香 港 大 學
THE UNIVERSITY OF HONG KONG

Internship/PhD proposal

Collective phototaxis of colonial swimming microorganisms

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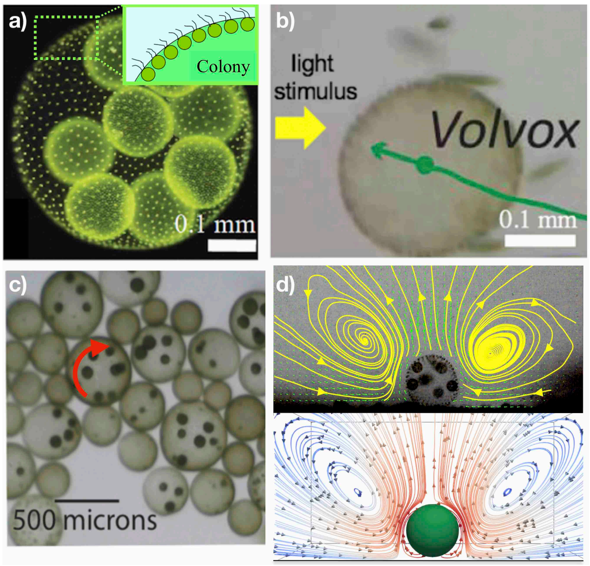
Start date: anytime from Feb. 2024

Context: Biological microswimmers develop versatile taxis strategies to adapt to their environments in both an individual level and a population level. Using the microorganism *Volvox* we recently observed quite interesting behaviors: at an individual level *Volvox* exhibits directional phototaxis towards the light source (Fig. 1b), where the phototaxis mechanism can be explained by the orchestral coordination of the many cilia from individual somatic cells on its surface (Fig 1a). At a population level where the density of *Volvox* in the fluid is high, we observed that a population of *Volvox* exhibits distinct collective dynamics compared to individual behavior in response to light stimuli, where hundreds of *Volvox* cells form a stable, rotating two-dimensional layer of active crystal (aggregate) suspended in a three-dimensional fluid chamber (Fig. 1c).

Volvox maneuver and stir fluids using synchronized movement of cilia, all of which are minuscule compared to the cell body size (Fig 1a). Yet, the mechanism of how individual's mechanical responses lead to complex collective responses remain incompletely understood. A fundamental challenge is how to obtain a computationally scalable model with a high accuracy on the mechanical details that bridge the individual and collective responses, which is currently lacking in existing models.



a) Microscope view of Volvox with its ciliated surface. b) Phototaxis of an isolated Volvox. c) Cluster of rotating Volvox cells formed by collective phototaxis. d) Measured and simulated flow around one Volvox near a wall.

Goals: In this project, we aim to establish a novel mechanistic framework that integrates experiments, theoretical analysis, and simulations to capture quantitatively the hydrodynamic interactions governing both individual and collective behaviors of microorganisms. Our proposed model captures active surface stresses of microorganisms that modulate spatiotemporally to mimic the forces exerted by their motile appendages. The stress distribution will be deduced via optimal control strategies and AI based on experimental data of fluid flows and surface movements around one or multiple cells subject to diverse stimuli and wall boundaries (Fig. 1d, preliminary results). We will integrate the deduced stress profiles into our computational tools to capture and obtain a full mechanistic understanding of the experimentally observed behaviors. These deduced stress profiles will subsequently be integrated into our computational tools, specifically adapted for large suspensions, to explore the captivating collective behaviors observed in our experiments.

The modelling and simulation parts will be carried out at LadHyX (Ecole Polytechnique) using the framework and numerical tools developed in the lab, in close collaboration with the group of Prof. Alan Cheng Hou Tsang at Hong-Kong University where experiments are performed.

Profile: Candidates must have a taste for numerical modeling, basic knowledge of Python, with good training in fluid mechanics or soft matter.

Environment: LadHyX is a world-renowned laboratory in fluid mechanics and interdisciplinary research at Ecole Polytechnique, near Paris. The intern/future doctoral student will benefit from interactions with other colleagues from LadHyX, collaborators from BCAM in Bilbao (Dr F. Balboa-Usabiaga), in addition to trips to the University of Hong Kong.

Contact: please send a CV, cover letter, and the name and email address of at least one reference to blaise.delmotte@ladhyx.polytechnique.fr.