Building Terrestrial Planets - Planetsimals to Planets

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Models of each stage of planet growth have largely been successful at identifying the important physics in different regions of space at different times. The earliest stages are dominated by small-body interactions, where km-size bodies collide with each other but also interact with the gaseous solar nebula. Later, the gravitational interaction between planetary embryos on long timescales becomes more important. However, splitting the problem into different stages, each modeling subsets of the total physics, has an inherit weakness - planet growth does not progress at the same speed at all locations. Rather the inner regions of the Solar System may have many gravitationally interacting planetary embryos, while outer regions are still dominated by small-body collisions.

Using the particle-based code LIPAD that models the fragmentation, accretion and dynamical evolution of a large number of planetesimals through the entire growth process, one can avoid the pitfalls of the classical piece-wise approaches [1]. This technique finds that growth timescales that are far more dependent on distance from the Sun than previously found. This leads to giant collisions between Mars-size planetary embryos at 1 AU before Ceres-size embryos have formed beyond 2 AU.

This disparate timescale has a strong impact on the results for simulations that include both fragmentation and gas affects. The difference in growth timescale for planetary embryos between 1 and 2au is large enough to span the expected lifetime of nebular disks [2]. This serves to stunt growth in the outer disk, beyond 2au, and to ultimately lead to a loss of material particularly notable around 1.5au. These simulations serve notice that the initial conditions typically used in Terrestrial Planet Formation simulations contain significant flaws.

References: [1] Levison et al. (2012) *Astronomical Journal* **144**, 4 [2] Haisch et al. (2001) *Astrophysical Journal* **553**, L153