PhD offer – Institute 3IA Côte d'Azur

Where Do Microplastics Go?

AI-Based Optimization of Flexible Particle Shapes in Turbulent Flows

Supervisors and location

- **Supervisor:** Christophe Eloy, Centrale Méditerranée, IRPHE
- **Co-supervisor:** Laetitia Giraldi, INRIA Côte d'Azur
- **Laboratory:** IRPHE, Centrale Méditerranée, Marseille

Project

Microplastic pollution has become a major environmental concern, yet the mechanisms governing the transport and accumulation of microplastics in natural flows remain poorly understood. Previous studies have shown that rigid non-spherical particles, such as ellipsoids or fibers, preferentially sample specific regions of turbulence, often accumulating in zones of high vorticity or strain. However, we do not know how the shape and flexibility of particles control their preferential sampling of turbulence. The main objective of the thesis is to optimize particle shapes and mechanical properties to maximize sampling of specific regions of a turbulent flow.

To achieve this goal, the project will rely on physical modeling combined with artificial intelligence–based optimization techniques. The particle dynamics will be studied in the Stokes flow regime, with elastic deformations projected onto a finite-dimensional space. Flexible particles will be modeled as assemblies of rigid spheres, allowing their dynamics to be formulated as systems of linear ordinary differential equations. Bayesian Optimization and Reinforcement Learning methods will be employed to solve the inverse problem of shape and flexibility optimization under targeted objectives. These approaches will be tested in flows of increasing complexity, including cellular flows, stationary, and fully developed turbulence.

Practical information

This work will be supervised by Christophe Eloy (IRPHE, Centrale Méditerranée), whose work spans fluid-structure interactions and

reinforcement learning, Laetitia Giraldi (Calisto, INRIA), an expert in mathematical modeling, optimal control, and Bayesian optimization.

Expected skills

We are looking for a candidate with a Master 2 degree in physics, mechanical engineering, or applied mathematics. We expect a strong background in optimization and machine learning. Good coding skills in Python, PyTorch are welcomed.

Application

Applications should contain a CV, a motivation letter, the grade records of the last two years, and the names and contact information of two references. Applications should be sent by email to christophe.eloy@centrale-med.fr.

References

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- E. Lauga, T. R. Powers, The hydrodynamics of swimming microorganisms. *Rep. Prog. Phys.* **72**, 096601 (2009).
- M. Niazi Ardekani *et al.*, Sedimentation of inertia-less prolate spheroids in homogenous isotropic turbulence with application to non-motile phytoplankton. *J. Fluid Mech.* **831**, 655-674 (2017).
- J. R. Picardo, D. Vincenzi, N. Pal, S. S. Ray, Preferential sampling of elastic chains in turbulent flows. *Phys. Rev. Lett.* **121**, 244501 (2018).
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