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Abstract:

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Kepler's bounty of sub-neptunes enables us to study a regime in planetary size and mass that is absent from the Solar System. This regime includes a transition from rocky planets to those with substantial envelopes of volatiles-- either "ices" or gases. Characterizing these worlds by their bulk densities can probe this transition, but doing so requires mass and radius determinations.

Outside our solar system, there is a small sample of planets with masses and radii both measured, mostly hot jupiters whose radii are known from transit depths, and whose masses are determined from radial velocity spectroscopy (RV). In the absence of mass determinations via RV observations, transit timing variations (TTVs) can probe perturbations between planets that pass close to one another or are near resonance, and hence dynamical fits to observed transit times can measure the masses and orbital parameters of planets at longer orbital periods than RV targets. In some cases, however, a degeneracy exists between mass and eccentricity that limits the accuracy of mass determinations. Nevertheless, in several compact multiplanet systems, fitting complex TTV signals can break this degeneracy, permitting useful mass determinations.

The precision in measuring the radius of a transiting planet rests on the uncertainty in the stellar radius, which is typically ~10% for targets with high resolution spectra and stellar modelling. With dynamical fits, however, solutions for the orbital parameters including the eccentricity vectors can, alongside the transit lightcurves, tightly constrain the stellar density which allows for a precise revision of the radius. Revisiting the six-planet system of Kepler-11, our dynamical fits to TTVs, alongside spectroscopic data on the host star, reduced the stellar and hence planetary radius uncertainties to just 2%, permitting useful constraints on the planetary density. In the case of Kepler-11, planetary densities are lower than typical RV determinations in the same mass range. Other planets amongst Kepler's multiplanet systems, like Kepler-33, follow the trend set by Kepler-11.