Emergent interactions in non-equilibrium suspensions

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We present a simple framework to compute the interactions between inclusions in different out-of-equilibrium solvents, i.e. suspensions of active particles and of granular particles. The character of the interaction between inclusions is of key importance in such systems thus it will determine the ability of the suspension to seggregate intrusive particles.

Firstly, we present a model of active, self-propelling and self-aligning, particles. The ability of the particles to align and swim is ubiquitous in bacterial or autophoretic suspensions. By trapping the inclusions we can measure the mean values of their effective interparticle force. A systematic exploration of the interparticle force as a function of the competition between propulsion and alignment allows us to identify three different regimes. We report a change in the qualitative behaviour of the forces, compared to thermal equilibrium. Specifically, tuning the particle activity we can go from atractive to repulsive and back to attractive effective forces.

Secondly, we present a simple model to simulate forced granular suspensions, as studied experimentally by C. Lozano *et al.* (Phys. Rev. Lett. **114**, 178002) in Navarra. The model takes into account the external forcing of a dense polydisperse mixture of disks, that model the poppy seeds in the experiment. In addition to the disks, we include two inclusions of greater mass and different behaviour under forcing to model the bronze spheres.

In our simulations we track the relative movement of the inclusions to extract the probability density $P(D)$, the probability to measure a distance D between the inclusions. For large values of the surface density, the probability distribution exhibits a nonmonotonic decrease as a function of the interparticle distance, implying that the two inclusiuons are more likely to be found at integer values of the diameter of the granular particles.

In both situations we report an emergent long-ranged interaction. This feature is of special interest since the interactions in the model are characterized by a finite range, the diametres of the particles. The origin of the interaction may be attributed to the out-of-equilibrium nature of the system; both the external forcing and the intrinsic difference in the mobilities of the particles.