Revisiting the (RV) exoplanet eccentricity distribution

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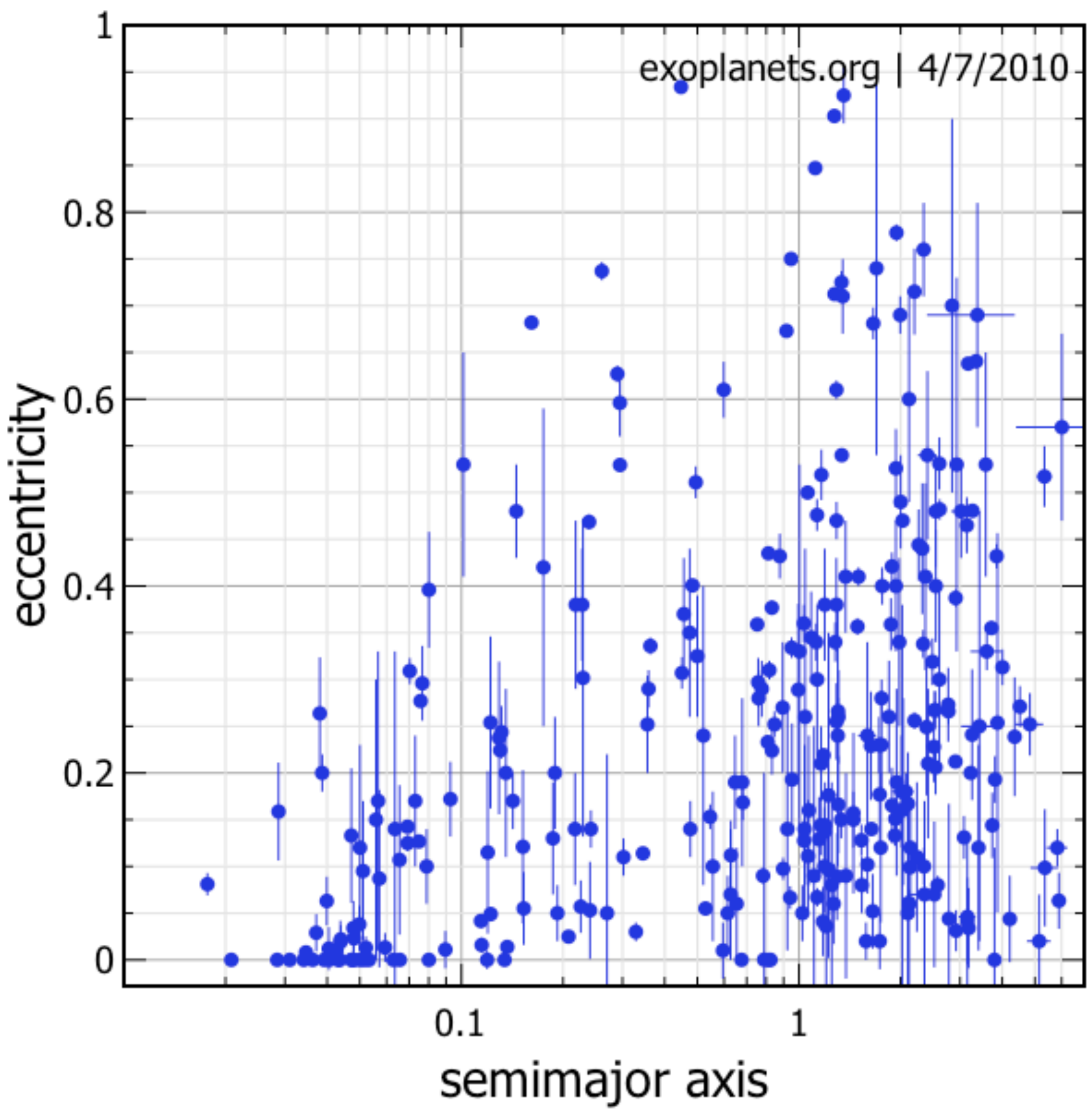
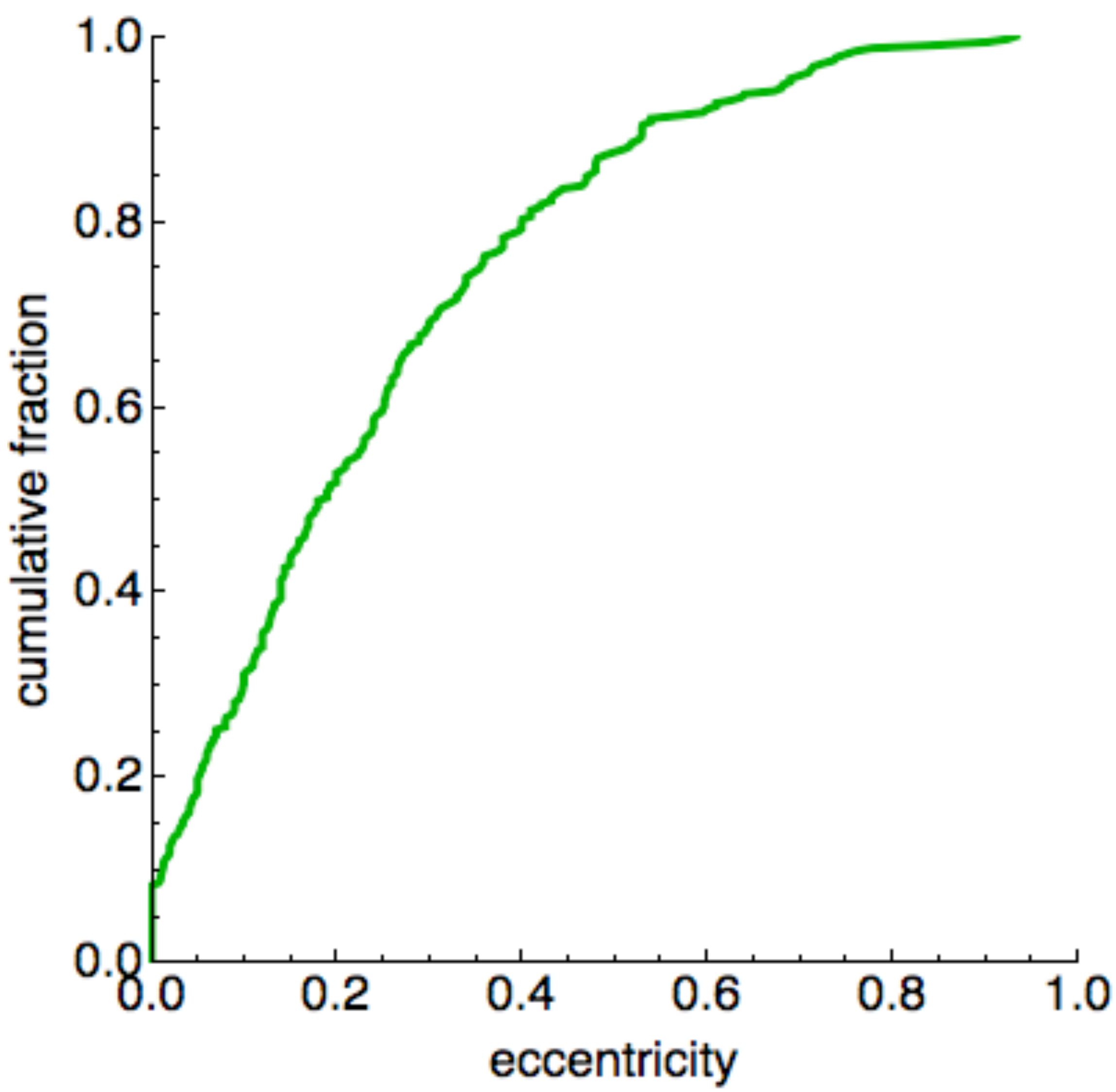
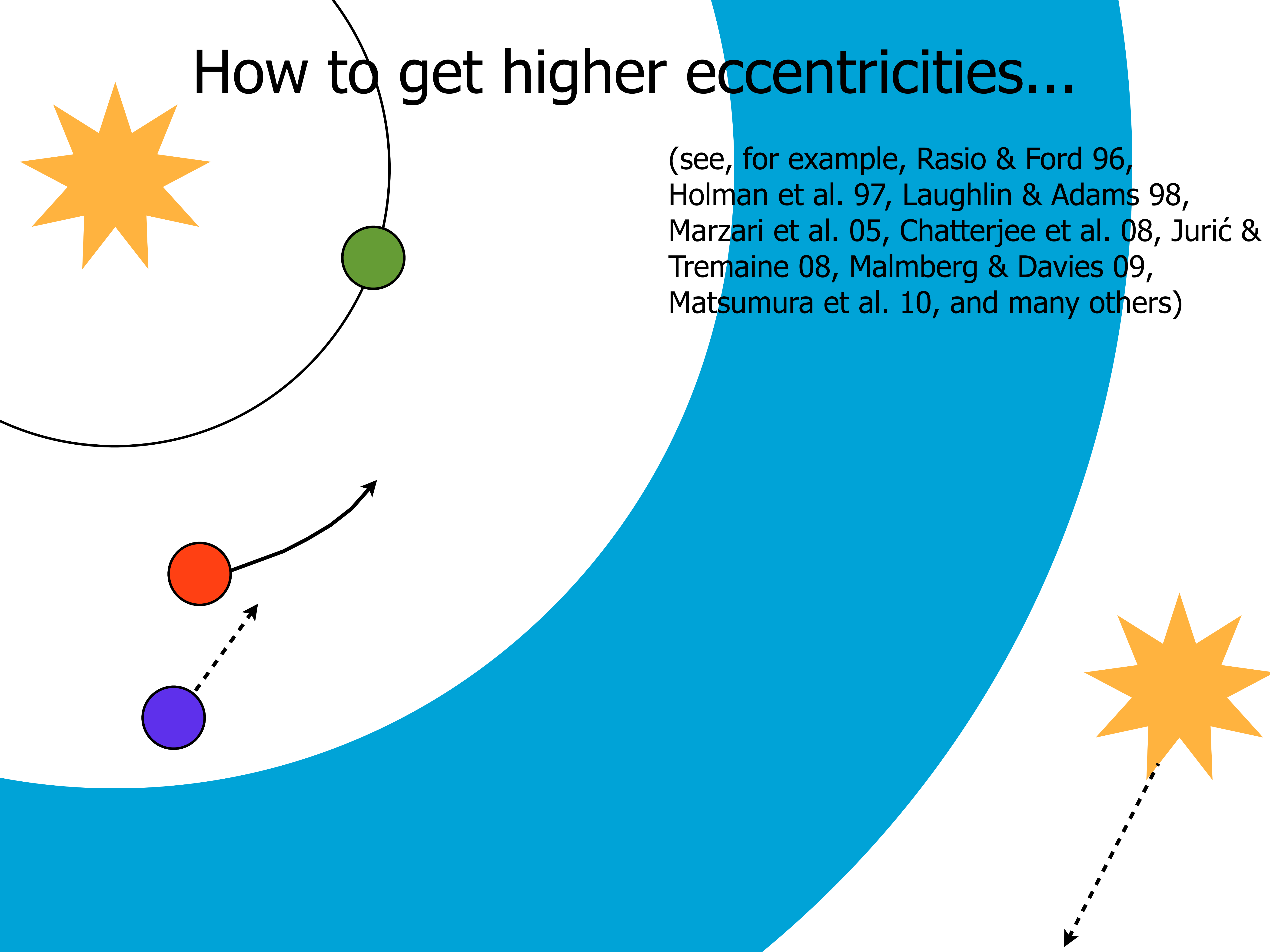


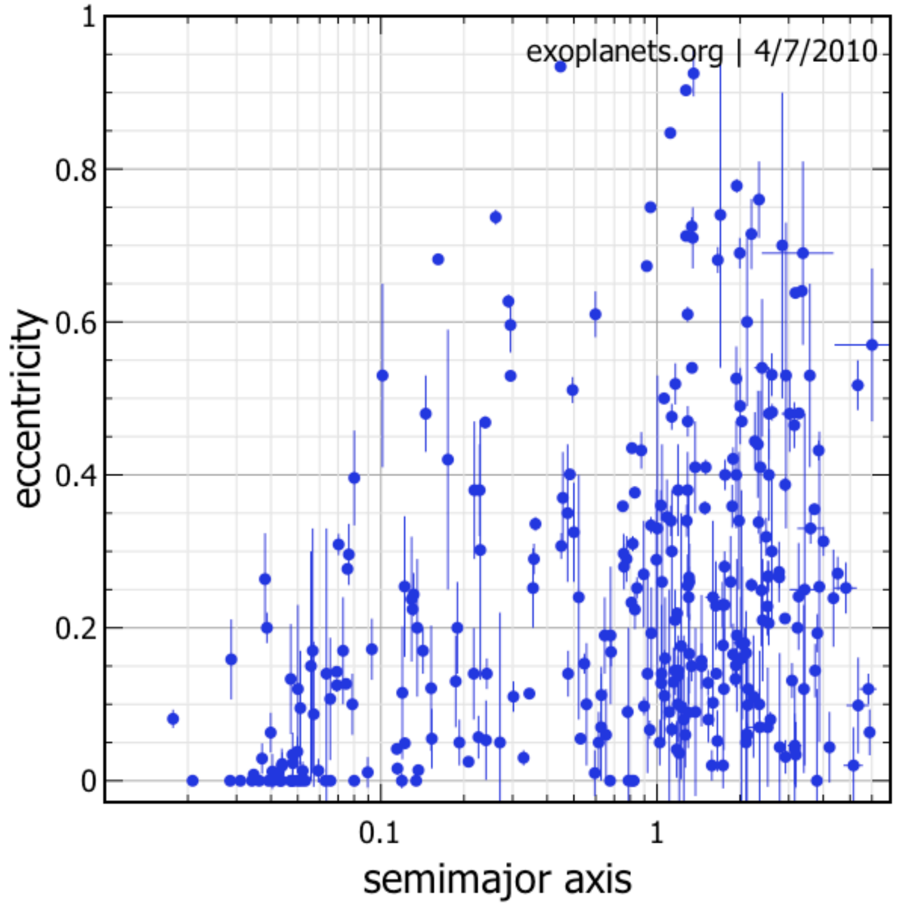


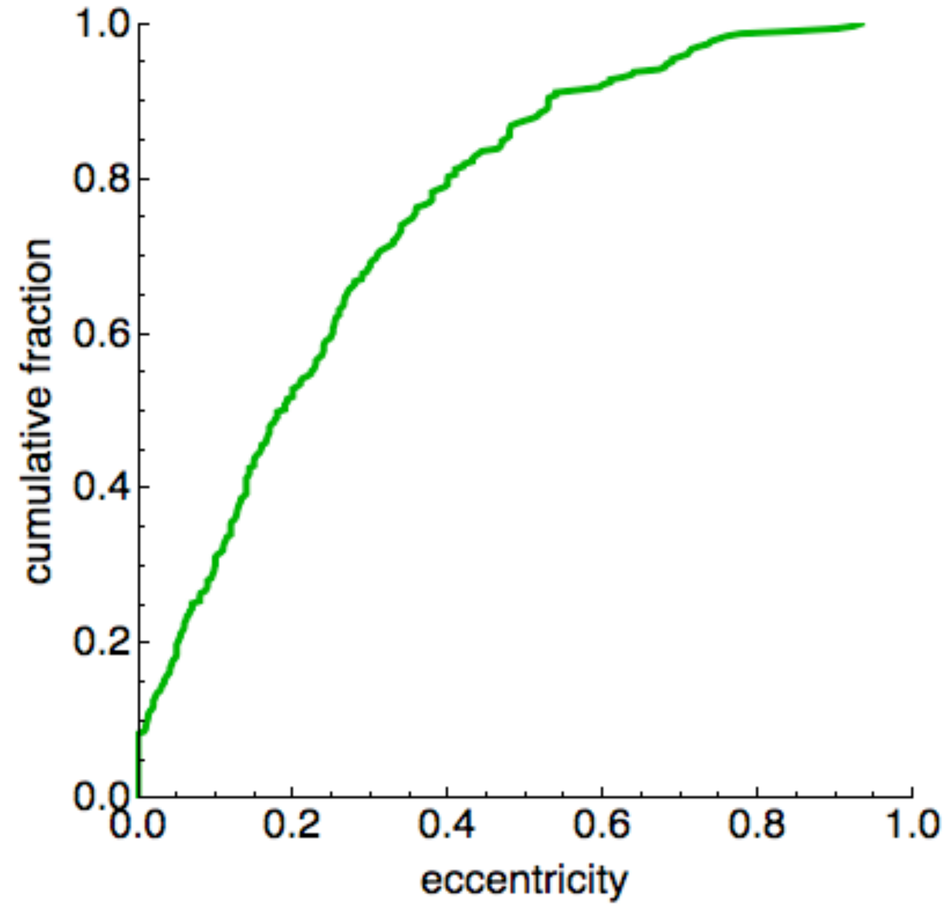
How to get higher eccentricities...

(see, for example, Rasio & Ford 96, Holman et al. 97, Laughlin & Adams 98, Marzari et al. 05, Chatterjee et al. 08, Jurić & Tremaine 08, Malmberg & Davies 09, Matsumura et al. 10, and many others)

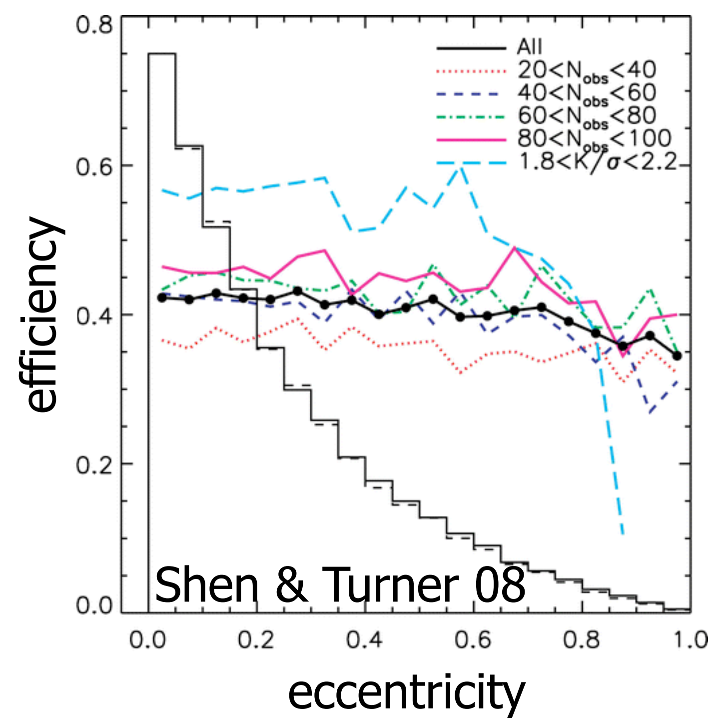


Should we take this as a given?

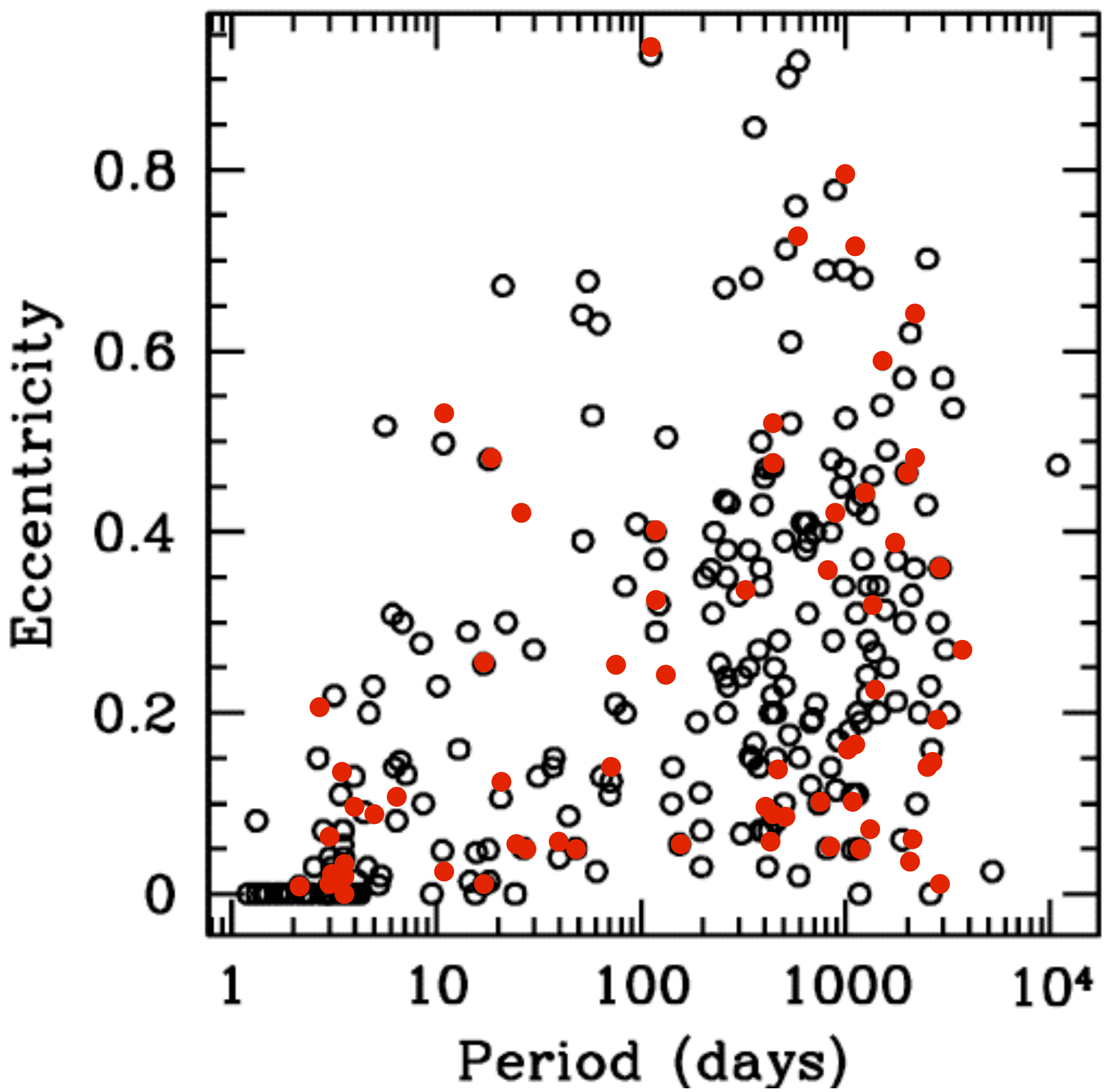


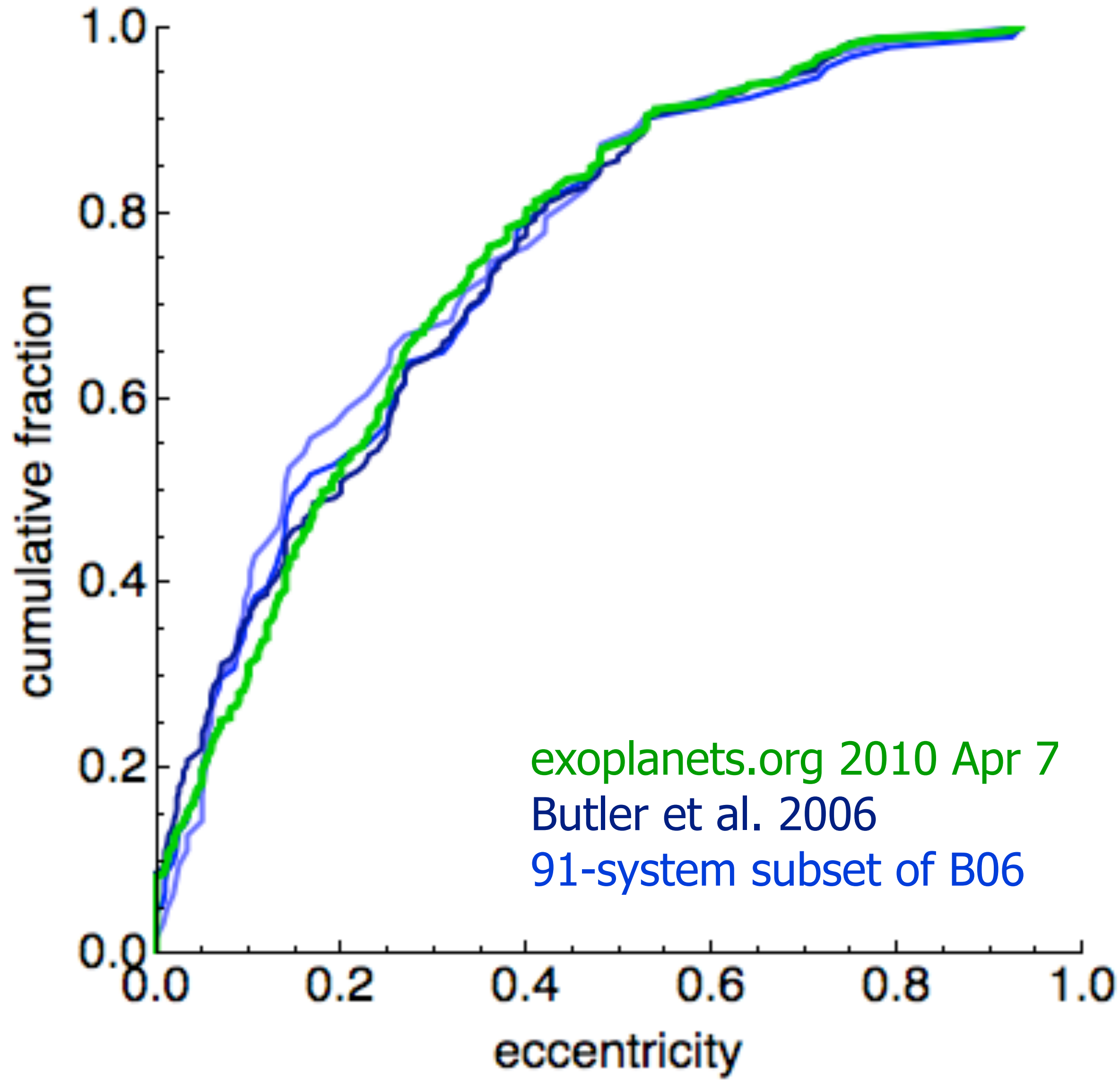


- No strong bias against high/low eccentricities in detection of RV planet signal (Endl et al. 02, Cumming 04, Shen & Turner 08)
- What about the orbit parameter extraction process?



Our experiment





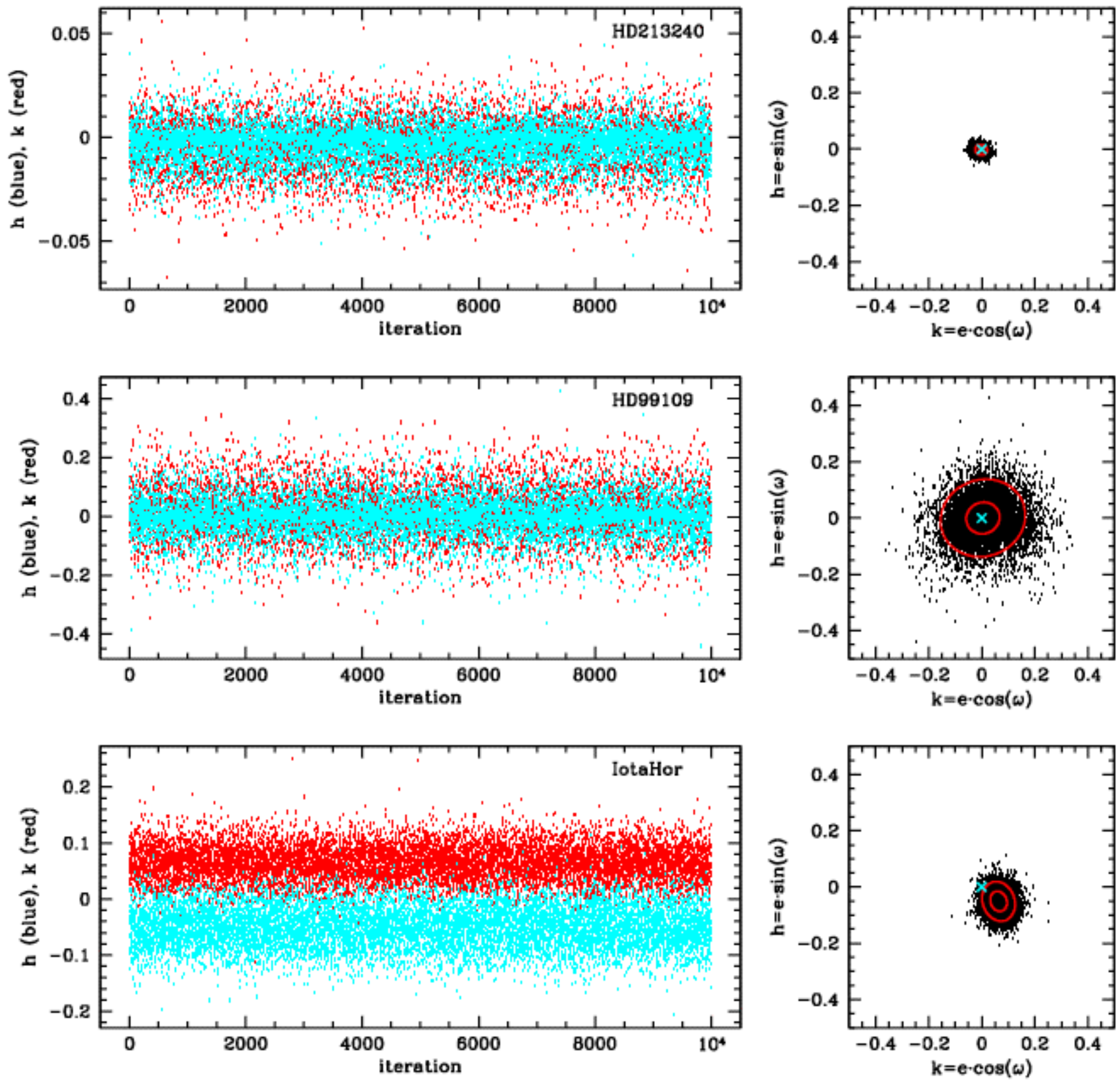
- Dominant planet of 91 systems in Butler et al. 2006 with $N_{obs} \leq 90$
- Retain period, velocity amplitude, observation times, uncertainties
- Use eccentricities 0, 0.05, 0.1, 0.3, 0.6

MCMC

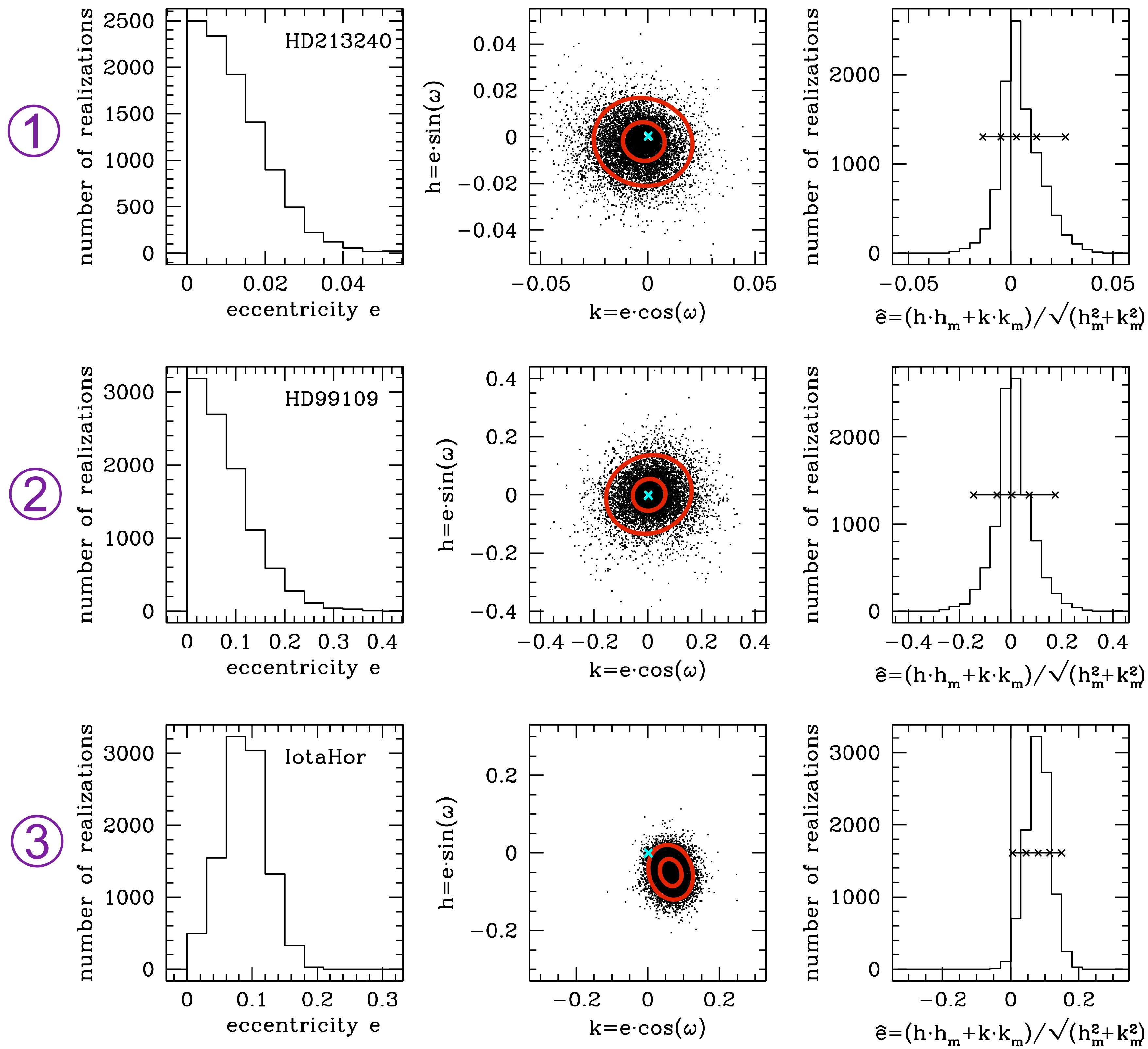
sample chain ①

sample chain ②

sample chain ③



Eccentricity measures

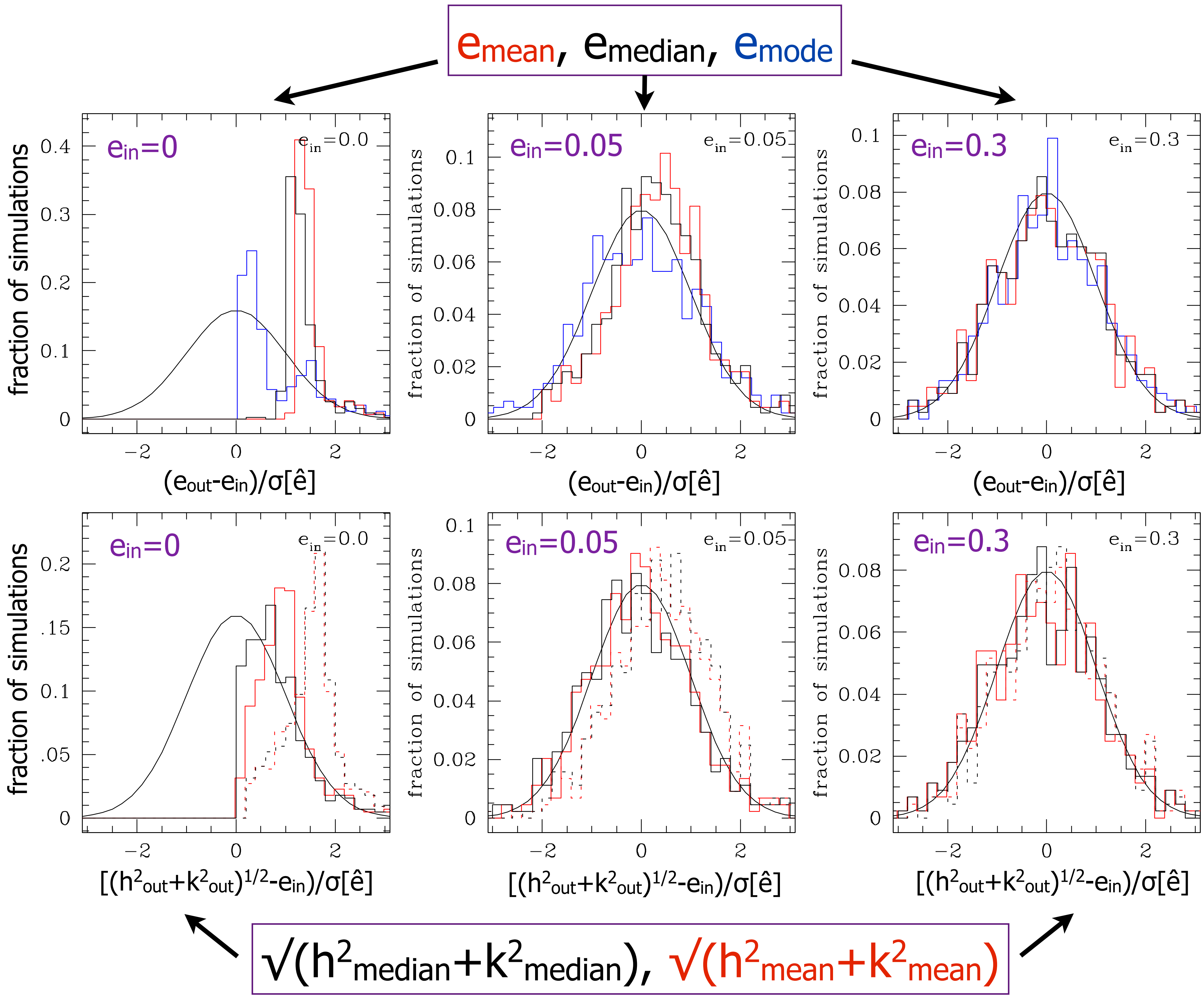


What eccentricity measure best represents the MCMC output?

- e_{mean}, e_{median}
- e_{mode}
- $\sqrt{h^2_{median}+k^2_{median}}$, $\sqrt{h^2_{mean}+k^2_{mean}}$

$h = e \sin \omega$, $k = e \cos \omega$

Eccentricity biases for mock systems

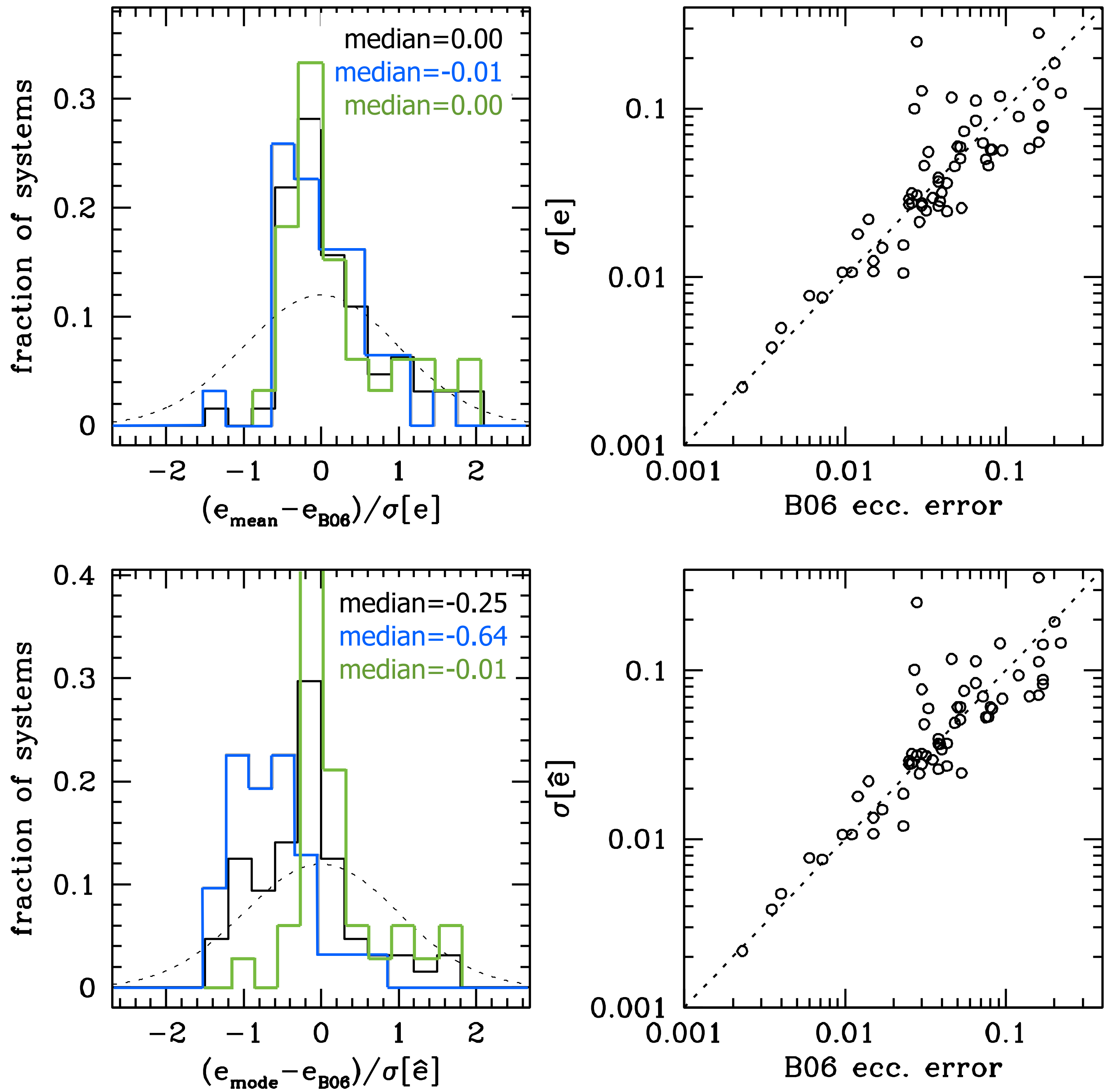


Real planets

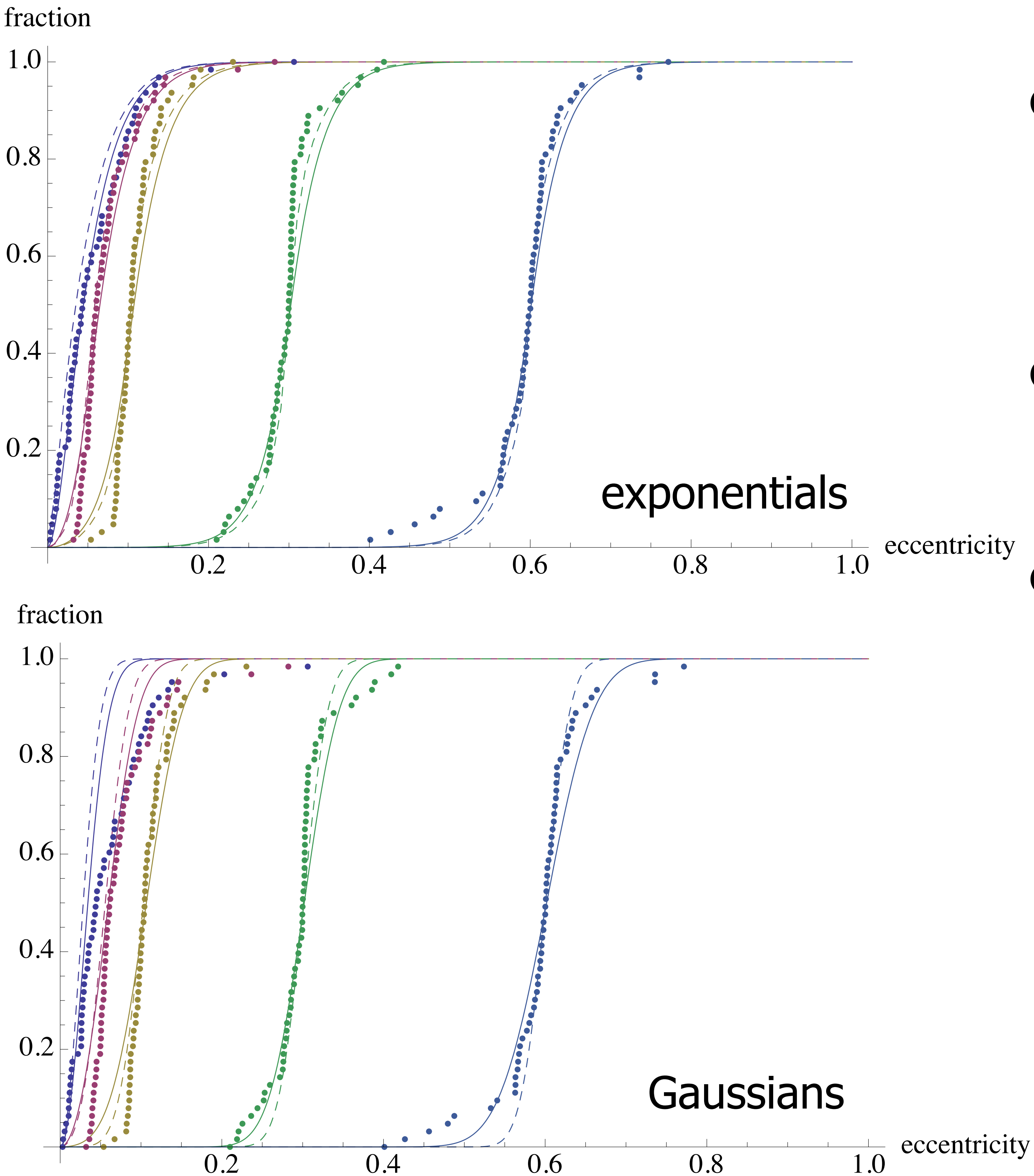
black=all systems ; blue=e<0.1; green=e>0.1

e_{mean}

e_{mode}

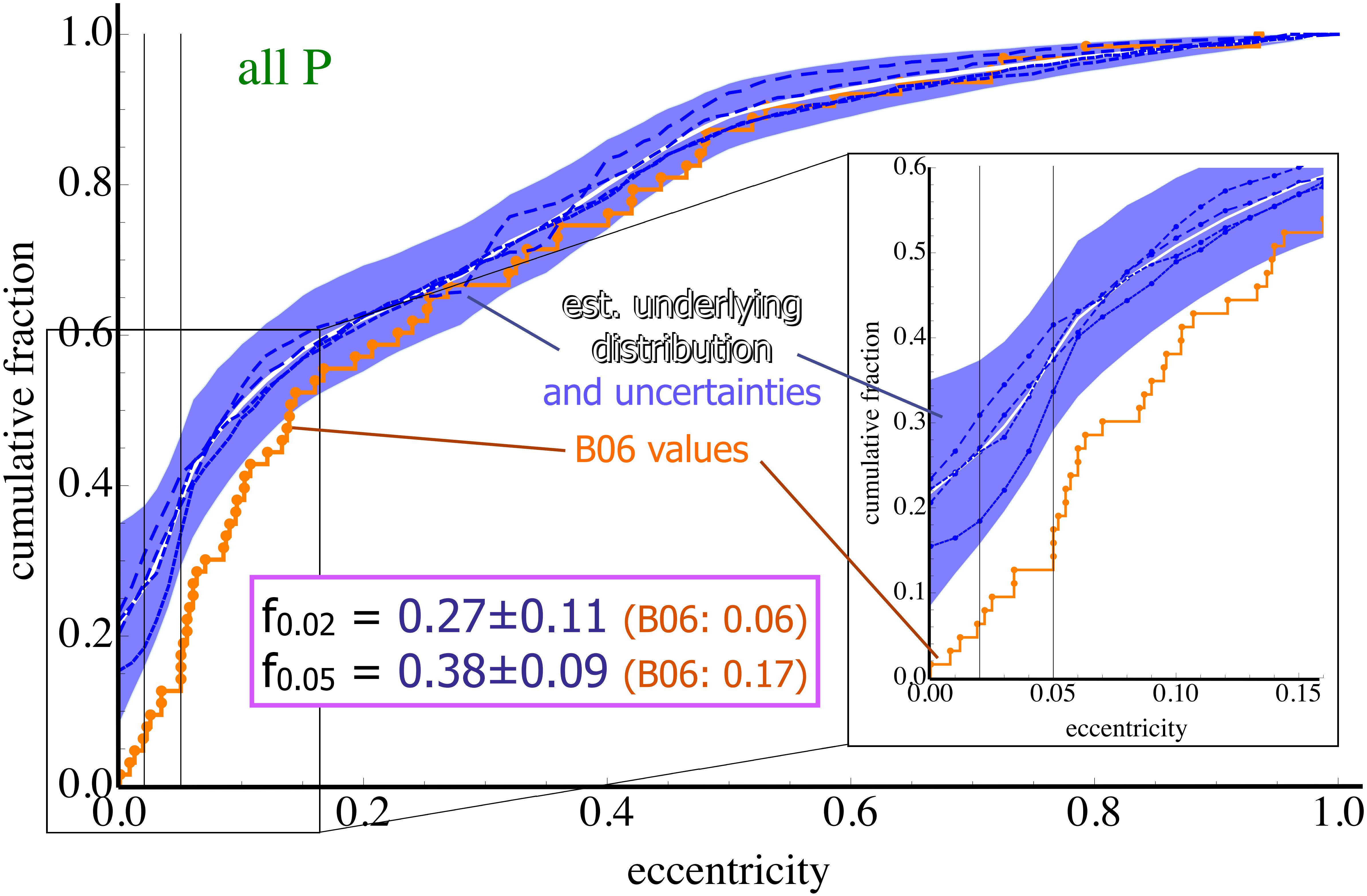


Estimating the underlying distribution

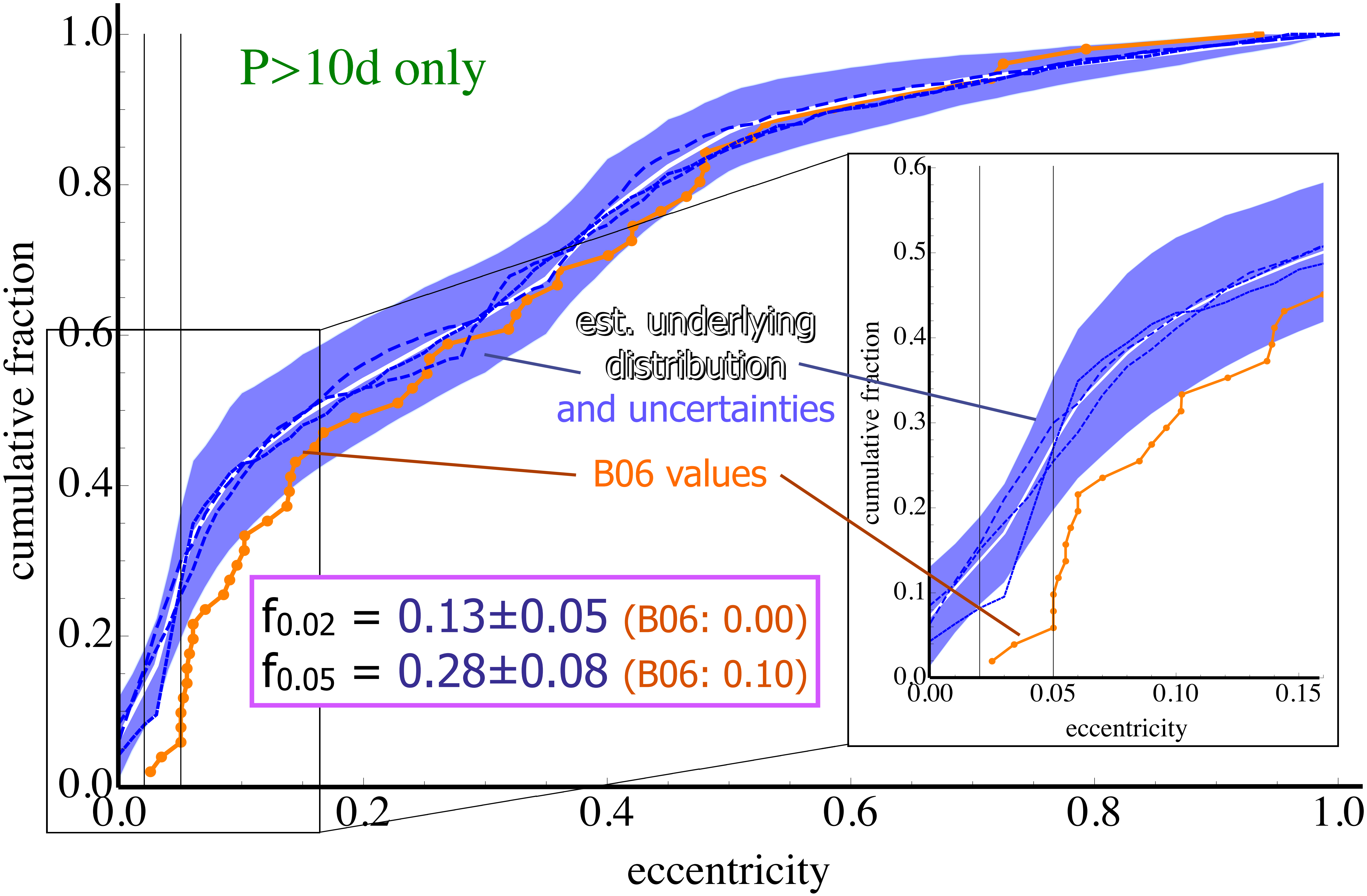


- Need P(e|ein); have measurements for e_{in}=0, 0.05, 0.1, 0.3, 0.6
- Gaussians in h, k (Shen & Turner 08) don't fit well
- Exponentials in h, k are better

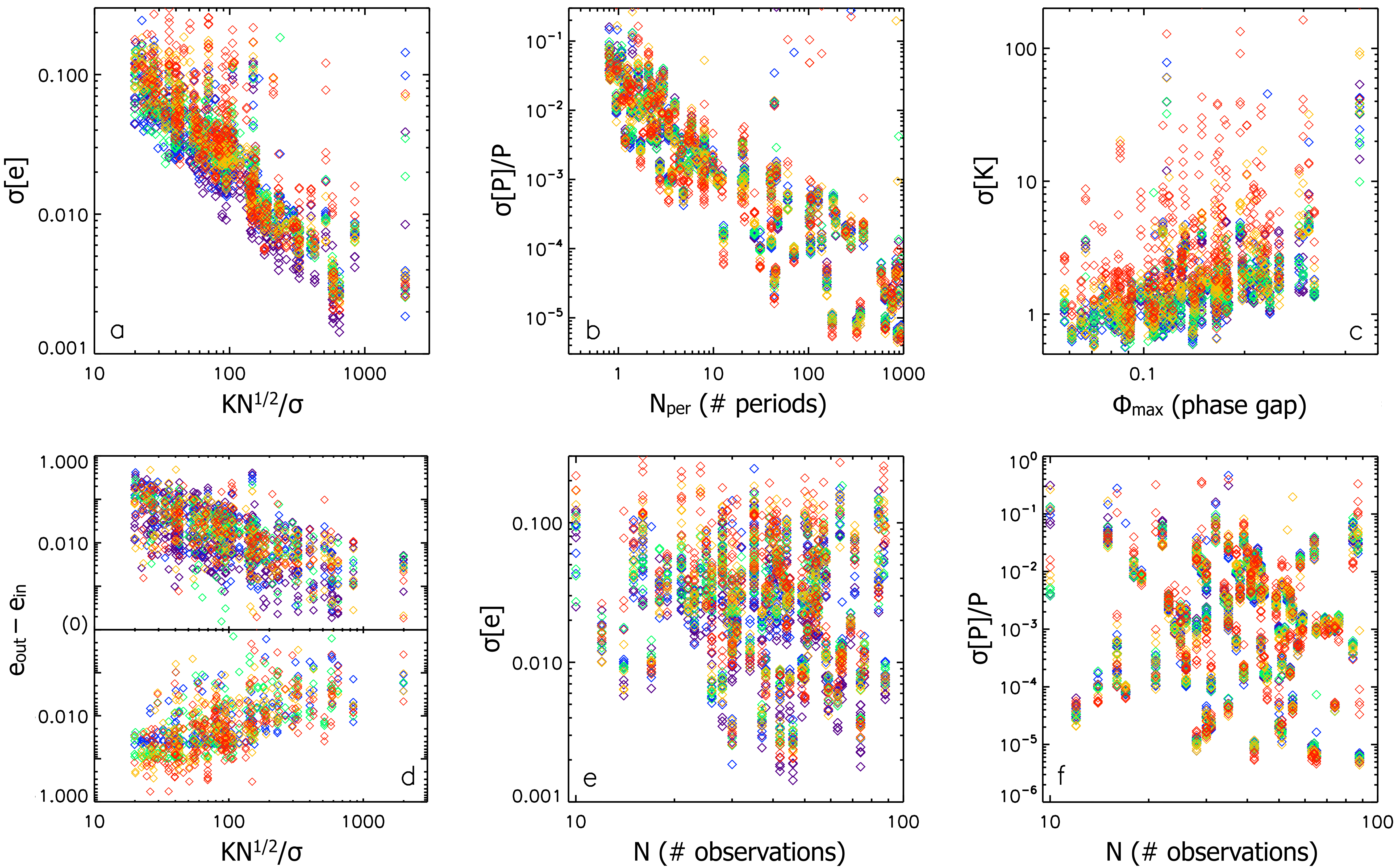
Estimating the underlying distribution



Estimating the underlying distribution



Trends in orbit parameter quality



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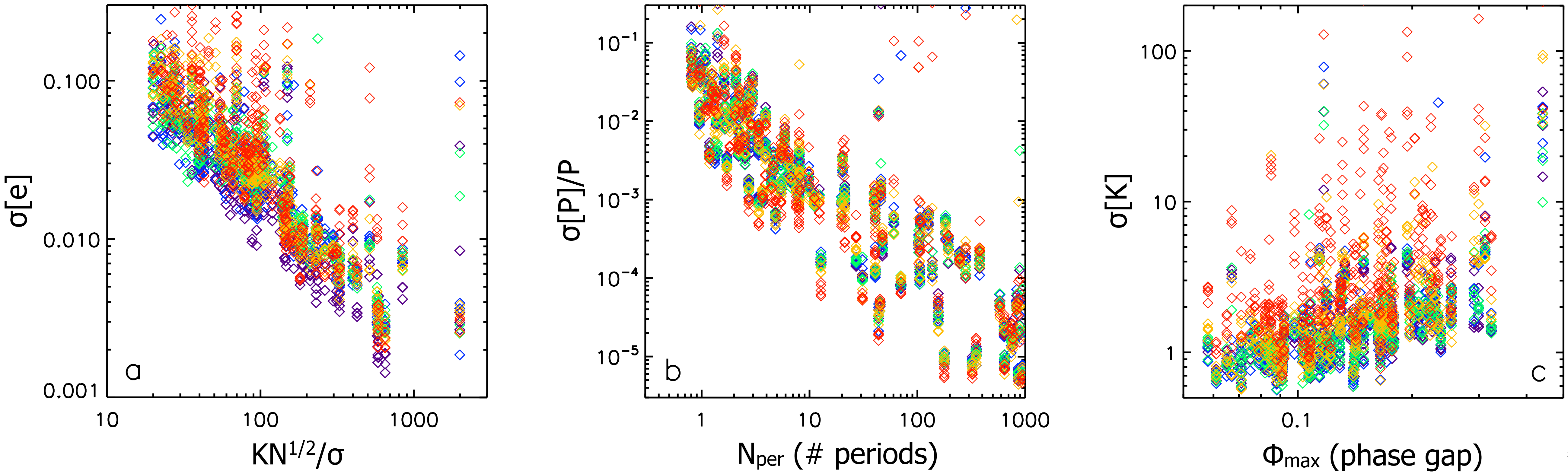

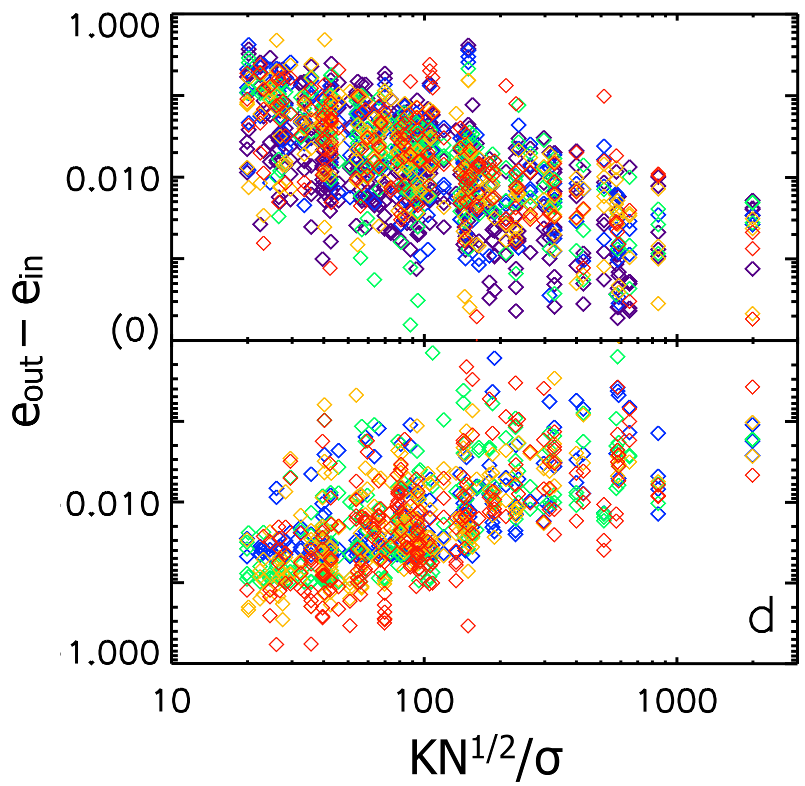

- σ[e]<0.05 requires effective S/N>~40
- σ[P]/P<0.1 requires N_{per}>1
  σ[P]/P<0.01 requires N_{per}>2-3
- σ[K]<3 m/s requires
  phase gap<0.3 when e≲0.1
  phase gap<0.15 when e≳0.3

Related work

- Shen & Turner 08 used χ^2 minimization to study eccentricity biases:
  - many variations on a single RV system rather than a catalog of systems
  - found eccentricity bias for datasets with low signal-to-noise ($K/\sigma<3$) and moderate number of data points (<60)

Summary

- Best-fit mean or median eccentricity output from orbit fitting procedures are biased high for $e \leq 0.05$
- We recommend e_{mode} as the reported eccentricity
- True fraction of low-eccentricity ($e \leq 0.05$) RV planets may be 35-40% rather than 15-20%
- Future work:
  - Larger planet catalog
  - Two-planet systems