PROPOSITION DE SUJET DE STAGE DE M2 ET/OU DE THESE

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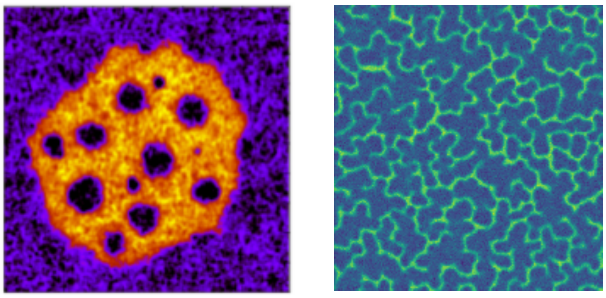
Lieu du stage: Saclay/Paris
Stage uniquement : NON Thèse uniquement: NON
Stage pouvant déboucher sur une thèse : OUI
Financement proposé : OUI (stage) si oui, type de financement : OK pour stage

Controlling phase separation in active systems

Expected skills: Knowledge of basic statistical physics; interest in using both analytical and numerical techniques; knowledge of field theories and soft matter is considered as a plus but is not mandatory. Interest in continuing the project for PhD after the internship.

Examples of active systems, formed of units that are able to extract energy from the environment and dissipate it to self-propel, are found everywhere in nature: flocks of birds, animal swarms, suspensions of bacteria or tissues are all biological active systems. Recently, scientists have built synthetic active systems using catalytic colloidal particles or micro-robots; active matter is a class of soft materials capable of new forms of self-organization. Furthermore, active systems have theoretically fascinating properties, a fact that drove a very intense research activity lately. Future applications may encompass the engineering self-assembling materials using active units, considered as a defining agenda in the community.
Large assemblies of active units display collective phenomena that are absent in equilibrium. One of the most ubiquitous is phase separation, where even repulsive but active particles phase separate into dense and dilute phases. In some cases, this resemble to liquid-vapor phase separation of standard fluids. Due to broken time-reversibility, however, active systems often shows very different features from liquid-vapor phase separation, and currents in the steady state: the dense regions can support a population of mesoscopic vapor bubbles (bubbly phase separation, resembling to a boiling liquid), or the vapor-liquid interface can be unstable, giving rise to active foam states. Even basic properties of phase separated system such as interfacial tensions are qualitatively impacted by activity.



Non-equilibrium types of phase separation arising in active systems due to negative surface tensions. Shown is the density field (bright colors denote dense regions). Bubbly phase separation (Left) and an active foam state (Right). One of the main goals of this project is to control such phases in particle-based models.

The main open theoretical question is how to control these novel states of matter in terms of microscopically tunable parameters. The main goal of this internship is to start filling this gap. We will employ both analytical (coarse-graining techniques, stochastic calculus, field theoretical analysis) and numerical techniques (direct numerical simulations of particle systems and field theories). The project is well suited to be continued during a PhD (subject to funding). On the long-term, this work will provide a guide for experimentalists to design novel self-assembling materials using active units.

References:

E. Thjung, C. Nardini, M.E. Cates, PRX, **8**, 031080, 2018; J. Tailleur, M.E. Cates, Ann. Rev. Cond. Mat., **6**, 219, 2015; G. Gommper et al., Journal of Physics: Condensed Matter **20**, 193001, 2020; G. Fausti et al., PRL **127**, 068001, 2021.