Pilot-wave dynamics of swimming particles in stratified fluids

M2 internship (5-6 months)
Location : IRPHE, 49 Rue F. Joliot Curie 13013 Marseille
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Grant: ~600 euros/month
Starting date: February 2026 (flexible)
PhD opportunity: encouraged to apply to the doctoral school PhD call after the internship
Keywords. Wave-particle interactions ; Collective behavior ; Pilot-wave hydrodynamics

Context. Over the past two decades, experiments with bouncing droplets have shown that macroscopic “pilot-wave” systems - where a particle is guided by its self-generated wave - can mimic certain aspects of quantum-like dynamics [1]. We recently demonstrated that similar dynamics emerge when a particle oscillates in a density-stratified fluid [2–3], such as in the ocean. The oscillating particle emits internal gravity waves and begins to swim horizontally due to a Doppler effect that creates a non linear propulsive force. These waves propagate over large distances, reflect on boundaries, and can strongly modify—or even cancel—the particle's motion. **A key open question now concerns collective states: how groups of such particles interact through their wave fields** [4]. This internship will focus on the simplest case—a pair of particles in the same horizontal plane—using experiments, theory, and simulations.

Objectives. The goal of the project is to **systematically explore pairwise interactions between oscillating particles**. We will:

- Investigate different collective behaviors (attraction, repulsion, oscillations, etc.) as system parameters vary (wave frequency, Froude number, Reynolds number).
- Build and compare phase diagrams from experiments and simulations.
- Develop simple theoretical models to rationalize observations.

These results will provide the foundation for studying larger ensembles of particles, which could be pursued in a PhD project.

Method. The student will work with:

- An existing **experimental setup based on the *ludion principle***: rigid capsules with an internal air bubble, whose buoyancy is modulated by controlled pressure oscillations.
- A **2D lattice-Boltzmann simulation code** to model wave-particle interactions.

Candidate profile. We welcome motivated Master's students in physics, fluid mechanics, applied mathematics, or related fields. Some familiarity with experimental work or numerical simulations is a plus, but enthusiasm and curiosity are most important.

[1] Bush & Oza, *Rep. Prog. Phys.*, 2020. doi:10.1088/1361-6633/abc22c
[2] Le Gal et al., *J. Fluid Mech.*, 2021. doi:10.1017/jfm.2021.931
[3] Gsell & Le Gal, *Phys. Rev. Fluids*, in press. doi:10.48550/arXiv.2501.04402
[4] Couder et al., *Nature*, 2025. doi:10.1038/437208a

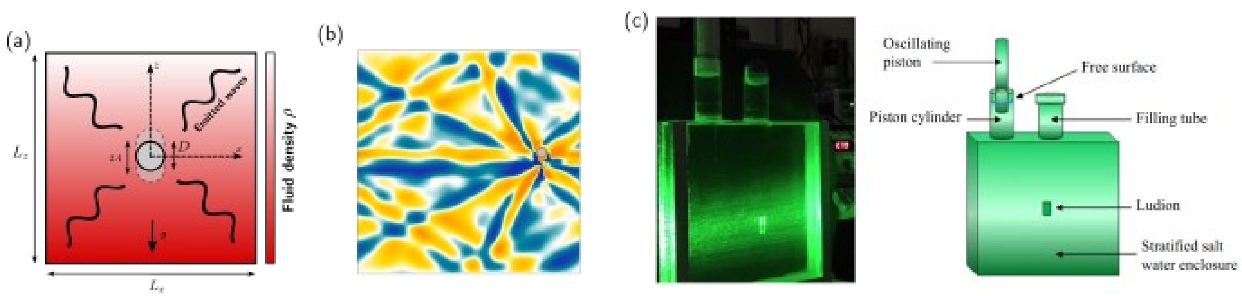

Fig. 1- *(a) Schematic view of an oscillating particle emitting gravity waves in a density-stratified fluid. (b) Simulated wave field around an oscillating particle. (c) Photograph and schematic of the experimental setup.*