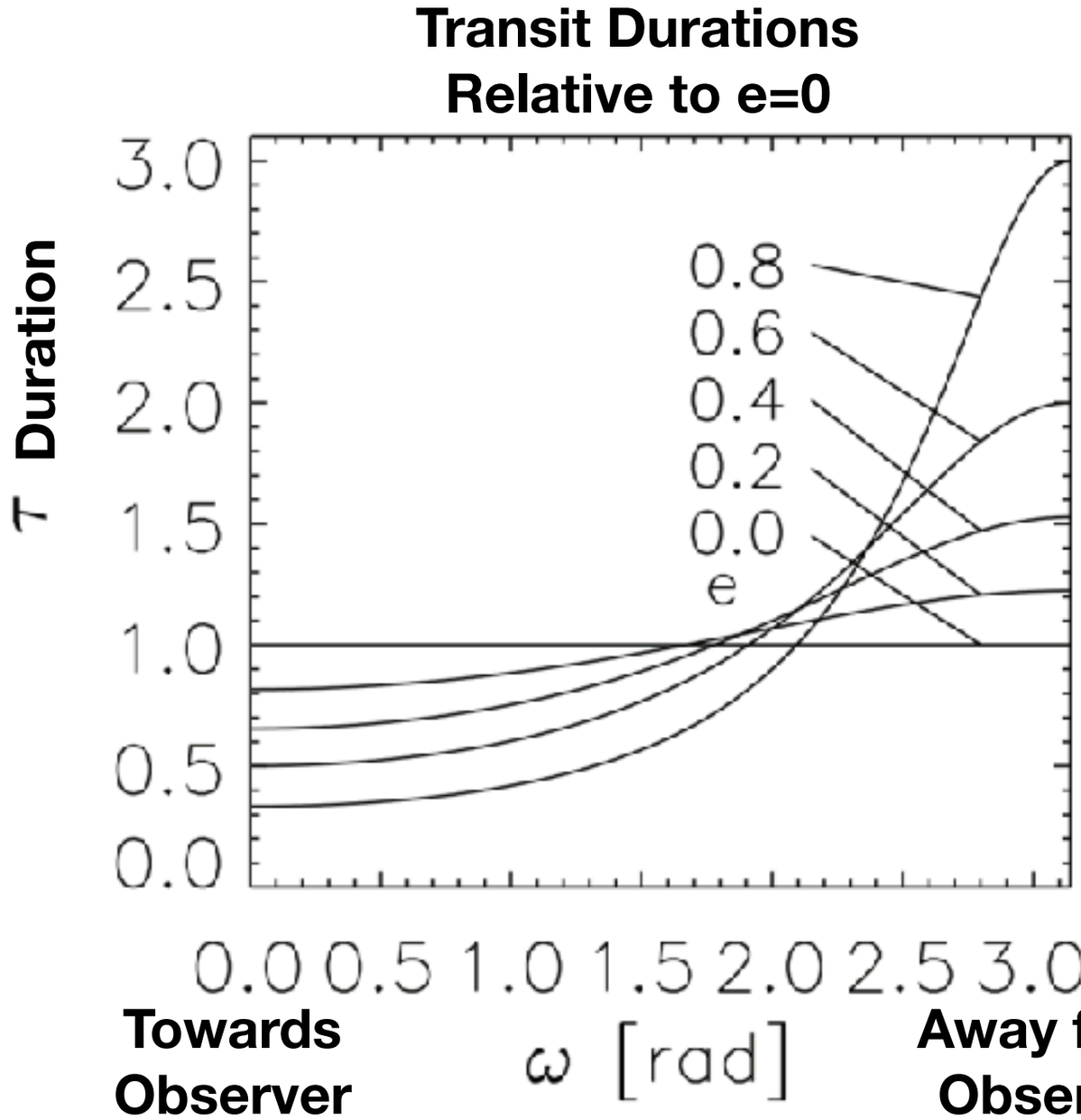
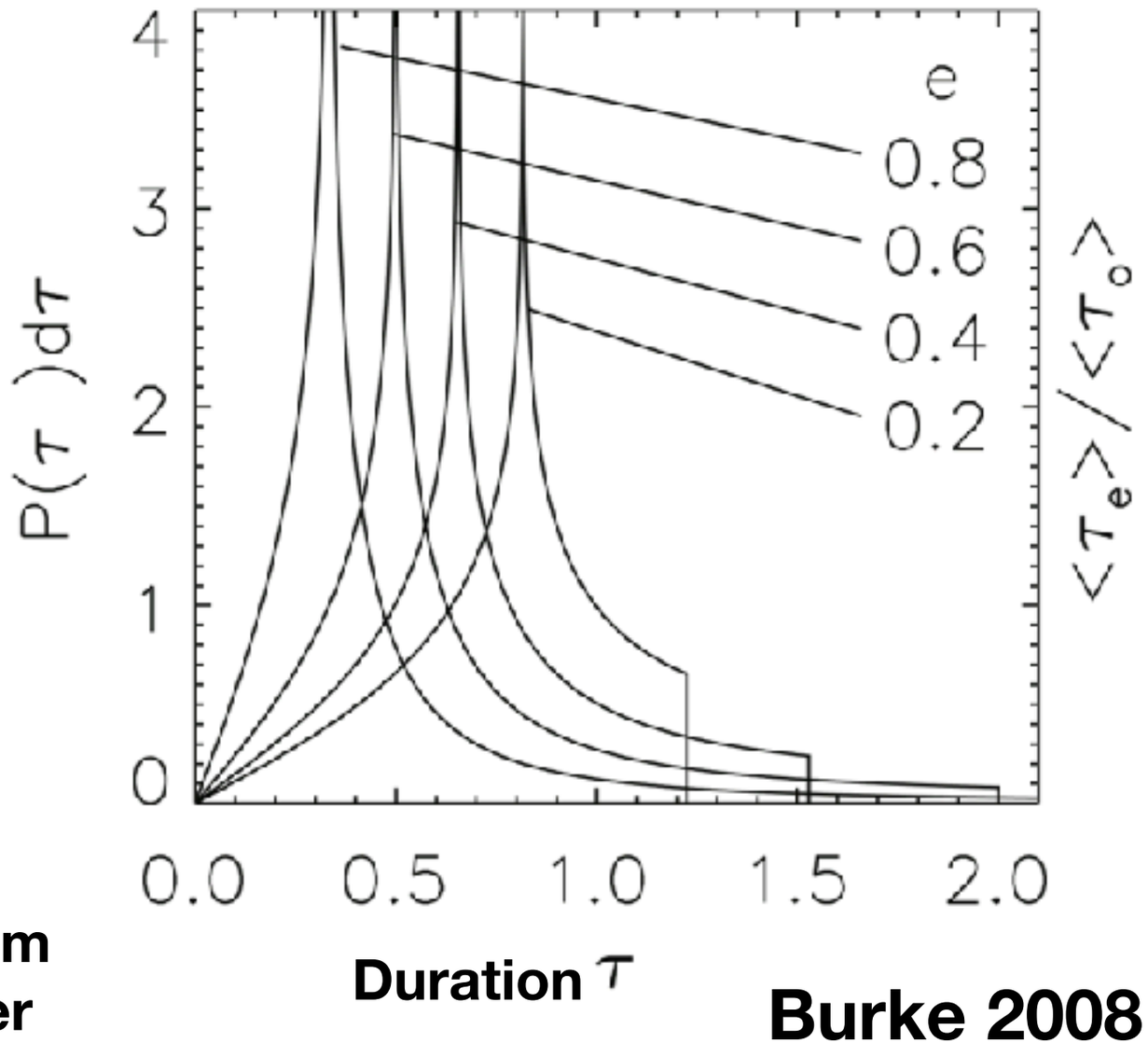
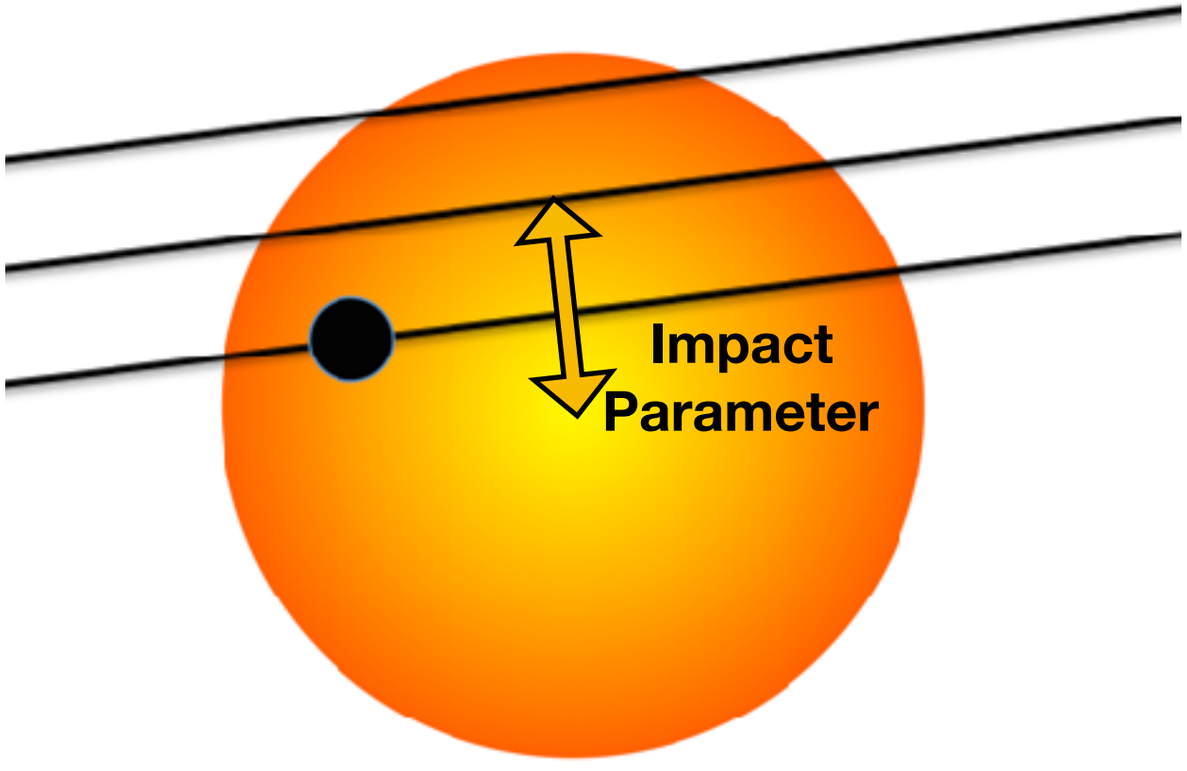
Transit Durations and Eccentricity





Burke 2008

Impact Parameter Effects

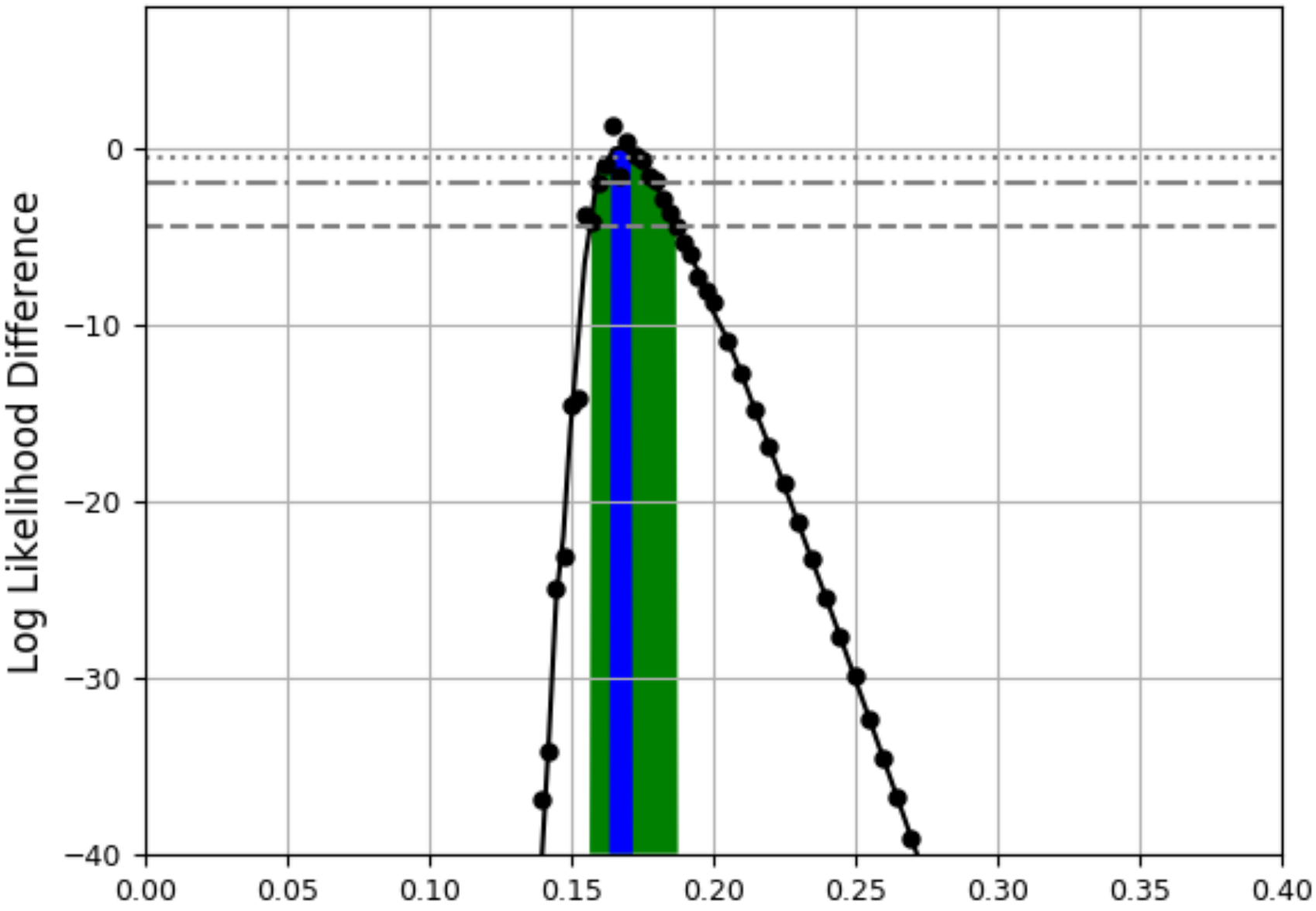


Random Viewing Orientations

Simulation Process

1. Choose an eccentricity distribution to compare to the data
2. Draw an eccentricity for a given planet from the distribution
3. Draw a viewing angle (randomly oriented)
4. Compute the resulting transit duration (geometry)
   Repeat from step (2) if anything is unphysical:
   - Planet hits star
   - duration = 0
   - S/N too low for detection in Kepler
5. Compute ratio of observed duration to circular, edge-on case, including all noise
6. Repeat steps 2-5 100000 times for each KOI

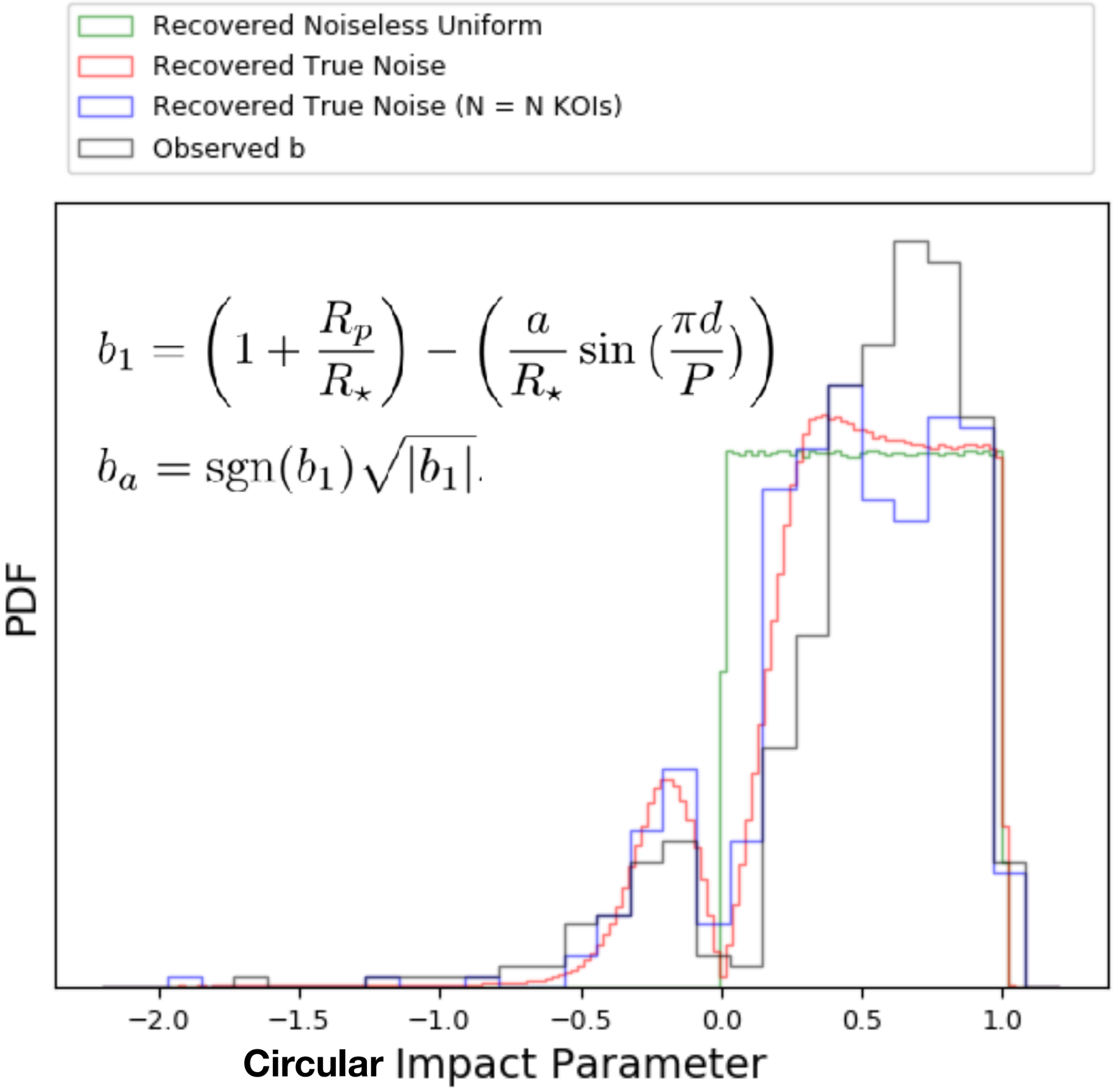
Single Transiting Planets

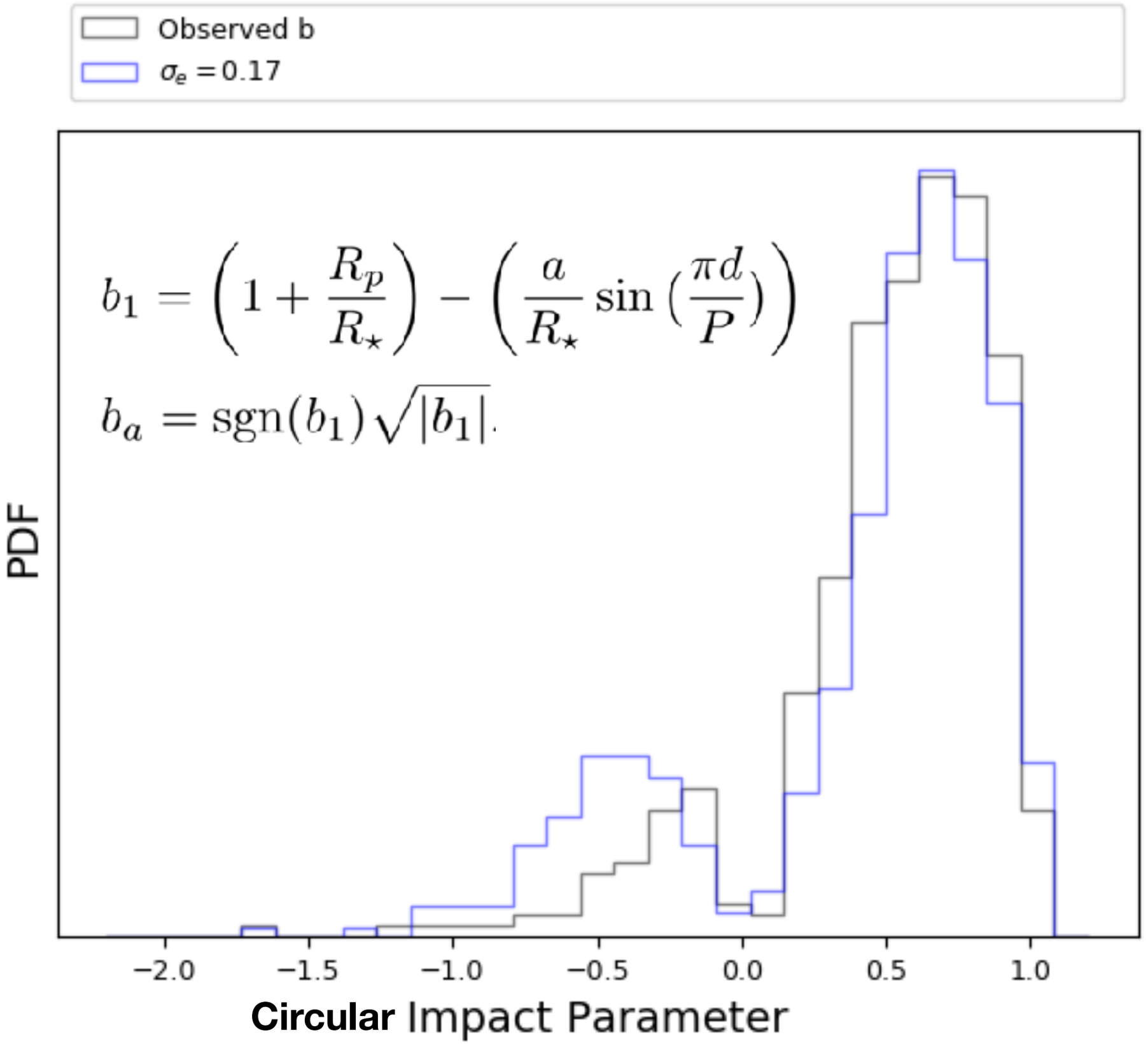


$$\mathcal{L}_{\sigma_e} = \int_r P(r_{sim}|\sigma_e) P(r_{obs}) \mathrm{d}r$$

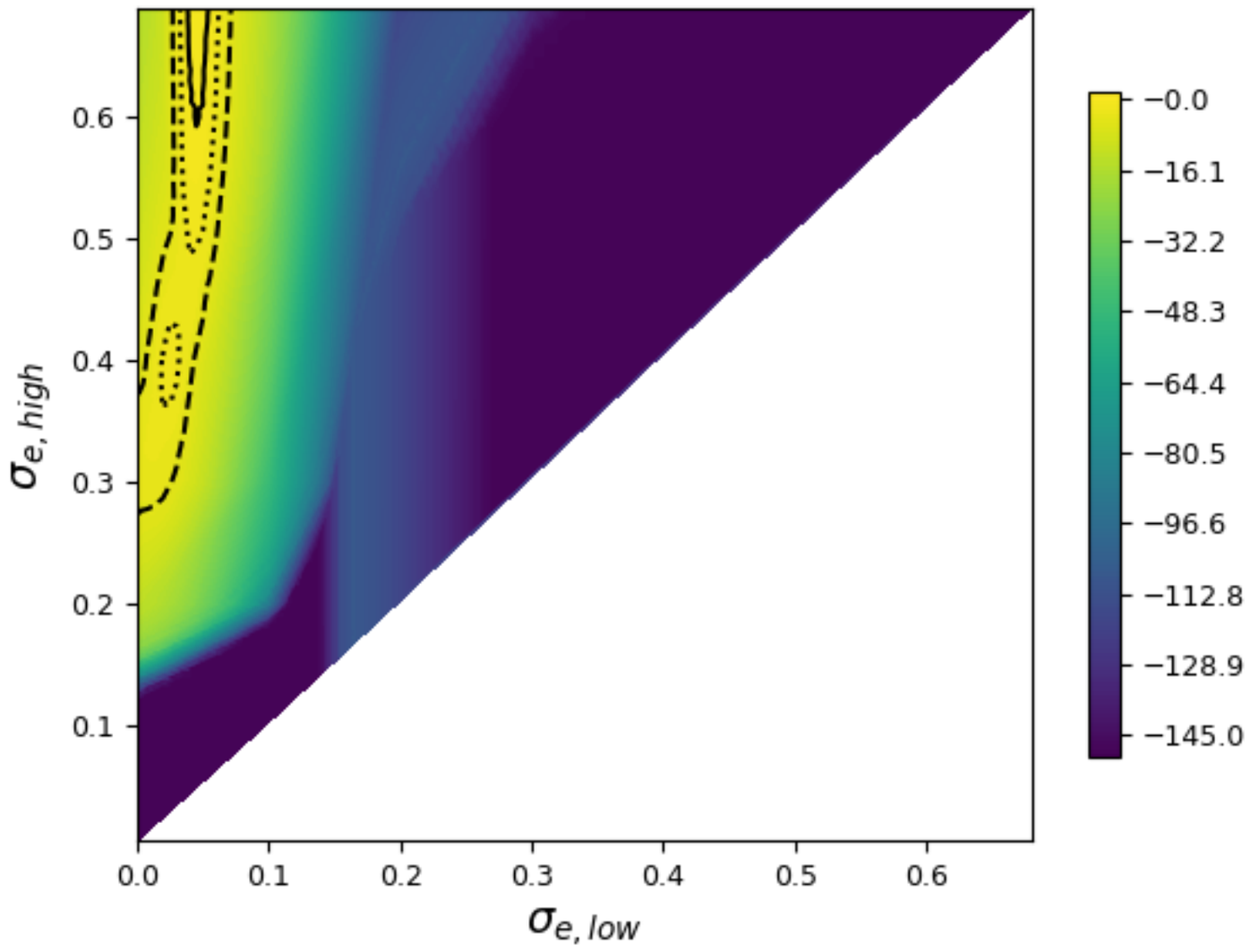
$$r = \frac{\text{Observed Duration}}{e = 0 \; i = 90 \text{ Duration}}$$

See also Xie+2016, Van Eylen 2018


Recovered Noiseless Uniform
Recovered True Noise
Recovered True Noise (N = N KOIs)
Observed b
$b_1 = \left(1 + \frac{R_p}{R_\star}\right) - \left(\frac{a}{R_\star}\sin\left(\frac{\pi d}{P}\right)\right)$
$b_a = \mathrm{sgn}(b_1)\sqrt{|b_1|}$.
PDF
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
Circular Impact Parameter


Observed b
$\sigma_e = 0.17$
$b_1 = \left(1 + \frac{R_p}{R_\star}\right) - \left(\frac{a}{R_\star}\sin\left(\frac{\pi d}{P}\right)\right)$
$b_a = \mathrm{sgn}(b_1)\sqrt{|b_1|}$.
PDF
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
Circular Impact Parameter

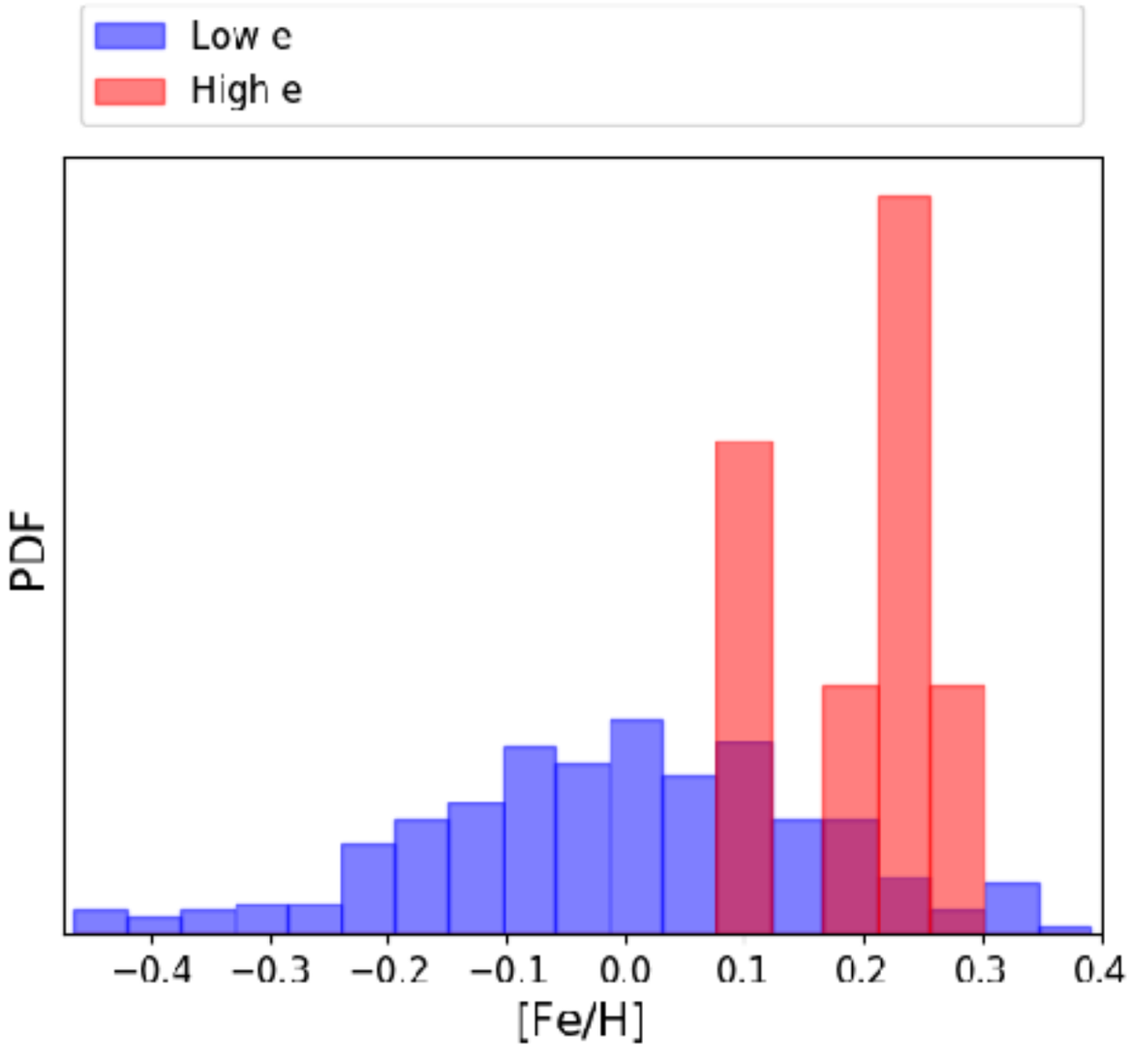
Two Populations?

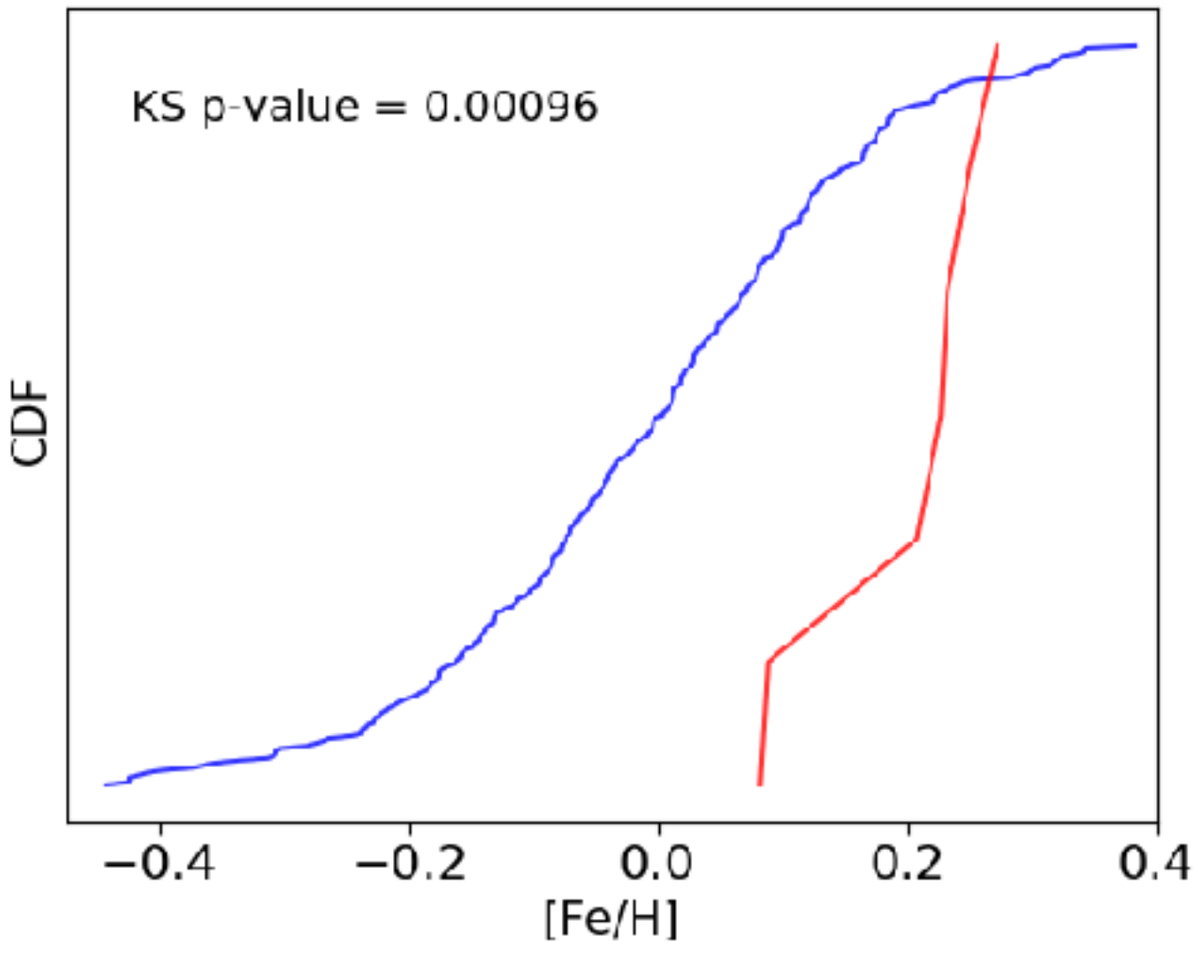


70% of single transiting planets in low e (~0.05) population

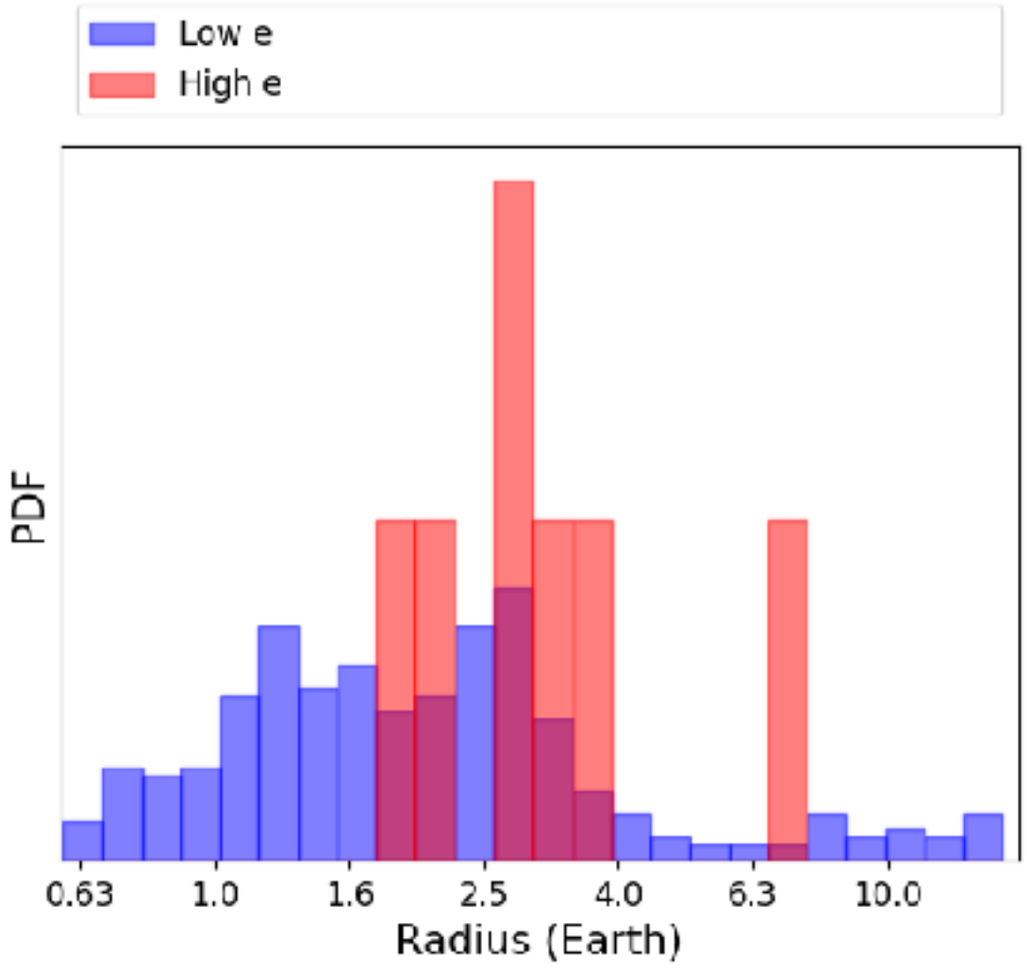
See also Xie+2016, Van Eylen 2018

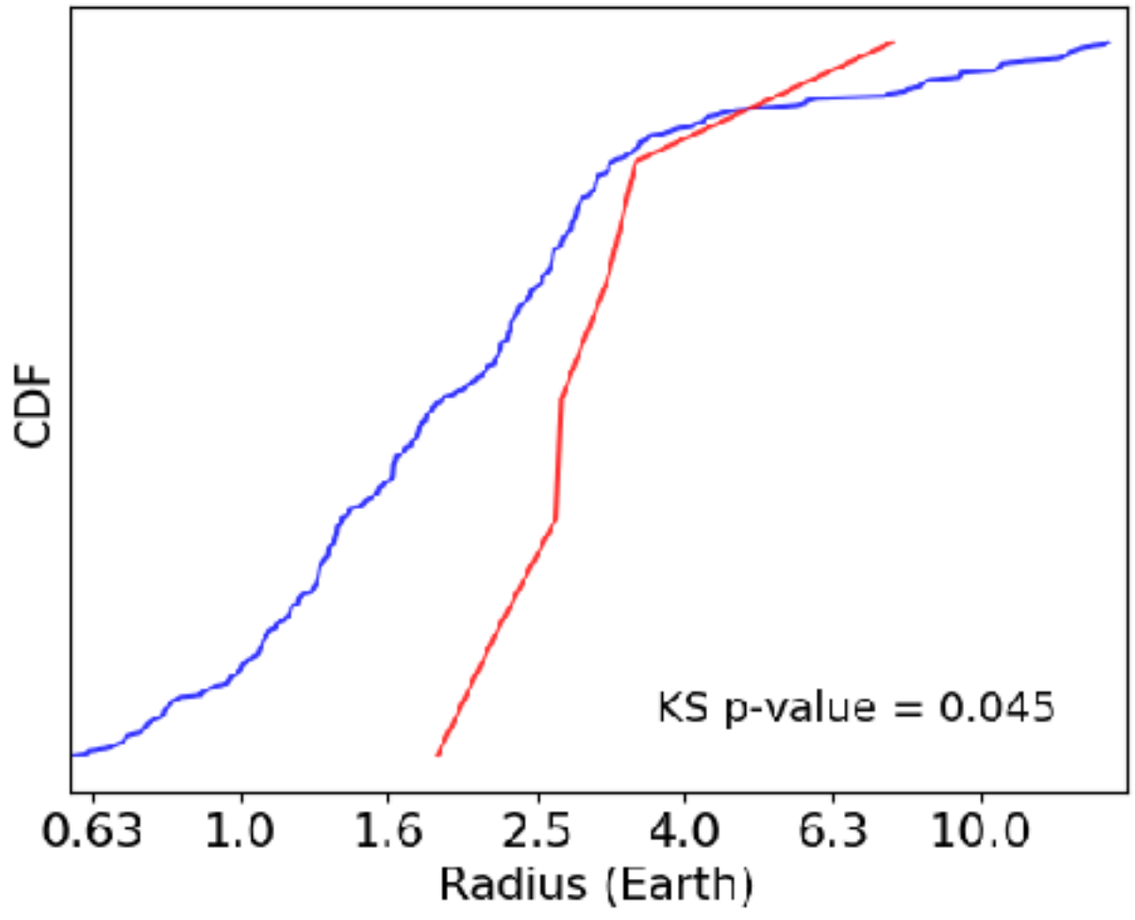
Top 5% of Planets that most confidently have high e, also have [Fe/H] > 0



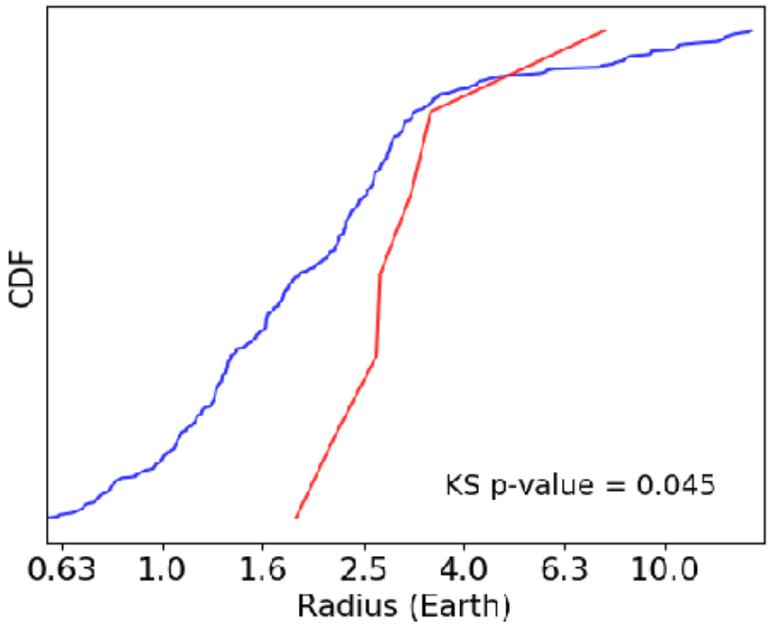


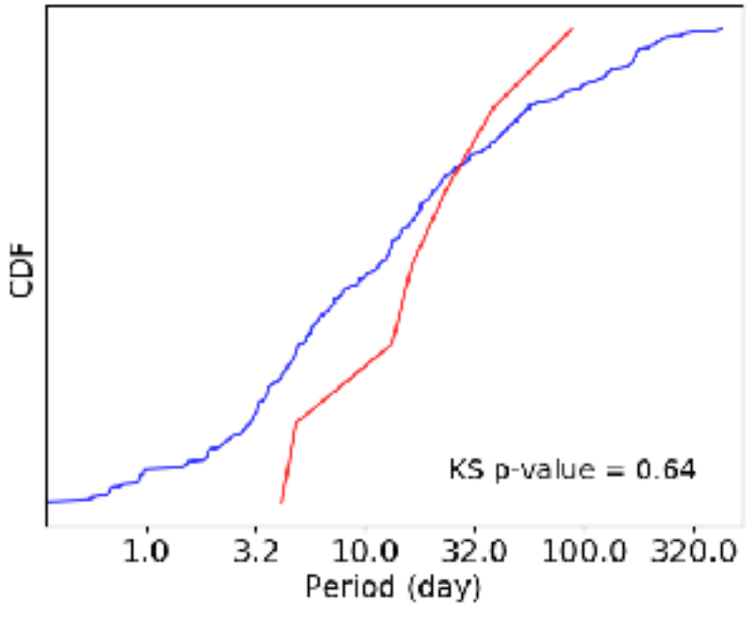
No Strong Radius Correlation

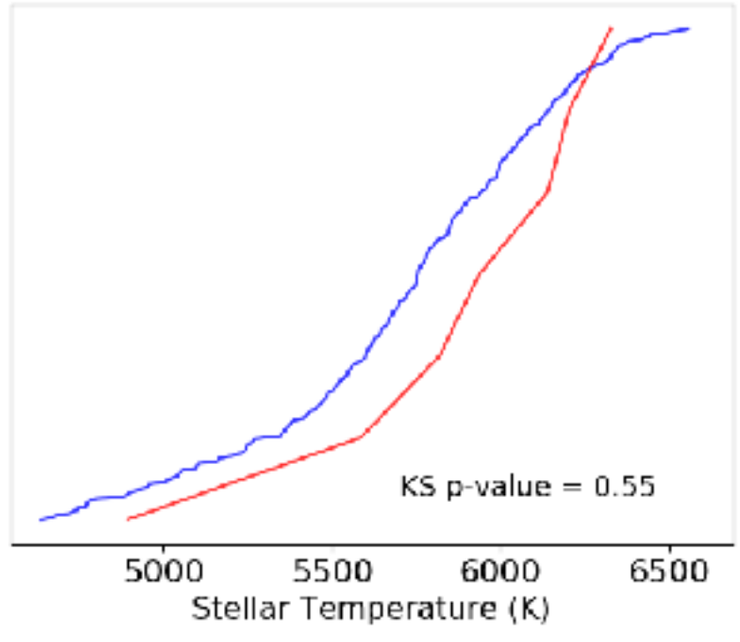




No Other Significant Correlations







Conclusions

- **(Some) small planets in singly transiting systems have high eccentricities (e~0.1-0.3)**
- **The planets that we are most confident require eccentricity prefer super-Solar stellar metallicity**
    - **Related to Giant Planet-[Fe/H] correlation (Fischer+Valenti) or [Fe/H] diversity correlation (Petigura Talk) or …?**
- **Planets in multiply transiting systems are consistent with all having low (e<0.1) eccentricities**

Thanks!

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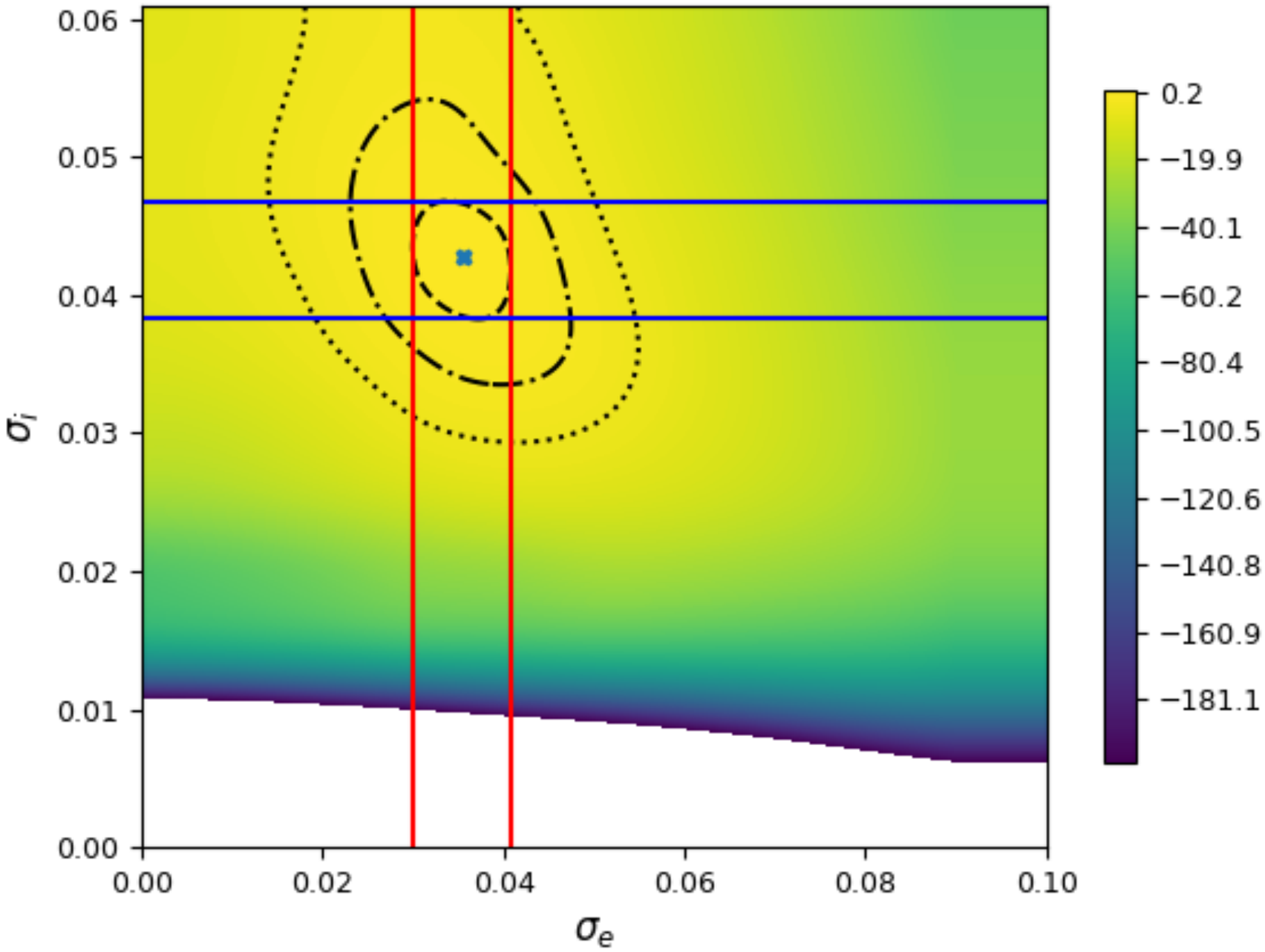
Multis Not Eccentric



b = 0

A

b ~ 0.15

Small Length
Uncertainty

Large b
Change

B

b ~ 0.85

Small Length
Uncertainty

Small b
Change