Collective dynamics of chemically-active droplets

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What are chemically-active droplets ?

In recent years, synthetic "micro-swimmers" have fascinated many researchers for their potential biomedical applications (e.g. targeted drug delivery) or to understand self-organization and collective motion in small-scale physical systems (in contrast with crowds and fish school dynamics). Unlike miniaturized robots, chemically-active droplets have no moving parts, require no microscopic assembling, and draw their chemical energy directly from their immediate environment, thus allowing for much simpler and cheaper designs. They swim by combining a physico-chemical *activity* (their slow solubilization in the outer fluid) and their Marangoni *mobility* (i.e. the ability to generate interfacial stresses in response to surface chemical gradients) [1].

In contrast with diffusion-dominated systems, convective transport of large surfactant molecules plays a dominant role for active droplets and introduces a nonlinear coupling of the flow and to the chemical transport. This poses great modelling challenges but also introduces many new and rich dynamical features for individual droplets that have been the focus of intense research at LadHyX in recent years : spontaneous symmetry-breaking to generate propulsion [1,2] or secondary-transitions to complex trajectories [3].

The project

As a result, their collective behaviour is profoundly different from other micro-swimmers, and will be central to the present PhD project. Building upon our recent complete modelling of binary collisions [4] and the development of a powerful effective collision model [5], the project will analyse the long-time statistical and effective behaviour of large assemblies of chemically-active droplets using a combination of analytical and numerical methods.

Note : depending on the student's interest and progress on the topic, this internship can be continued onto a PhD.

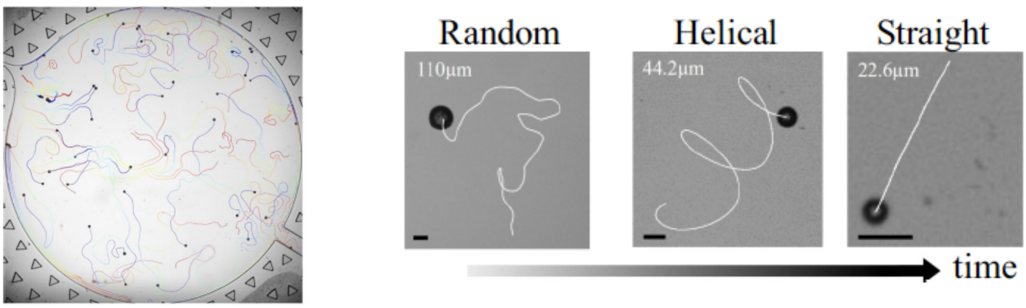

Figure 1 – (Left) Collective dynamics of active droplets in a microfluidic chamber [2](Right) Transition in the trajectory shape of liquid-crystal droplets [4].

References

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[4] K. Lippera, M. Morozov, M. Benzaquen & S. Michelin, 2020 : Collisions and rebounds of chemically-active droplets, *J. Fluid Mech.*, **886**, A17

[5] K. Lippera, M. Benzaquen & S. Michelin, 2020 : Alignment and scattering of colliding active droplets, *Soft Matter*, **17**, 365–375