Collisional accretion of centimeter-sized protoplanetesimals

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Abstract. The seeds of planetesimals that formed in the turbulent gaseous environment of the nascent protoplanetary disk have many barriers to overcome in their growth from millimeter to meter-sized and larger objects. At these sizes self-gravity is almost non-existent and surface forces such as van der Waals-type forces play a critical role in holding loosely bound rubble-piles together. We wish to further understand the mechanical, material, collisional properties, and outcomes of collisions between cm-sized rubble-piles, which at low speeds may lead to accretion. The collisional outcomes can be determined by a set of definable collision parameters, and experimental constraints on these parameters will improve formation models for planetesimals. We have carried out a series of laboratory microgravity collision experiments of small aggregates to determine under what conditions collisional growth can occur in two experiments with one using mm-sized silica beads and the other using SiO_2 dust as simulants. In our free-fall chambers we obtain collision velocities ranging from 1 to 200 cm s^{-1} and we measure the coefficients of restitution, sticking thresholds, and fragmentation thresholds of the porous and non-porous aggregates. We then compare the results of our experiments with numerical simulations we performed using a collisional N-body code. We find that cm-sized agglomerates made up of mm-sized silica particles or of mm-sized SiO_2 dust aggregates are very weakly bound and require high porosity or internal cohesion to avoid fragmentation in agreement with both the simulations and the experiments. The velocity threshold for sticking is found to be <10 cm s^{-1}, far from the fragmentation threshold of ~1 m s^{-1} for cm-sized bodies. Quiescent regions in the mid-plane of the disk may cultivate abnormally low relative velocities permitting sticking to occur (~cm s^{-1}), however, without a well-defined path to formation it is difficult to determine whether collisional accretion as a mechanism can overcome low thresholds for sticking and fragmentation. We discuss this research's implications to both the meter-barrier and planetesimal formation.

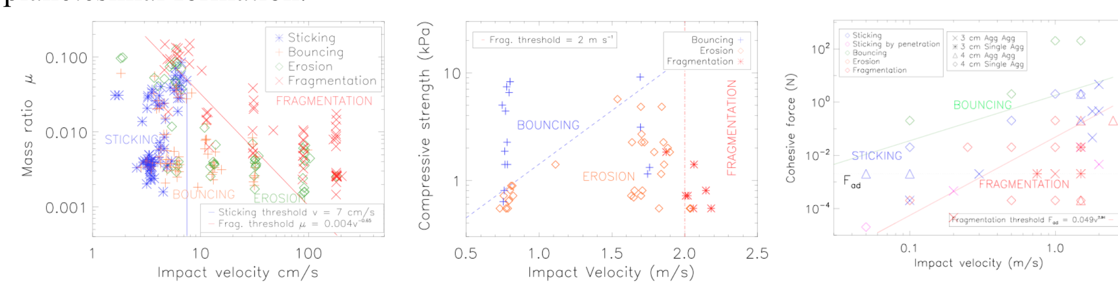

Figure 1: The parameter spaces covered in the three experiments color coded by the type of collisional outcome. Going from left to right (1) the outcomes from the SiO_2 aggregates, (2) from the silica aggregates, and (3) from the N-body simulations of the silica aggregate collisions.