## PhD Position :

# Collective motion in reactive suspensions

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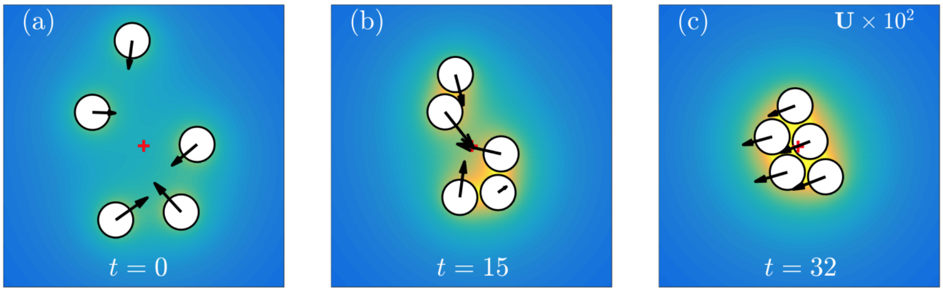
We have all witnessed the flocking of starlings in the sky and the schools of fish that form in the ocean. This kind of organization of living systems is not limited to those that we see, but also occurs for those that we don't : swimming micro-organisms. Suspensions of micro-swimmers, such bacteria or sperm cells, exhibit a rich dynamics. They can form coherent structures due to collective motion, mix the surrounding fluid or tune some of its effective physical properties, such as its rheology. Beyond the fundamental interest in the physical understanding of such "active fluids", their precise modeling is also likely to have applications to the design of new fluid systems with synthetic controllable properties.

More recently, artificial micro-swimmers have been developed to mimic these behaviors, but also to achieve specific functions, such as targeted drug delivery or transport in microfluidic systems. In particular, phoretic micro-swimmers have recently received much attention. These particles react with the surrounding solvent and interact with their neighbors (Fig 1a). The motion of large collections of phoretic particles remains to be explored because of the complex interplay between chemical reactions and hydrodynamic interactions. In this sense, numerical methods offer a promising tool. Yet, an accurate description of the micro-swimmers in a suspension containing thousands (or millions) of individuals, must involve a wide range of coupled scales (from one micron, $10^{-6}$m, to several millimeters, $10^{-3}$m). What happens at large scales depends on sophisticated mechanisms occurring two or three orders of magnitude below. Therefore, efficient numerical methods are needed to simulate such systems at the macroscopic scale, while keeping an accurate description at the individual level.

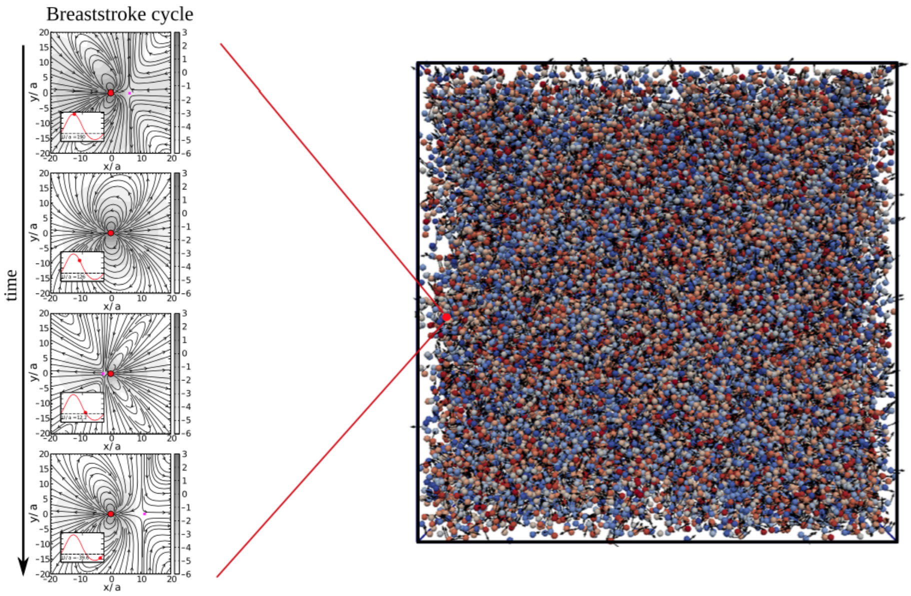
This PhD project aims to design such a versatile yet accurate method that is able to account accurately for the different interaction routes between a large number of particles, and as such will extend a well-known numerical method used to simulate the hydrodynamic behavior of particle suspensions : the Force Coupling Method (FCM). FCM has already been used to simulate suspensions of magnetic particles and micro-swimmers at very large scales (cf. Fig 1b). This project will generalize this approach to the coupling of the detailed swimming motion of the colloids to the diffusive dynamics of a chemical solute. In a second part, this framework will then be used to analyze the collective behaviour of phoretic colloids within suspensions and their response to external stimuli.

**Profile :** Prospective candidates must have a solid background in Microhydrodynamics, Computational Fluid Dynamics and Programming.

**Funding :** This position is fully funded by the European Research Council, starting on October 1st, 2019.




(a) Clustering of phoretic micro-swimmers due to the coupling between chemical reactions and hydrodynamic interactions (Varma *et al.*, *Soft Matter*, 2018).




(b) Simulation of 40000 breast-stroke micro-swimmers immersed in a viscous fluid using the Force Coupling Method (FCM) (Delmotte *et al.*, *J. Comp. Phys.*, 2015).

**Environment :** The doctorate studies will be held at LadHyX (Ecole Polytechnique), a research institution recognized worldwide for its expertise and leadership in hydrodynamics. He/she will benefit from a highly stimulating, dynamic and multidisciplinary environment, including experts on soft matter, low-Re flows, aerodynamics, biomechanics, fluid-solid interactions and geophysical flows.

This work will be part of a broader ERC research project, CollectSwim, led by Dr. Michelin on the modeling and control of active fluids.

**Application :** Interested candidates should contact us as soon as possible, including a CV, a description of their past research experience and motivation to join this project, and the name of two academic references.