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Abstract:

Correctly Accounting for Planets in Multiples when Determining Occurrence Rates

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Kepler's discovery of systems of multiple transiting planets has opened the doors to a variety of exciting and important scientific investigations. To improve our understanding of the formation and evolution of planetary systems, we are developing a model to explore the exoplanetary occurrence rates as a function of orbital architecture. For example, Kepler has clearly demonstrated a large population of Systems with Tightly-packed Inner Planets (STIPs), which have already engendered many additional studies. Quantifying the frequency of STIPs, inner solar system analogs, and other exoplanetary populations requires debaising techniques that account for many details not required in planet-by-planet occurrence rates. However, the presence of multiple planets in a system can significantly affect the inference of occurrence rates even in planet-by-planet calculations. Incorrectly accounting for planets in multiples can result in estimates of eta Earth that are incorrect by a factor of ~2. We have found that a careful and critical distinction must be made in distinguishing the average Number of Planets Per Star (NPPS) and the Fraction of Stars with Planets (FSWP). We will present analytical and numerical calculations that demonstrate the following key results. 1) By definition, the average multiplicity is the ratio of NPPS/FSWP. 2) Analyses that study planet by planet cannot estimate FSWP or the average multiplicity but can infer NPPS. 3) To produce an accurate value of NPPS, analyses must include all detectable planets (e.g., not just the most detectable planet). 4) Accounting for the multi-transiting geometry can solve for the average multiplicity, the inclination distribution, NPPS, and FSWP. 5) Calculations for multi-transiting geometry can be reduced to differential geometry problem on the sphere and we have developed a new fast efficient code called CORBITS that takes any planetary system and returns the probability that any subset of planets is seen in a transiting configuration. Using Kepler's remarkable dataset, these results will guide future studies of the occurrence rates of individual planets and exoplanetary systems.