Modeling Period and Period Ratio Distributions of Kepler Exoplanetary Systems

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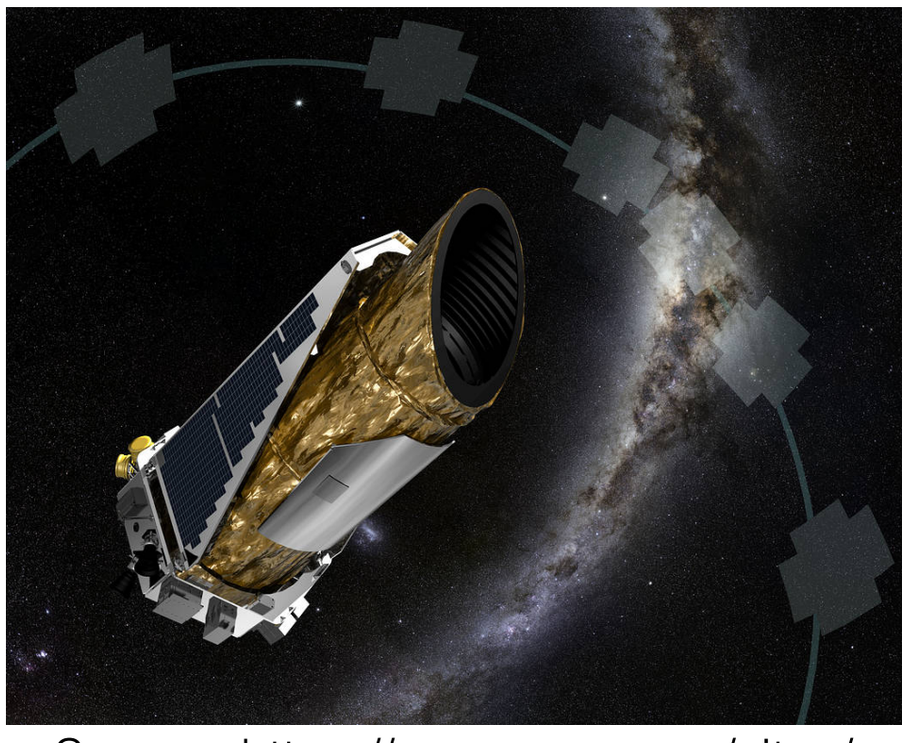
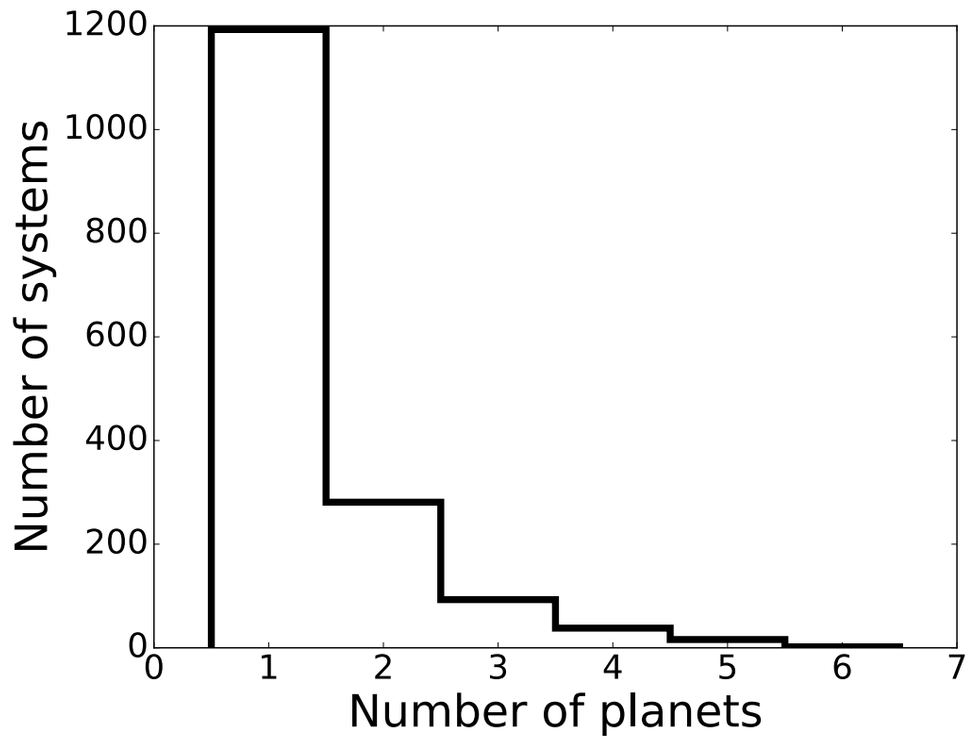
Introduction: the Kepler exoplanet population

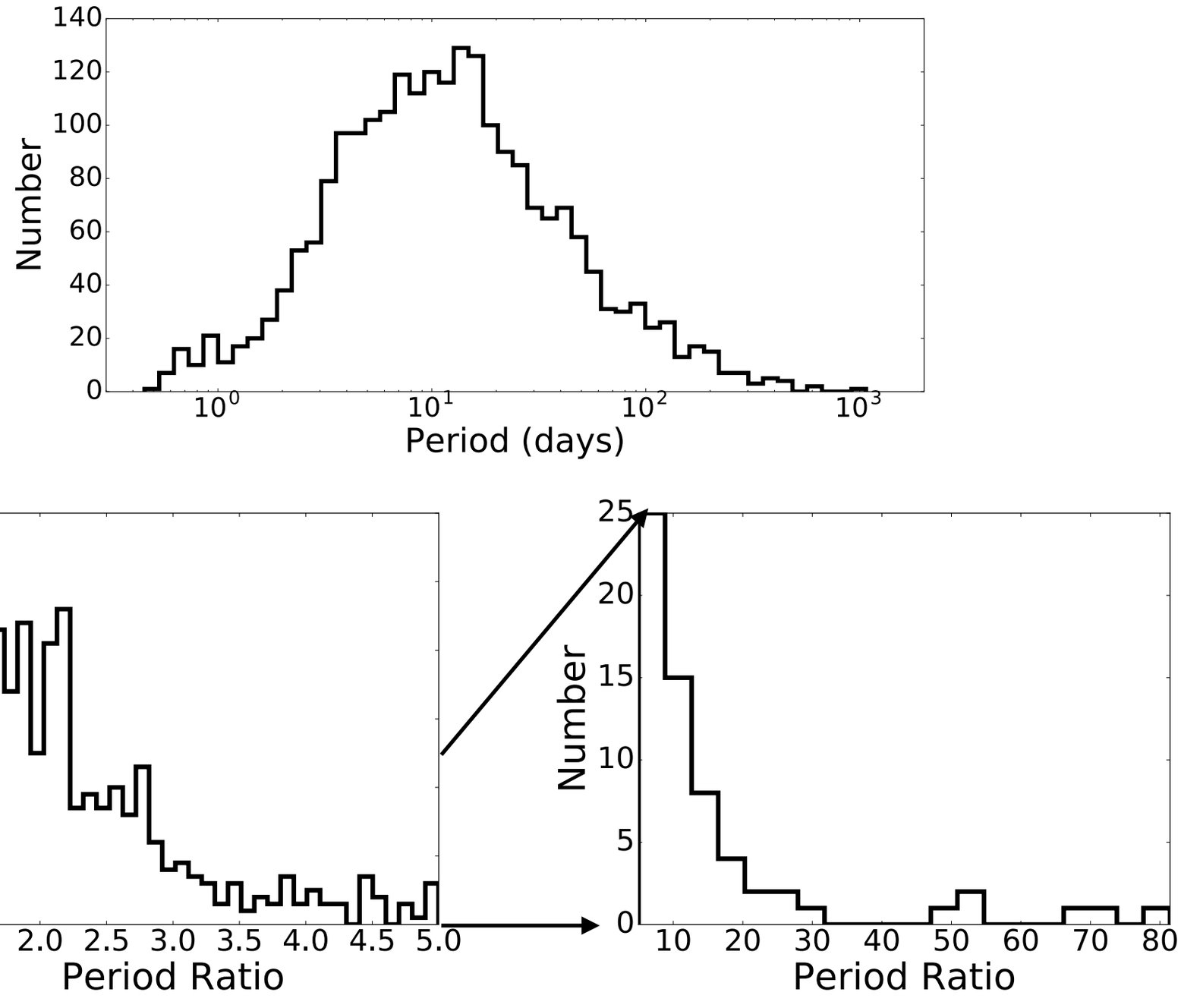
- Kepler space telescope launched in 2009 by NASA
- Discovered several thousand exoplanet candidates to date using the transit method
- Many single and multi-transiting planetary systems



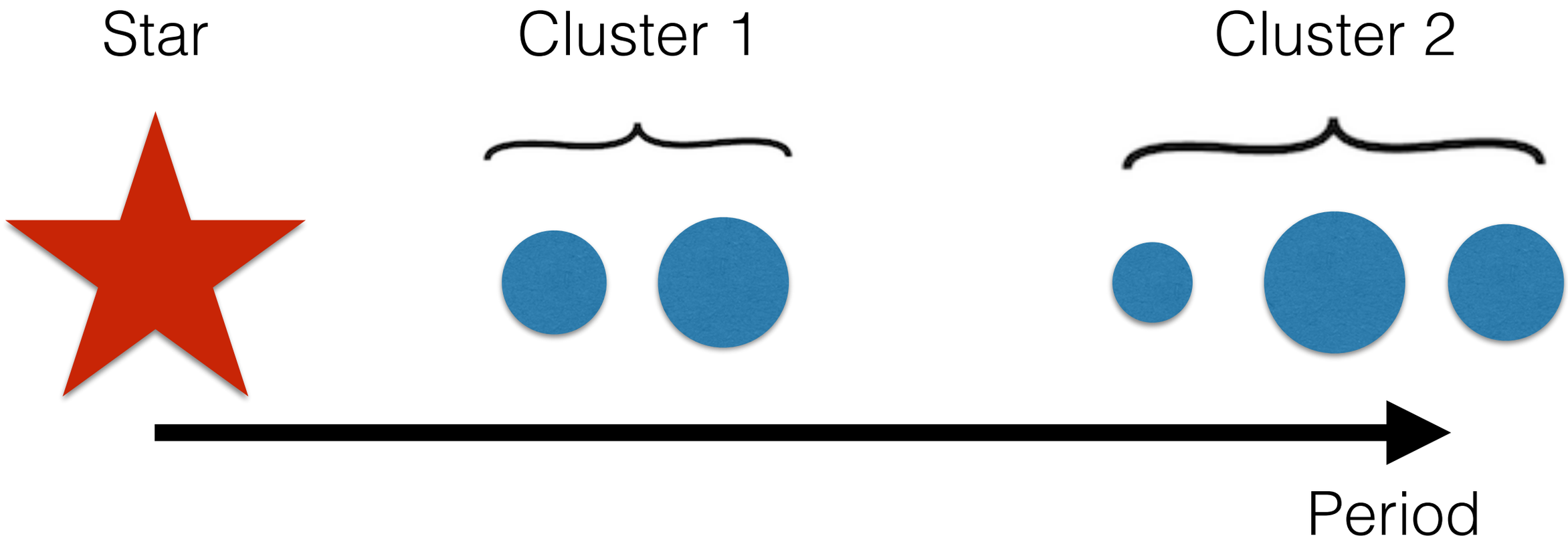
Source: https://www.nasa.gov/sites/default/files/kepler-k2_artistconcept.jpg



The period and period ratio distributions are well known

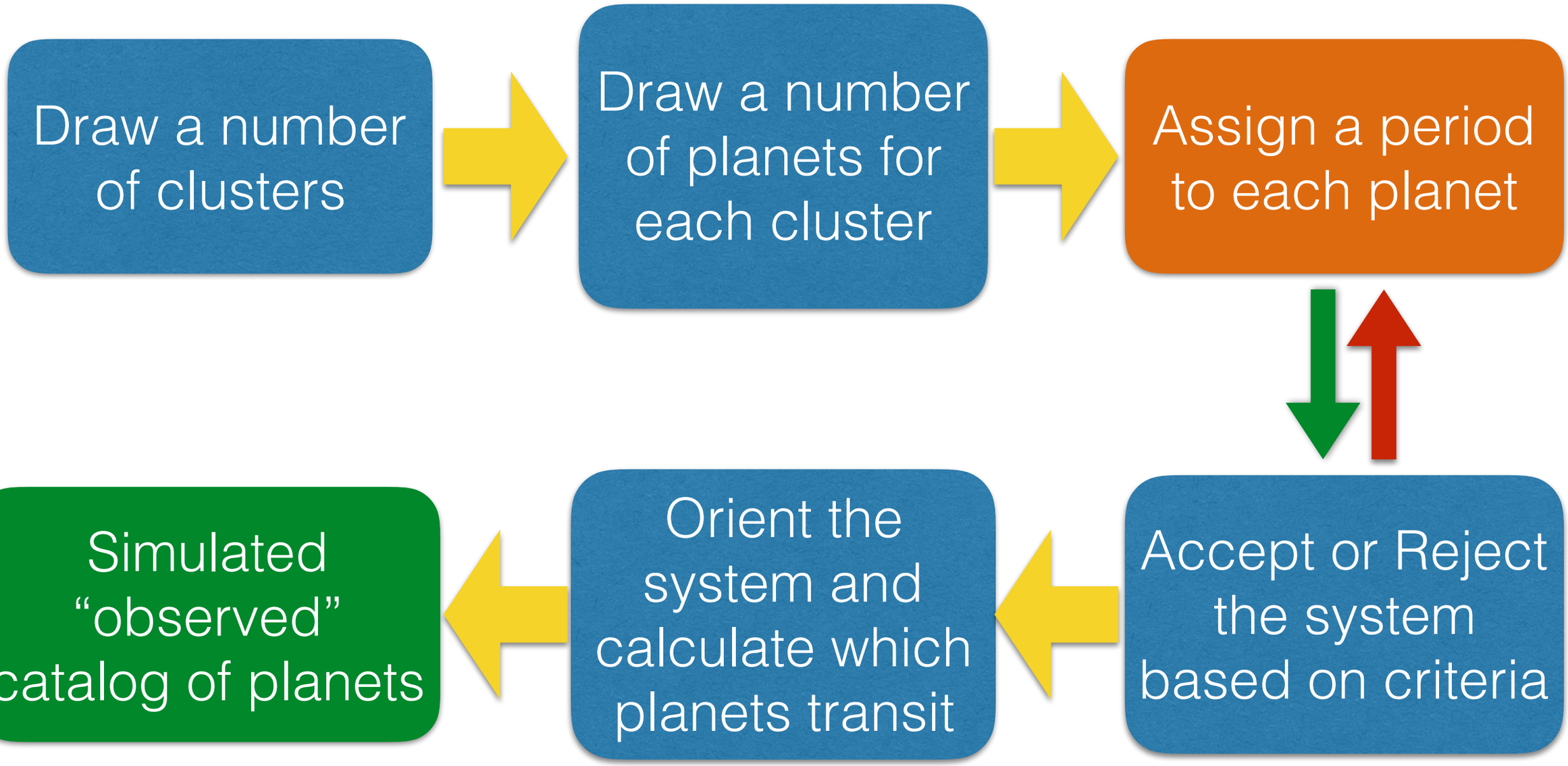


New approach: Planetary systems as a clustering process

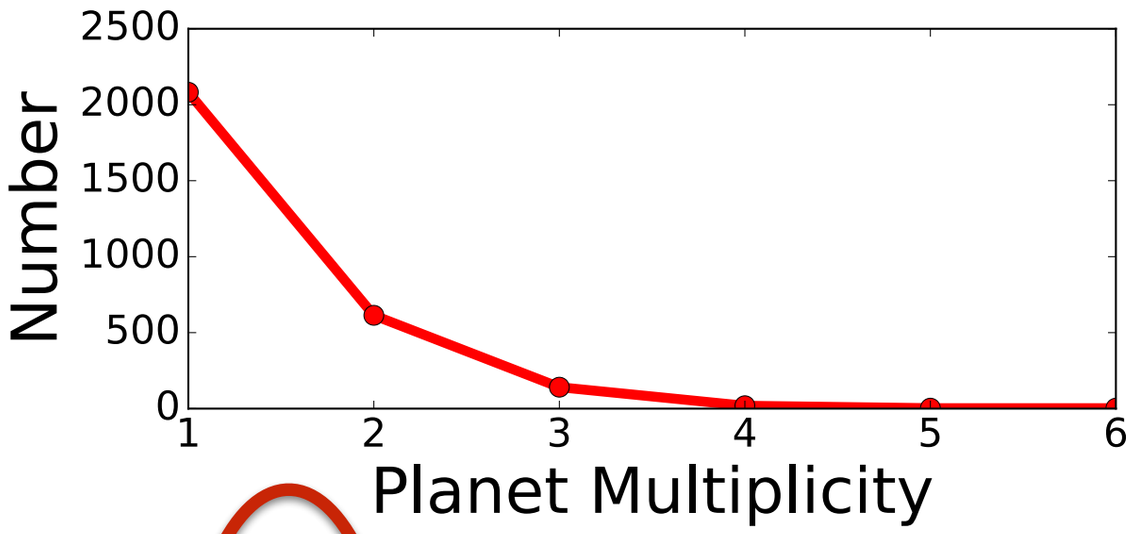


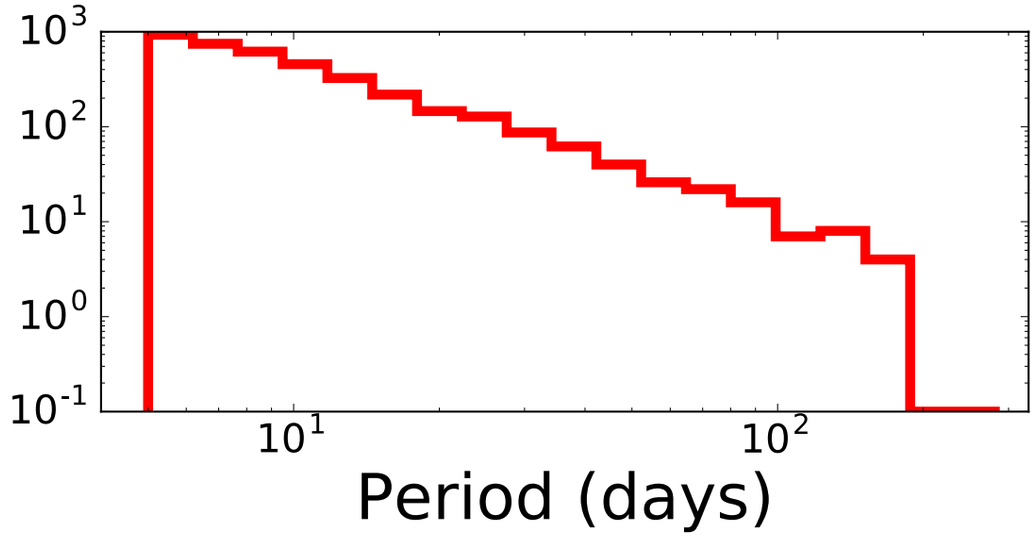
Modeling planetary systems as clusters of planets may better reproduce the observed period ratios

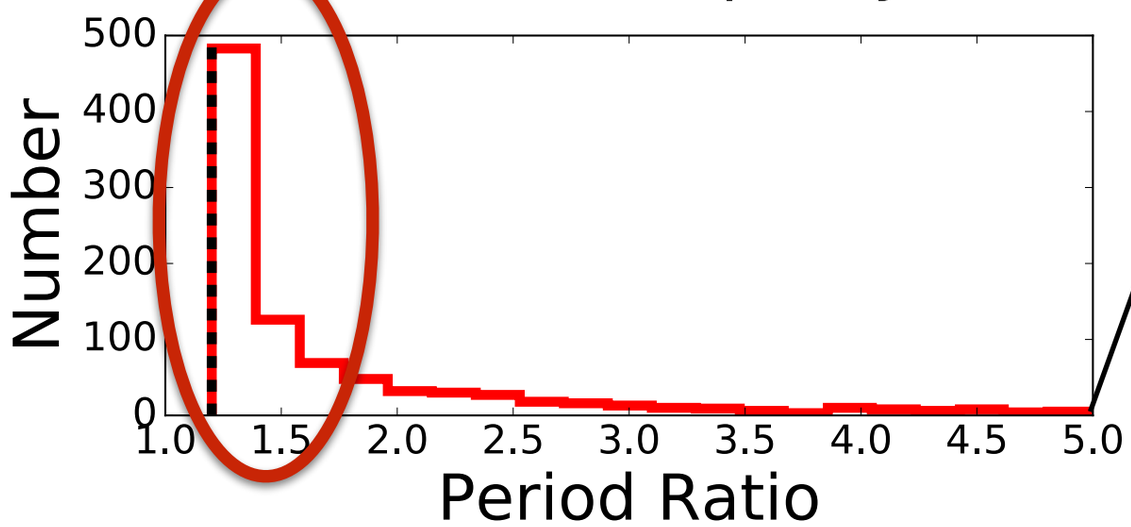
Goal: Statistical modeling of the Kepler exoplanets

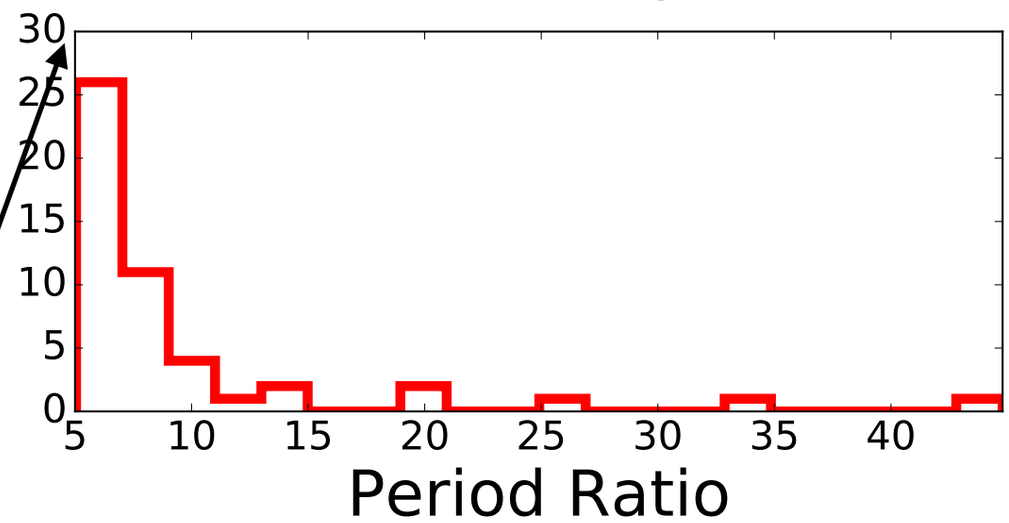


Model 1: Lognormal cluster periods with minimum period ratio





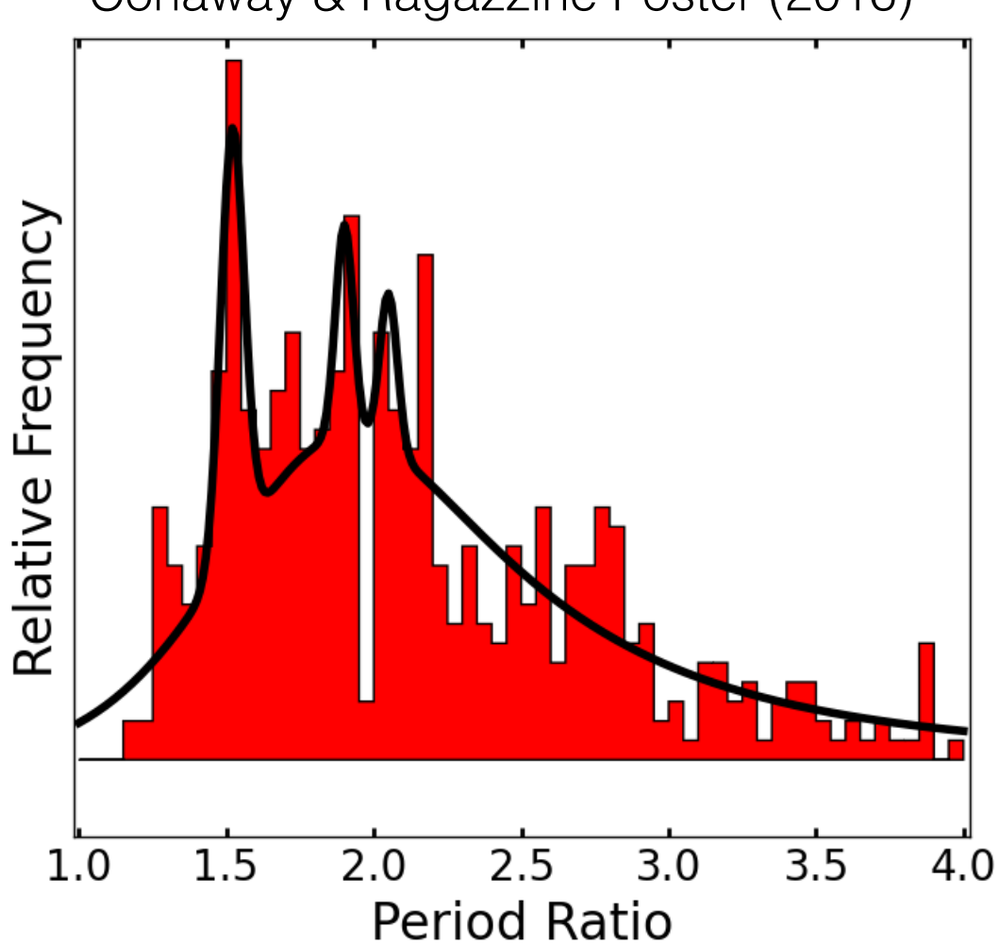




Model 2: Period ratios from Conaway & Ragozzine model

$$f(x) = \left[\left(\frac{x}{b}\right)^{\alpha_1 n} + \left(\frac{x}{b}\right)^{\alpha_2 n}\right]^{-\frac{1}{n}} + \sum_{i=1}^{N} C_i \frac{1}{\sigma_i \sqrt{2\pi}} e^{\frac{-(x-\mu_i)^2}{2\sigma_i^2}}$$

Conaway & Ragazzine Poster (2016)

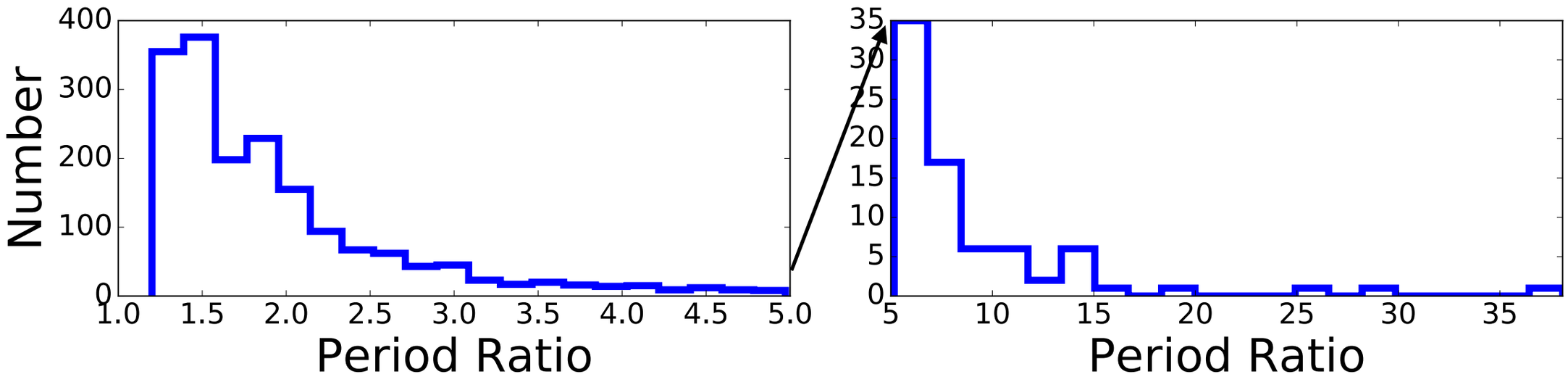


Smoothly broken power law

Gaussian peaks at 1.52, 1.90, 2.05 (i.e. near 3:2 and 2:1 resonances)

Model 2: Period ratios from Conaway & Ragozzine model

- The number of planets and period distributions look qualitatively similar to before (model 1)



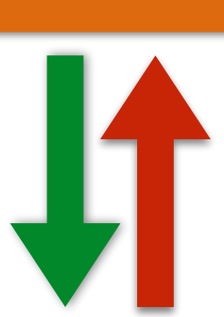
Model 3: Lognormal cluster periods with mutual Hill stability criteria

Assign masses to the planets to calculate their mutual Hill radii:

$$R_H = \left(\frac{a_1 + a_2}{2}\right)\left[\frac{m_1 + m_2}{3M_\star}\right]^{1/3}$$

Gladman (1993)

Assign a period to each planet

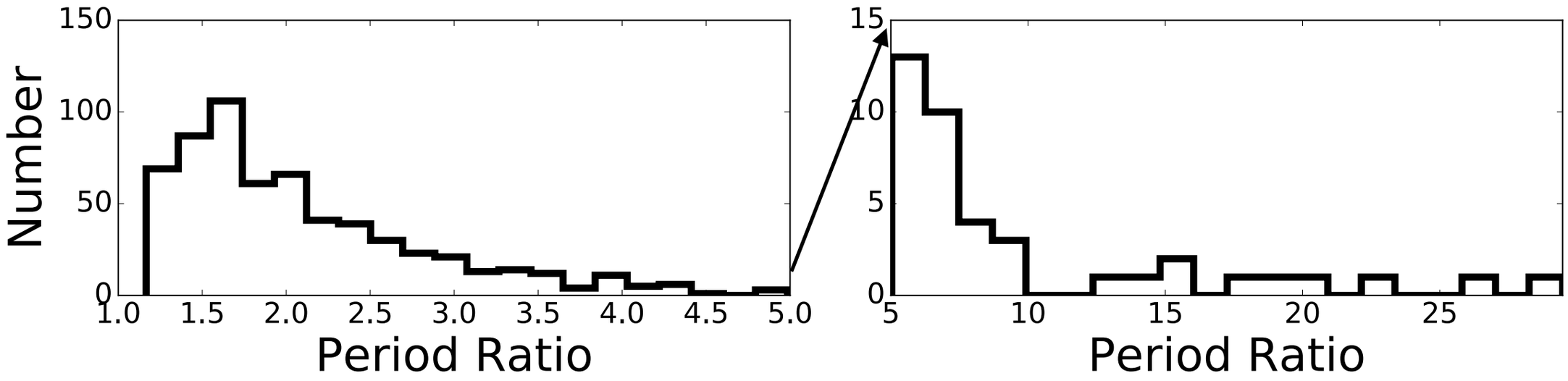


Accept or Reject the system based on criteria

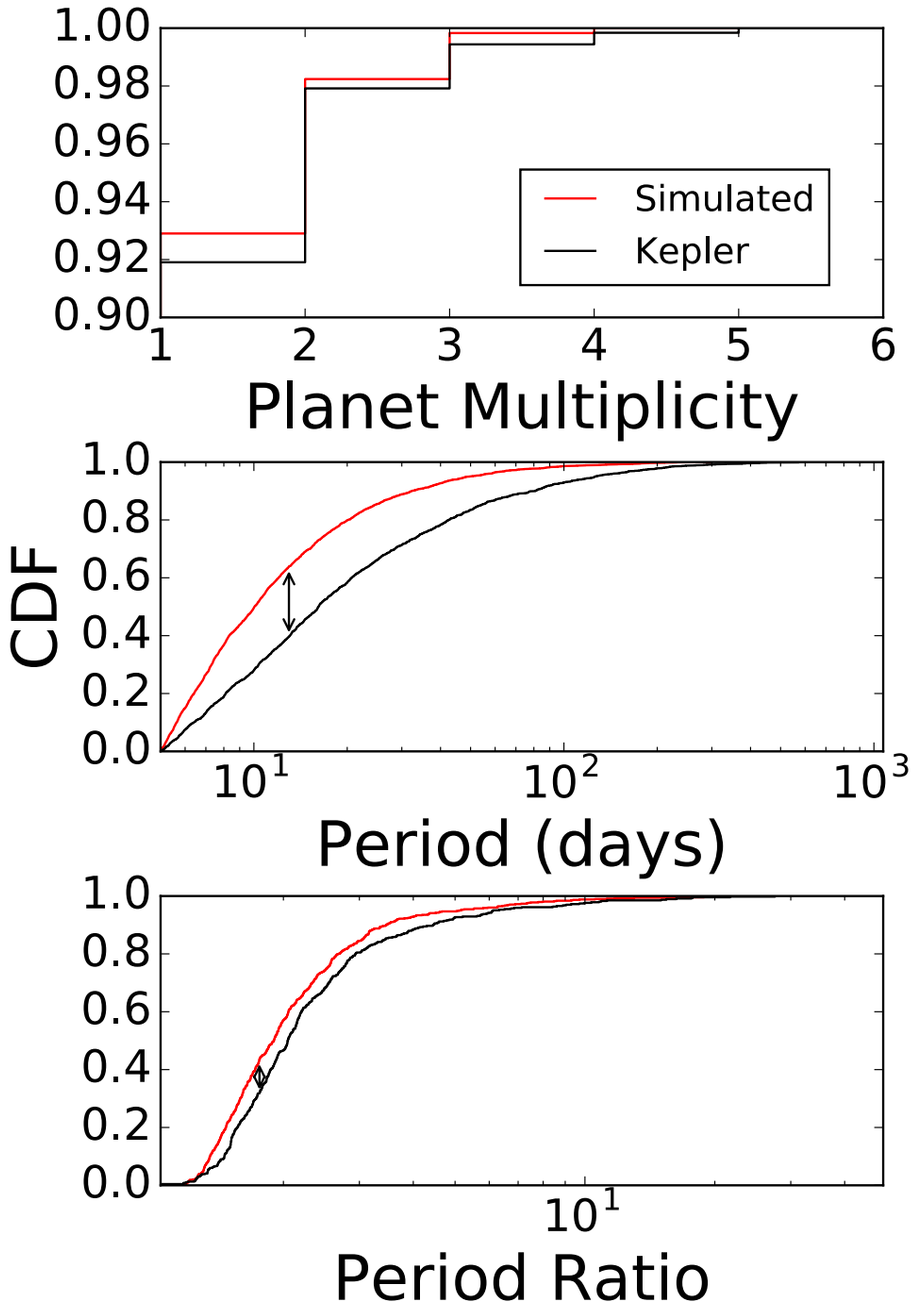
Accept if all planets are separated by many R_H

Model 3: Lognormal cluster periods with mutual Hill stability criteria

- The number of planets and period distributions look qualitatively similar to before (model 1)



Next steps



- Explore parameter space to find the best fit values for a given model
- Improve efficiency of algorithm
- Combine/improve models to better reproduce overall period ratio distribution as well as resonances

Summary

- We develop statistical models with the goal of reproducing the observed period and period ratio distributions of Kepler
  - ✳ Want a model which produces tightly-packed and widely-spaced planets (hence, clustering algorithm)
  - ✳ Account for features at/near the orbital resonances

- Models 1 and 2 produce too many tightly-spaced planets packed next to the minimum period ratio

- Model 3 more accurately reproduces the period ratio distribution but lacks resonance features