On the absence of collective motion in a bulk suspension of spontaneously rotating dielectric particles

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A suspension of dielectric particles rotating spontaneously when subjected to a DC electric field in two-dimensions next to a no-slip electrode have proven to be an ideal model for active matter [Bricard et al., 2013]. In this system, an electrohydrodynamic (EHD) instability called Quincke rotation was exploited to create self-propelling particles which aligned with each other due to EHD interactions giving rise to collective motion. It is natural to question whether a suspension of such particles in three-dimensions will also display collective motion and spontaneously flow like bacterial suspensions do. Using molecular dynamics type simulations, we show that dielectrophoretic forces responsible for chaining in the direction of the applied electric field in conventional electrorheological fluids prevent collective motion in suspensions with individual particle rotation. Our simulations discover that the fundamental microstructural unit of a suspension under Quincke rotation is a pair of counter-rotating spheres aligned in the direction of the electric field. We perform a linear stability that explains this observation [Das and Saintillan, 2023].

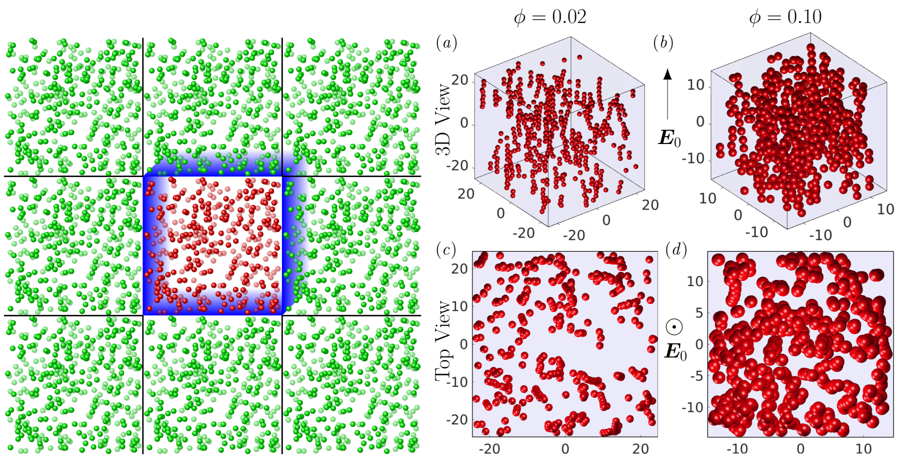

Figure 1. **Left**: Schematic diagram of dielectric particles in a periodic domain subject to an electric field. The physical box is highlighted with blue faces and red spherical particles while their periodic images are shown in green color. **Right**: These three-dimensional plots shows suspensions with Quincke rotation ($E_0/E_c = 2$) at $t = 500$ scaled with τ_{MW} for two different volume fractions, $\phi = 0.02$ (a) and $\phi = 0.10$ (b). Particle number is fixed at $N - 500$ while $L = 47$ for (a) and $L = 28$ for (b). The corresponding top views are shown in (c, d).

References

A. Bricard, J.-B. Caussin, N. Desreumaux, O. Dauchot, and D. Bartolo. Emergence of macroscopic directed motion in populations of motile colloids. *Nature*, 503:95–98, 2013.

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