CONSTRAINING PLANET FORMATION MODELS FROM THE KEPLER EXOPLANET POPULATION. G.D. Mulders[1], I. Pascucci[1], D. Apai[1,2], F.J. Ciesla[3], and D. P. O'Brien[4], [1]Lunar and Planetary Laboratory, The University of Arizona, 1629 E. University Boulevard, Tucson, AZ 85721, USA, mulders@lpl.arizona.edu, [2]Department of Astronomy/Steward Observatory, The University of Arizona, 933 N. Cherry Avenue, Tucson, AZ 85721, USA. [3]Department of the Geophysical Sciences, The University of Chicago, 5734 South Ellis Avenue, Chicago, IL 60637, USA, and [4]Planetary Science Institute, 1700 E. Ft. Lowell, Suite 106, Tucson, AZ 85719, USA

Introduction: The Kepler Spacecraft has discovered a population of exoplanets ranging in size from Mars to Neptune and in orbital period from a day to a year. This population of exoplanets orbits the majority of stars in the galaxy, and has changed our idea of what typical planetary systems look like, how they may form, and what composition they may acquire. The composition of rocky planets in terms of water and other bio-critical ingredients may not be directly observable right now, but statistical constraints can be gained from understanding how these planets form and where they accrete their material from [1,2]. With a well-understood detection efficiency and survey bias, the Kepler exoplanet population provides the most stringent constraints to date on exoplanet formation models.

Exoplanet Populations: Kepler has monitored stars with a wide range of masses and metallicities for transiting planets. These stellar properties trace the conditions in the protoplanetary disk at the time of planet formation, and leave an imprint on the exoplanet population. We derive planet occurrence rates as a function of stellar mass [3] and metallicity [4]. We find that lower mass stars contain more planets overall, but fewer giant planets. The heavy-element mass of planetary systems anti-correlates with stellar mass, in stark contrast with observed protoplanetary disk dust masses which show a positive correlation, see Figure 1. The increased efficiency at which low-mass stars form planetary systems close to their host stars shows that inward migration of planetary building blocks plays a crucial role in the planet formation process [5].

Exoplanet Composition: Inward migration of forming planets significantly impacts the amount of water and other volatiles that can be accreted from outside the snow line(s). As part of the Earths in Other Solar Systems team (EOS, PI:D. Apai) we are currently running creating a large database of high-resolution planet formation simulations including a detailed accretion history for individual planets. By comparing the planetary systems formed in these simulations with the observed exoplanet population we can put statistical constraints on exoplanet composition.

Constraining Planet Formation Models: In this talk I will showcase the Exoplanet Population Observation Simulator (EPOS). EPOS is a tool to compare the outcome of planet formation and planet population synthesis models with observed exoplanet populations that accounts for survey completeness and planet multiplicity. I will show how current planet population synthesis models compare to the Kepler data: different planet formation mechanisms, in particular in situ formation and planet migration, reproduce different regions of exoplanet parameter space. I will highlight areas where these models need to be augmented, in particular in damping the inlinations of multi-planet systems formed in situ and in reproducing the orbital-period distribution of super-earths that migrated to their current locations.

References: [1] Ciesla, F.J. et al. (2015) *ApJ, 804,* 9. [2] Mulders, G.D. et al. (2015) *ApJ, 807,* 9. [3] Mulders, G.D., Pascucci, I. & Apai, D. (2015a) *ApJ, 792,* 112. [4] Mulders, G.D. et al. (2016) *AJ, 512*, 187. [5] Mulders, G.D. , Pascucci, I. & Apai, D. (2015b) *ApJ, 814*, 130.

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Figure 1: Heavy-element mass of exoplanetary systems compared to protoplanetary disk dust mass.