Internship Proposal

Collective dynamics of micro-organisms: plume migration

Where? Institut Jean Le Rond ∂'Alembert, Sorbonne Université, Paris.
With whom? Hélène de Maleprade & Francesco Picella*
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Micro-organisms are at the foundation of our ecosystem, and their resilience in face of pollution and climate change is crucial to the survival of higher life classes. It is therefore necessary to understand the spontaneous dynamics of microorganisms in order to anticipate their reaction towards the introduction of an external parameter.

The green microalga Chlamydomonas Reinhardtii (CR) is a model microorganism, representative of unicellular and bi-flagellate eukaryotes. A dense solution of these microalgae spontaneously destabilises to form *plumes* (Fig. 1) [1]. The center of the plumes appears black, indicating an area of high algal concentration. Surprisingly, currents generated in these convection cells are up to 10 times faster than the swimming speed of a single microalgae itself. The wavelength that naturally appears in this pattern is proportional to the depth of the solution, and the plumes are statistically steady. But, what happens when the thickness of the solution is not constant?

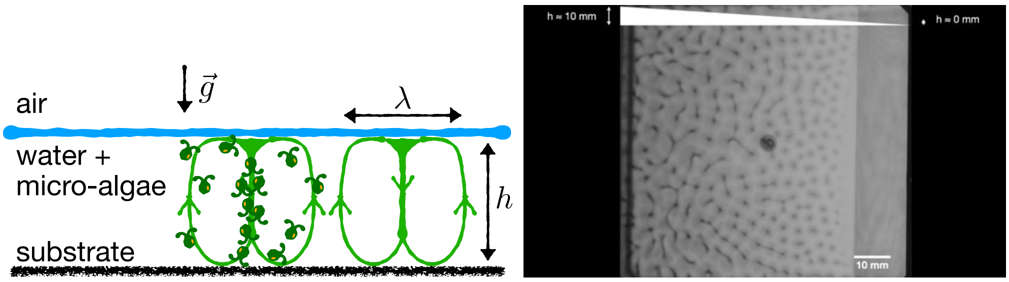

Figure 1: (Left) Sketch of CR plume, side view. Inner column, characterised by higher algae concentration, tends to sink, due to high algae density, while outer ring tends to swim upwards. Cell size */lambda* is proportional to liquid depth h. (Right) top view from an experiment, with the onset of plume patterns in a CR solution. Black dots characterise areas of high algal concentration. Depth of the container linearly decreases from 10 (left) to 0 (right) mm.

Indeed, when depth varies, the size of the convection cells changes proportionally. When two vortexes of different sizes are close, how do they interact? Does a vortex of greater or lesser amplitude attract or repel its neighbors? Also, these vortices are themselves asymmetrical, resting on an inclined substrate: is there any *net* propulsion? And what is the self-propulsion dynamics of an individual vortex? To answer these questions, the trainee will conduct an experimental study combining microscopic and macroscopic dynamics. He/she will follow the movement of plumes through a parametric study combining physical factors (angle, concentration) and biological factors (motility of micro-algae *via* mutants). Experimental results will help to discriminate between inertial and viscous propulsion hypotheses, in order to develop a theoretical hydrodynamic model. Numerical modelling of the problem will extend understanding of the phenomenon to the mesoscopic scale, unreachable by experiments due to the opacity of the solution.

During the 6-month internship, the trainee will spend one month setting up the experiments and the optical set-up for observation, two months following the dynamics of the plumes on a macroscopic scale, one month looking at the microscopic scale and finally two months modelling the physical phenomenon. We are looking for an M2 student with strong interests in experimental work together with modelling and simulation of *coupled* physical systems, at the boundary of biology, active matter and fluid mechanics. Knowledge in *hydrodynamic stability* is advisable but not mandatory. This project is supported by *Institut de l'Ocean*, Sorbonne Université.

References

[1] John O. Kessler. Co-operative and concentrative phenomena of swimming micro-organisms. *Contemporary Physics*, 26(2):147–166, March 1985.

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