Phase separation of active fluids on substrates

Nom des responsables du stage ou thèse: Ananyo Maitra and Cesare Nardini
(Theoretical & numerical internship, possibly leading to a Ph.D.)

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Téléphone : 06 32 33 27 70 **Lieu du stage**: Saclay and Jussieu
Stage pouvant déboucher sur une thèse : OUI **Financement proposé** : OUI (stage)

In a nutshell: Phase separation of active systems on substrates. Possible collaboration with an experimental group.
Expected skills: Basic training in statistical mechanics. Interest in continuing for a PhD.

Active systems are formed of units that are able to extract energy from the environment and dissipate it to self-propel, and are found everywhere in nature: flocks of birds, suspensions of bacteria or tissues are all biological active systems. Recently, scientists have built synthetic active systems in the lab, using catalytic colloidal particles or micro-robots. Future applications may encompass the engineering self-assembling materials using active units, considered as a defining agenda in the community [1].

Much of the recent advancement in the statistical mechanics of active matter has come from examining the simplest possible example of phase transition—phase separation [4,5]. This is ubiquitous in active systems e.g., tumors are phase-separated from heallty tissues, or protein-rich condensates deeply affect the structure of cells. In the last 15 years, minimal models of phase-separating active systems have been studied both theoretically and experimentally. Part of this work has been devoted to understand whether quantities such as pressure or interfacial tension can be defined out of equilibrium. Yet, our understanding is still very far from being complete: most theories assume that the particles are all identical, and that these move in void.

The internship is planned as a well-defined entry point in the problem of characterizing phase separating active systems, and it can be naturally continued for a PhD. A combination of analytical and numerical work is envisaged.

You will start from building a minimal model inspired by a recent experiment, in which vertically vibrated active rods are immersed in a compressible media made of passive spherical beads [2]. Here, an ordered array of elongated active particles can solidify a macroscopic bead domain; this is a novel kind of phase separation between a passive solid and an ordered active fluid whose macroscopic properties remain so far unexplained.

If continued for a Ph.D., the project will develop by diving in the characterization of active phase separation. Questions we will address encompass:
1/ What impact does it have that active particles usually move in a fluid (while such feature is often forgotten at theoretical level) [3] ?
2/ Can we predict the interfacial tension of phase-separated biological tissues [6]?
3/ Can we characterize the shape fluctuations of biomolecular condensates in cells [7]?
4/ How chirality in the motion of active particles affects phase separation?

During your Internship, you will be supervised by A. Maitra and C. Nardini (PIs) and collaborate with S. Burekovic (a Ph.D. student working with us). A collaboration with the group of S. Ramaswamy (IISC Bangalore, India) is also foreseen. The skills required are a Master-level training in theoretical or statistical physics; no experience on active matter or biophysics is required. What you do not know and is needed, you will learn!

[1] C. Marchetti et al., Rev. Mod. Phys. **85**, 1143 (2013). [2] R. Kant et al., arXiv: 2403.18329 (2024). [3] A. Tiribocchi et al., Phys. Rev. Lett. **115**, 188302 (2015). [4] E. Tjhung, C. Nardini, M. Cates, Phys. Rev. X **7**, 021007 (2017). [5] J. Tailleur, M. Cates, Annu. Rev. Condens. Matter Phys. **6**, 219 (2015). [6] L. Balasubramaniam et al., Nat. Mater. **20**, 1156 (2021). [7] C.A. Weber, et al., Rep. Progr. Phys. **82**, 064601 (2019).