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Simulations of giant planet core formation

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In the standard core accretion model of giant planet formation, a rocky/icy core accretes from a disk of km-sized bodies (planetesimals) in the outer solar system. Gas giant planet cores must reach a critical mass (about 10 Earth masses) to initiate runaway accretion of their gaseous envelopes from the solar nebula. The challenge is that this growth must occur within a few Myr since observations of stellar disks show that gas disks dissipate within this timescale. The work presented here examines the dynamical processes that could allow such rapid core growth.

We have performed numerical simulations of giant planet core formation using a new Lagrangian integrator “LIPAD”) devised by Levison, Duncan, and Thommes (2012). LIPAD is based on the symplectic N-body integrator SyMBA (Duncan, Levison and Lee 1998). However, unlike other numerical orbit integrators, LIPAD couples dynamics with collisional evolution, handling large numbers of planetesimals statistically and including accurate accretion and fragmentation. Starting with only a disk of km-sized planetesimals, our simulations show that core accretion can be responsible for generating planetary embryos that are $\sim 10^5$ km in size (several Earth masses).

Our results show that sub-km fragments, created by collisional grinding of planetesimals, can enhance embryo growth rates. However, some of the small particles can also become locked in mean motion resonances with the embryos, driving the entire system towards the central star due to gas drag. We also show that outward embryo migration driven by planetesimal scattering is an important dynamical process to ensure the survival of the embryos. Overall, we show that while our simulations often generate embryos with masses of a few Earth masses, it remains a challenge for any core accretion simulation to routinely reach the critical value of 10 Earth masses within the gas disk lifetime. However, these simulations do show that core accretion can be responsible for forming the super-Earth sized planets found in extrasolar systems.

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