PhD – Effective rheology of reactive suspensions

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Suspended passive particles introduce microscopic stresses to resist the surrounding's fluid deformation, resulting in an increased shear- and concentration-dependent energy dissipation or effective viscosity. Bacteria and other microswimmers also modify, and can even reduce, the suspension's viscosity by injecting mechanical energy at the micron scale to compensate viscous dissipation [1]. Tuning the rheology of these active suspensions is an important step toward the design of functional metamaterials.

Phoretic particles are interesting synthetic alternatives to biological swimmers in their simplicity and their ability to convert chemical energy into fluid motion and interact with inhomogeneous physico-chemical fields (e.g. a solute concentration). In practice, the surface coating of a phoretic particle can be designed to encode a given hydro-chemical response. This provides a route for controlling their behavior at the collective level and the effective physical properties of a whole suspension (e.g. rheology). Analysing the response of a phoretic suspension requires solving numerically the coupled equations for hydrodynamics and chemical transport. This remains a particularly challenging task for large numbers of particles as a result of the wide range of coupled scales involved (from one micron to several millimeters).

Recently, efficient numerical methods were developped at LadHyX and BCAM to simulate and analyse this coupled hydro-chemical problem for particles with arbitrary shapes [2,3] to simulate the spontaneous organisation of large suspensions in various geometries (Figure 1).

The main objective of this PhD (in collaboration between LadHyX and BCAM) will be to analyse the effective rheology and dynamic response of the suspension to mechanical forcing (e.g. shear flow). To do so, the first step will consist in simple numerical developments of the existing solvers to account for an external forcing by a shear flow. In a second step, the project will exploit these numerical developments to study in detail the evolution of the suspension's rheology with particle density, shape and surface properties, as well as its response to chemical signaling.

Prospective candidates must have a solid background in Microhydrodynamics and Computational Fluid Dynamics.

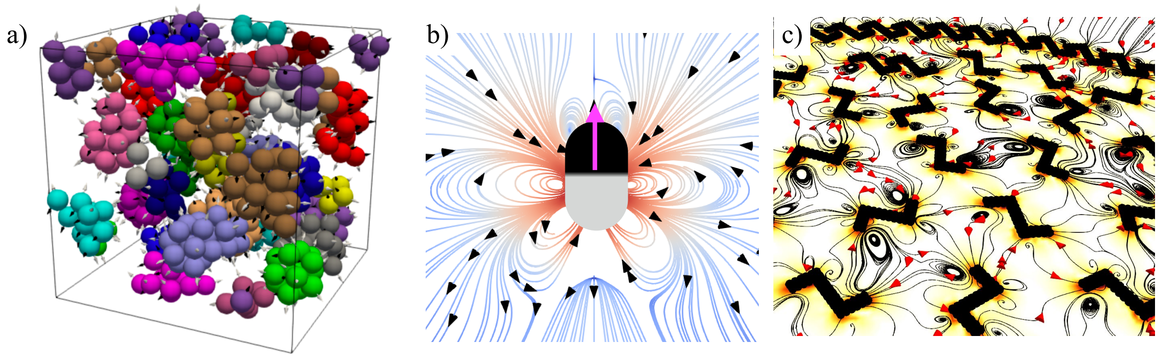

Figure 1 – (a) Self-organisation of a suspension of unforced Janus phoretic particles (i.e. with asymmetric surface properties) into moving clusters. (b) Simulated flow field around a Janus rod above a solid wall. c) Flow field and self-organization due to reactive chiral particles that spontaneously rotate.

References

[1] H. M. López, J. Gachelin, C. Douarche, H. Auradou & E. Clément, 2015 : Turning Bacteria Suspensions into Superfluids, *Phys. Rev. Lett.*, **115**, 028301

[2] F. Rojas-Pérez, B. Delmotte & S. Michelin, 2021 : Hydrochemical interactions of phoretic particles : a regularized multipole framework, *J. Fluid Mech.*, **919**, A22

[3] B. Delmotte & F. Balboa, 2023 : A scalable method to simulate large suspensions of phoretic particle with arbitrary shapes, *to be submitted*