Internship + PhD proposal

Periodic and chaotic fiber deformation in porous media

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Start date: anytime from Jan. 2025
Thesis possibility after internship: YES / Funding : doctoral school fellowships

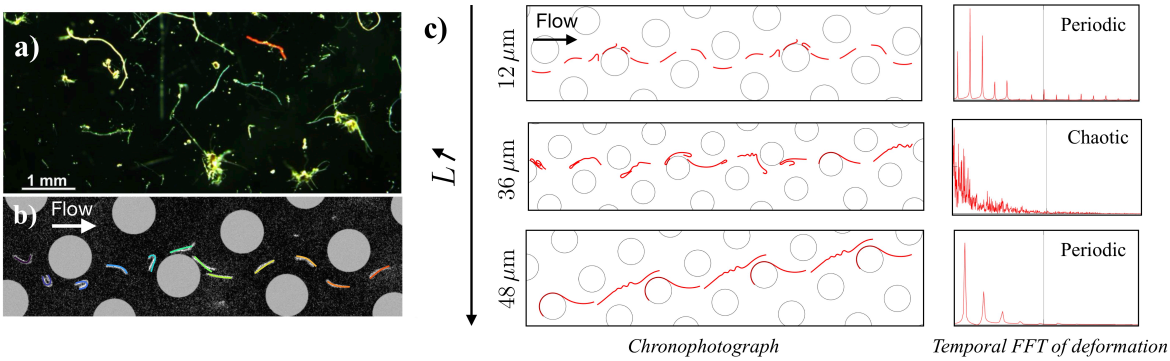

Figure 1: a) Microplastic fibers [1]. b) Chronophotograph of a flexible fiber flowing in a periodic square lattice. Experiments (grey scale) and simulation (colored by time) are overlaid [3]. c) Left panels: chronophotographs of flexible fibers of increasing length flowing in the periodic lattice. Right panels: Temporal Fourier transform of the fiber deformation showing clear peaks for short and long fibers (periodic deformation) and a noisy signal for intermediate length (chaotic deformation).

Context: the separation of elongated and/or deformable particles, such as microplastic fibers [1] (Fig. 1a) or pathogens, using structured media, such as pillar arrays, is essential for many processes such as pollution control, environmental assessments, diagnosis or biological analysis. However, it remains a highly challenging task due to the extensive range of morphologies fibers can adopt when interacting with flows and obstacles [2,3]. **Predicting and controlling** the trajectory of elongated elastic structures in a flow embedded with obstacles is essential to understand the **physics of biological and industrial systems but also to design efficient separation techniques.**
In our recent collaborative works, which combine experiments and simulations, we found that, when flowing in a periodic lattice of rigid cylindrical pillars, flexible filaments can exhibit a wide variety of migration patterns controlled by their length relative to the lattice spacing in a non-trivial way (Fig. 1b-c) [3]. In particular, we showed that repeated interactions with the obstacles could induce lateral migration of fibers within a given length range, and used this length-dependent motion to sort flexible fibers by size. More surprisingly, we found that the time evolution of the fiber deformation could transition between periodic and chaotic behaviors depending on their length relative to the lattice spacing (Fig. 1c). These transitions and the exact order parameters that control this complex dynamical system must be understood to predict fiber motion in crowded environments.

Goals: The aim of this project is to investigate the migration of flexible fibers due to pressure-driven flows in structured media embedded with obstacles using theoretical models and numerical simulations. The intern will use theoretical analysis and numerical tools developed by the group of Blaise Delmotte, and will collaborate closely with the groups of O. du Roure and A. Lindner, where experiments are performed. She/he will first study numerically the occurrence of periodic and chaotic migration patterns and then investigate the influence of the fiber parameters (aspect ratio, flexibility) on the transition between these regimes. She/he will build a simplified model, with fewer degrees of freedom, to find which physical ingredients are needed to reproduce and understand these transitions.

Profile: Candidates must have a taste for numerical simulations and theory, 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 to regular interactions with the groups of A. Lindner and O. du Roure at PMMH.

References
[1] Kane, I. A., & Clare, M. A. (2019). Dispersion, accumulation, and the ultimate fate of microplastics in deep-marine environments: a review and future directions. *Frontiers in earth science*, *7*, 80.
[2] Du Roure, O., Lindner, A., Nazockdast, E. N., & Shelley, M. J. (2019). *Annual Review of Fluid Mechanics*
[3] C. Bielinski, Z. Li, A. Lindner, B. Delmotte and O. du Roure, A band-pass filter for sorting flexible fibers, *in preparation*.