School of Mathematics and Statistics
Faculty of Science, Technology, Engineering and Mathematics

2026 PhD Projects

Project title	Hydrodynamic interactions of active microswimmers in surfactant layers
Principal supervisor	Dr. Abdallah Daddi-Moussa-Ider
Second supervisor	Dr. Elsen Tjhung
Discipline	Applied mathematics
Research area/keywords	Active matter, microswimmer, hydrodynamics, dual integral equations
Suitable for	Both full-time and part-time applicants

Project background and description

The goal of this project is to advance the development of a theory for the motion of self-propelled surfers in thin structured films and membranes. Particularly, this project focuses on understanding the dynamics of membrane-bound active objects, which play a crucial role in various biological and physical chemistry processes. Specifically, we aim to study the motion of swimming objects within a viscous surface film that lies atop a fluid of finite depth. The fluid dynamics will be modelled through a system of dual integral equations. We will investigate how different length scales in the system influence the swimming behaviour, providing insights into the interplay between surface viscosity, film thickness, and fluid depth.

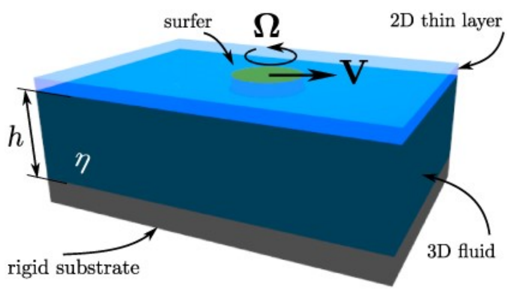

Figure 1: A disk-shaped microswimmer embedded in surfactant layers atop a finite-depth subphase.

We will model the swimmer as a squirmer, embedded in surfactant layers in the presence of a finite-depth subphase. A squirmer is a theoretical model used to describe a self-propelled particle that moves by generating surface flows rather than through external forces or body deformation. It is modelled here as a disk-like object with a prescribed tangential velocity at its surface, which mimics the propulsion mechanism of organisms like ciliates or bacteria. The squirmer model captures the fluid dynamics around the active swimmer, allowing for analysis of its movement and interactions with the surrounding medium. We aim to characterize the translational and rotational swimming velocities and investigate the impact of geometric confinement on the overall dynamics. Following this, we will explore the hydrodynamics of swimmer pairs and potentially study suspensions of multiple microswimmers moving within the surfactant layer.

Background reading/references

- A. Daddi-Moussa-Ider, E. Tjhung, T. Richter, and A. M. Menzel, Hydrodynamics of a disk in a thin film of weakly nematic fluid subject to linear friction, *J. Phys.: Condens. Matter* **36**, 445101 (2024).
- A. Daddi-Moussa-Ider, E. Tjhung, M. Pradas, T. Richter, and A. M. Menzel, Rotational dynamics of a disk in a thin film of weakly nematic fluid subject to linear friction, *Eur. Phys. J. E* **47**, 58 (2024).