Buoyant forces in active Brownian particles?

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Active Brownian Particles (ABP) are known to accumulate close to walls [1], how do passive particles behave in such dense fluids? The ABP model introduces particles with spherical symmetry, and diameter σ_a, diffusing in a thermal bath with an out-of-equilibrium characteristic: ABPs have the intrinsic ability to self-propel in a given direction. The orientation of the propulsion diffuses in time, and thus defines a dimensionless number that compares propulsion to rotational diffusion the so called 'Péclet' number, Pe.

It has been previously reported that ABPs propelling towards a wall find themselves an increase of their residence time in contact to the wall. Active particles keep propelling towards the wall until their orientations are diffused so that ABPs can escape, the higher the Pe the higher the residence time.

This increase of the residence time close to walls leads to the formation of a dense layers of ABPs for high enough density, and activity [2]. We have characterized the layer thickness, and fluctuations in terms of the activity and introduced probe particles, passive particles or inclusions, to study the emergent forces. This technique has previously been used [3] to study the emergence of forces between pairs of inclusions in diluted suspensions of ABPs. Here we present a series of measures of emergent forces in the interior of the dense phase, and reveal the appearance of buoyant forces even though no gravity intervenes in such microscopic systems.

We define a computational model to simulate the emergence vertical forces of interactions, F_y, between probe particles and the confining walls of the system. In addition, we introduce forces in the centre-to-centre direction between inclusions F_r, see Fig. 1 for a schematic representation of the system.

Measures of the normal force F_y for fixed probes at different heights reveal the emergence of a force that expels the probe particles from the dense phase to the gas phase. In Fig. 2 we present the normal force for pairs of particles separated a surface-to-surface distance either 1.5, or 3 ABP's diameters, and for a sole inclusion $F_y^{(1)}$. Force computations reveal the emergence of a large wall-repulsion force that extends to the whole layer of particles and reaches a long plateau of constant normal force $F_y^{\rm est}$. Then at distances beyond the average thickness of the layers the repulsion decreases, and finally disappears. A detailed analysis of the density field of ABPs close to the inclusion pairs reveals a deformation, and vertical pull of the interface between the dense, and gas fluid ABPs phases mediated by the inclusions. Measures for $d = 3\sigma_a$ reveal minor deviations from results on one particle, while in $d = 1.5\sigma_a$ we report an additional two-body contribution to the normal forces.

In the talk I will introduce a simple calculation to capture the constant vertical force for sole inclusions in the system, and numerically extract the two-body contributions to the buoyant force between pairs. Finally, I will extend this calculations to the relative force between pairs and discuss the effect of the coupling with Z in the emergent pair interactions.

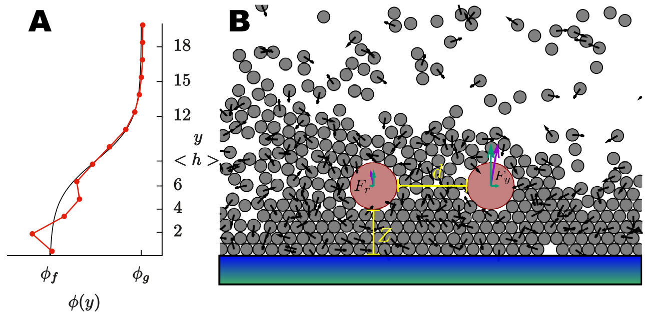

Fig. 1. Accumulation of ABPs close to a wall. (a) Local density of ABPs at a distance y from the wall, the interface is located at $\langle h \rangle$. (b) Sketch of the system with a pair of probe particles in the dense layer of ABPs, in yellow the surface-to-surface distances d for probe-probe distances, and Z for the wall-probe distance. In arrows the radial force F_r, and the normal force F_y on each particle.

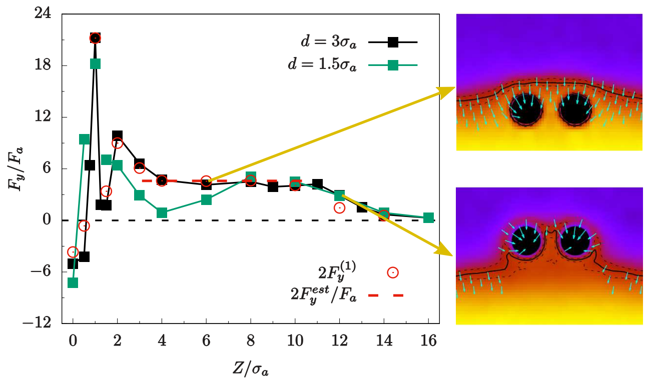

Fig. 2. A pair of inclusions different heights from the surface of the wall for $d = 1.5\sigma_a$, $d = 3\sigma_a$, and two sole inclusions in red dots. The right panels depict the average density field of active particles with arrows pointing in average direction.

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