Master 2 internship proposal

Physique et Mécanique des Milieux Hétérogènes

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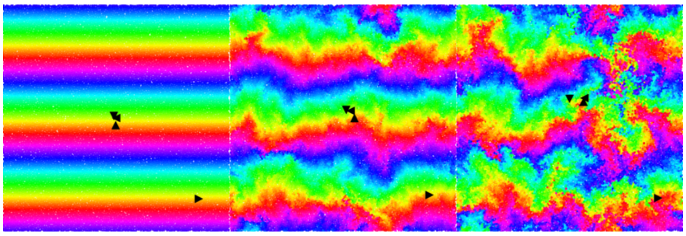
Internship location: PMMH, Sorbonne Université (Jussieu), 7 quai Saint-Bernard, Paris 5[e]
PhD opportunity: No
Possibility of M1 internship: Yes

Active turbulence of self-propelled deformable particles

Active materials (*e.g.* driven colloids, cells, organisms) are nonequilibrium systems whose components consume energy to generate forces and which generically display emergent collective flows [1]. Active turbulence is an umbrella term which describes, in these systems, chaotic advective flows similar to inertial turbulence [2]. Contrarily to inertial turbulence though, these may emerge without inertia and without injecting energy on a global scale. While descriptions of active turbulence have traditionally focused on the specific symmetries of the agents, namely polar or nematic, it was shown recently that self-propelled spheres also display this behaviour [3].



This internship will evaluate whether deformable self-propelled particles, which display local nematic order when their relative sliding is penalised [4], generate active turbulent flows similar to or intermediate between self-propelled and nematic active particles. The first goal of this internship is to implement the new method introduced by Ref. [5] to model deformable particles into the software `HOOMD-blue` to perform molecular dynamics simulations on GPU. The second goal is to characterise active turbulence in this system, using kinetic energy spectra and two-point dynamical correlations [3], as a function of the degree of nematic alignment in the system.

References

[1] Y.-E. Keta, R. L. Jack, and L. Berthier, "Disordered collective motion in dense assemblies of persistent particles", *Phys. Rev. Lett.* **129**, 048002 (2022).

[2] R. Alert, J. Casademunt, and J.-F. Joanny, "Active turbulence", *Annu. Rev. Condens. Matter Phys.* **13**, 143 (2022).

[3] Y.-E. Keta, J. U. Klamser, R. L. Jack, and L. Berthier, "Emerging mesoscale flows and chaotic advection in dense active matter", *Phys. Rev. Lett.* **132**, 218301 (2024).

[4] M. Chiang, A. Hopkins, B. Loewe, M. C. Marchetti, and D. Marenduzzo, "Intercellular friction and motility drive orientational order in cell monolayers", *Proc. Natl. Acad. Sci. U.S.A.* **121**, e2319310121 (2024).

[5] N. Saito and S. Ishihara, "Cell deformability drives fluid-to-fluid phase transition in active cell monolayers", *Sci. Adv.* **10**, eadi8433 (2024).

Expected skills: This project in mainly numerical thus the prospective student should be proficient with at least Python; C++ or CUDA would be a plus. Knowledge in molecular dynamics simulation, (nonequilibrium) statistical physics, and stochastic processes is welcome but not mandatory.