Planet Formation and Differentiation: A Link between Monte--Carlo Simulations and Computational Fluid Dynamics

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The formation of a planetary core in terrestrial planets is still not well understood. It is commonly assumed that the separation of the iron and silicate phase happened rather rapidly. However, it is still unclear how and when this process took place. Recent research has lead to the conclusion that even relatively small bodies like asteroids can be differentiated. Merk et.al. (2002) showed that the interior is strongly heated due to the decay of Al26. Sometimes even the solidus temperature of silicate material is exceeded. Yoshino et. al. (2003) showed that heating within planetesimals by decay of short-lived radionuclides can increase the temperature sufficiently above the iron-sulphur melting point (approx. 1200K) and thus trigger the fast segregation of iron alloy. Therefore even small planetesimals (30km radius) are expected to be at least partially differentiated. Since these objects would have been most abundant in the terrestrial region of the protoplanetary nebula (Kokubo, 2000), it is not unlikely that the Earth and other terrestial planets formed by accretion of previously differentiated planetesimals.

From the above it is clear that planet formation and differentiation happened more or less simultaneously and therefore must also be considered simultaneously in a consistent theory. We propose a model in which the dynamics of planetary accretion and core accretion are made consistent. The timescale for differentiation of planetesimals by sinking of iron droplets is calculated for bodies of different sizes and compared to the typical collision timescale involving these planetesimals. We argue that by the time (or equivalently size of planetesimals) the two timescale become equal, planetary growth proceeds with differentiated bodies only.