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An Analytic Model Approach to the Frequency of Exoplanets

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Abstract. The underlying population of exoplanets around stars in the Kepler sample can be inferred by a simulation that includes binning the Kepler planets in radius and period, invoking an empirical noise model, assuming a model exoplanet distribution function, randomly assigning planets to each of the Kepler target stars, asking whether each planet's transit signal could be detected by Kepler, binning the resulting simulated detections, comparing the simulations with the observed data sample, and iterating on the model parameters until a satisfactory fit is obtained. The process is designed to simulate the Kepler observing procedure. The key assumption is that the distribution function is the product of separable functions of period and radius. Any additional suspected biases in the sample can be handled by adjusting the noise model or selective editing of the range of input planets. An advantage of this overall procedure is that it is a forward calculation designed to simulate the observed data, subject to a presumed underlying population distribution, minimizing the effect of bin-to-bin fluctuations. Another advantage is that the resulting distribution function can be extended to values of period and radius that go beyond the sample space, including, for example, application to estimating eta-sub-Earth, and also estimating the expected science yields of future direct-imaging exoplanet missions such as WFIRST-AFTA.

Keywords. methods: statistical

1. Overview

There are at least two different approaches that can be taken in order to derive the frequency (or occurrence rate) of exoplanets in the population, from a sample as observed by the Kepler mission. The approach taken by Mulder, Pascucci, & Apai (2015), for example, is the one that is taken by most authors. This requires starting with the probability of detecting a planet (given the transit geometry of the system, a model for the noise, and a model for the instrument bias), binning the observed planets in convenient bins of period and radius, and estimating the population of planets in each bin by inverting the sum of the probability of detection for each observed planet in each bin. An alternative approach Traub (2015) is to start with similarly calculated probabilities and binned observed planets, assume a parameterized functional form for the population, simulate the detection of randomly selected planets from the assumed population, compare the resulting population to the observed sample (e.g., as in Fig. 1), and adjust the parameters so as to achieve an optimized fit.

Each method has its merits. The latter one is worth exploring because it provides an analytical expression for the occurrence rate at every period and radius within the range of inputs, and by extrapolation it yields an occurrence rate for points outside that range. These estimates may provide insights into the formation and evolution processes of the system that cannot be obtained by the former method.

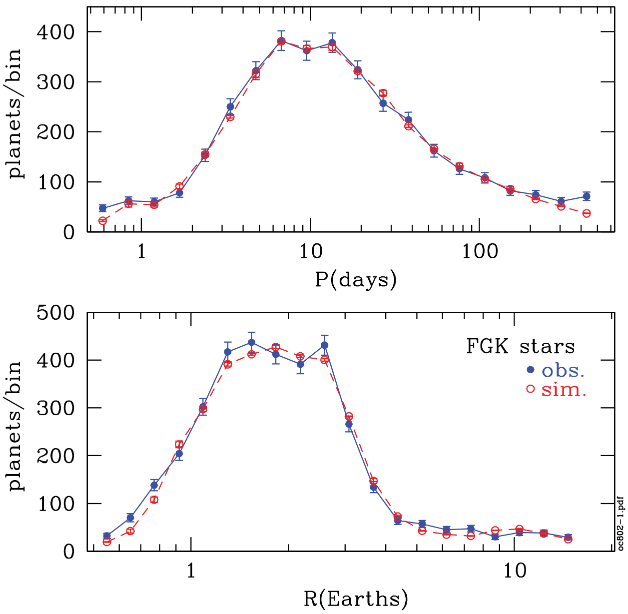

Figure 1. Example showing an observed sample of Kepler planets projected onto period and radius axes, along with a simulated sample derived from a model of the population.

References

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