M2 Research internship

Marangoni propulsion

The presence of surfactant such as amphiphilic molecules at the air-water interface may locally alter the surface tension and induce a flow in the underlying water, as exemplified in the celebrated tears of wine phenomenon. Such Marangoni effects have a long history - with early observation dating back to 1557- but their study has received a new impetus with the current interest in active matter. Indeed, they can be exploited to design "Marangoni swimmers": macroscopic particles without moving parts that spontaneously self-propel at the surface of water (image). Such swimmers have been developed in our team [1] where their behavior was shown to motivate a host of questions, from their individual propulsion to striking collective properties, such as active turbulence [2].

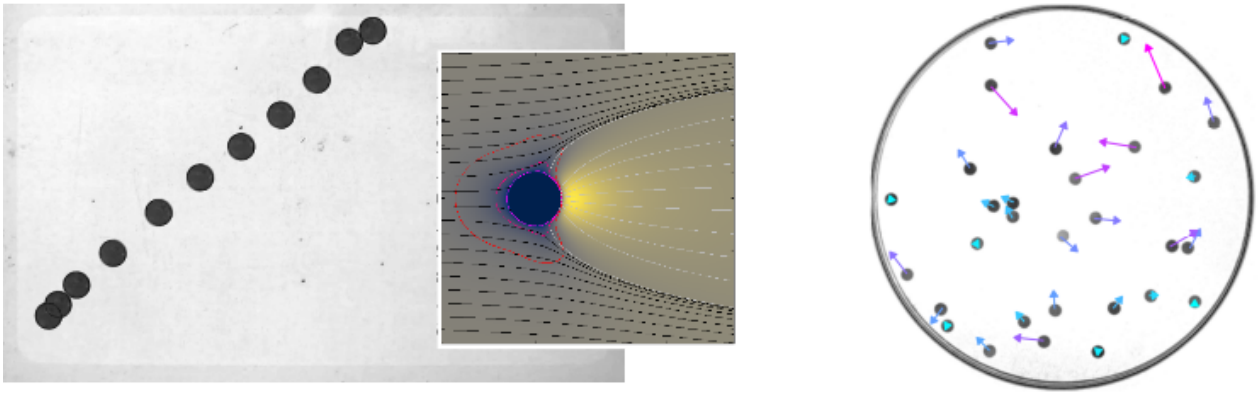

Figure: (Left) Top view of one Marangoni swimmer in a pool. Inset: simulated flow. (Right) Assembly of swimmers.

As regards the propulsion mechanism, recent results suggest a picture more complex than anticipated, with surface tension effects that act through different paths. In particular, Marangoni flows display a surprisingly ambivalent contribution that changes from motor to resistive depending on the situation.

The goal of the internship is accordingly to investigate the role of Marangoni flows in the propulsion mechanism. To do so, the student will aim at a simultaneous experimental characterization of the force and flow that develops around a swimmer moving at *imposed velocity*, by using techniques such as PIV and cantilever force sensor. The measurement will also be helpful to assess theoretical models.

On the longer term, the various modes of motion of Marangoni swimmers, their interactions with a wall and with each other, the resulting collective effects, as well as the possibility of Marangoni pumps, are all phenomena that remain to be understood. The student will combine experimental investigation and exploration of simplified models to develop a clear physical picture. This topic lies at the confluence of soft matter, fluid mechanics and statistical physics.

Opening toward a PhD: yes (funding with «bourse ministère»).

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References

[1] Self-propulsion of symmetric chemically active particles: Point-source model and experiments on camphor disks Boniface, Cottin-Bizonne, Kervil, Ybert and Detcheverry, *Physical Review E* (2019).
[2] Kolmogorovian active turbulence of a sparse assembly of interacting Marangoni surfers, Bourgoin, Kervil, Cottin-Bizonne, Raynal, Volk and Ybert, *Physical Review X* (2019).