Granular Gases of Frictional Spheres: in-situ smart sensing and optical evaluation with matching simulation

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Granular gases are dilute ensembles of macroscopic grains interacting rarely, by dissipative collisions. They occur in natural contexts such as the formation of plantesimals, as well as in technical applications. Being one of the simplest non-equilibrium many-particle systems, the current literature comprises numerous theoretical and numerical predictions, one of the most famous being Haff's prediction of the energy decay in absence of external energy supply (granular cooling). Experimentally, granular gases in three dimensions can only be realized under strong external forcing or in microgravity, and results are still scarce. A second problem is the comparison of experiments to theory in itself: the simplifying approximations or assumed system sizes can usually not be experimentally reached. Whereas theoretically, the simplest model are granular gases of spheres, the spherical symmetry poses yet another experimental challenge: identifying sphere rotations and collisions.

We perform microgravity experiments in the drop tower of ZARM Bremen and on parabolic flights, investigating granular gases of centimeter-sized spheres during permanent external energy supply and during granular cooling. Translations and rotations as well as collisions are identified, where possible, optically. In addition, we developed and employ a new measurement system including a set of smart particles (particles with internal autarkic gyroscopes and accelerometers) reliably detecting collisions and rotation rates in situ at rates of up to 1600 Hz. Our experiments are accompanied by customized, validated simulations to identify the effect of initial conditions and ensemble size on the results, at varied friction coefficients. We analyze statistical properties such as the mean energy and its distribution on the degrees of freedom or the velocity distributions and collision rates in the system.