

Dust in Protoplanetary Disks: A Clue as to the Critical Mass of Planetary Cores

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Dust in protoplanetary disks is widely recognized as building blocks of planets that are eventually formed in the disks. In the core accretion scenario, one of the standard theories of gas giant formation, cores of gas giants are considered to be built initially by collisional growth of dust and planetesimals, followed by the accretion of gas onto the cores. Many previous models show that the critical mass of planetary cores ($M_{c,crit0}$) that can initiate gas accretion is about $10 M_{Earth}$. We investigate the typical value of $M_{c,crit0}$ for the observed exoplanets by adopting a semi-analytical model, wherein the standard core accretion scenario is coupled with planet traps at which rapid type I migrators are halted. Using the model, we generate planetary populations as a function of the dust density in the disks (or metallicity). We statistically examine the populations, and show that $M_{c,crit0}$ is likely to be smaller than $10 M_{Earth}$ in order to account for the so-called Planet-Metallicity correlation - massive exoplanets are observed preferentially around stars with high metallicities while low-mass exoplanets do not have such a correlation. This correlation was originally inferred from the radial velocity observations, and has recently confirmed by the *Kepler* transit observations. Our findings are consistent with the recent, more detailed numerical simulations which suggest that $M_{c,crit0} < 10 M_{Earth}$ in a more realistic situation. We also calibrate statistically the "mean" mass of planetary cores ($\langle M_c \rangle$) that indeed initiate gas accretion in our model and show that the correlation originates from $\langle M_c \rangle$ that is an increasing function of metallicity. We thus demonstrate that the core accretion model is a preferred mechanism for understanding the observations of exoplanets, in agreement with the previous studies. Finally, our model shows that low-mass planets formed via the core accretion scenario are insensitive to metallicity. This indicates that such "failed" cores of gas giants may occupy a large fraction of the observed super-Earths and hot Neptunes.