Spécialité : PHYSIQUE / Physique statistique

Laboratoire : /SPEC/SPHYNX

# Contrôle de la séparation des phases dans les systèmes de matière active


## Responsable de stage : NARDINI Cesare

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Stage pouvant se prolonger en thèse : Oui
Durée du stage : 3 mois


**Résumé:**

Les systèmes actifs, depuis les volées d'oiseaux jusqu'aux colloïdes autopropulsés, présentent des comportements collectifs fascinants, cruciaux à la fois en biologie et pour l'ingénierie future d'une nouvelle classe de matériaux mous. Nous étudierons et, nous l'espérons, contrôlerons l'un des plus importants d'entre eux, tant sur le plan informatique qu'analytique, en utilisant des techniques de mécanique statistique hors équilibre.


**Sujet :**

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, these 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: unlike in equilibrium systems, 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, phase separation in active systems often shows very different features from a liquid-vapor phase separation, and currents in the steady state. For example, the dense regions can support a population of mesoscopic vapor bubbles (bubbly phase separation, qualitatively resembling to a boiling liquid), or the vapor-liquid interface is unstable, giving rise to active foam states.

Non-equilibrium types of phase separation arising in active systems. 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, with possible extension to a PhD (subjected on funding), is to fill this gap. We will employ both analytical and numerical techniques, such as direct numerical simulations of particle systems and of continuum descriptions of the system (field theories). If successful, this work will provide a guide for experimentalists to design novel self-assembling materials using active units. Given the ubiquity of phase separation in non-equilibrium contexts, we will further explore the relevance of these results to other out-of-equilibrium systems, such as biological tissues and granular materials. If the stagiare continues with a PhD, the work will be inscribed in a larger collaboration ongoing with researchers in the UK (Cambridge) and Sweden (Lund).

References :
- E. Thjung, C. Nardini, M.E. Cates, Cluster phases and bubbly phase separation in active fluids: reversal of the Ostwald process, PRX, 8, 031080, 2018
- J. Tailleur, M.E. Cates, Motility-Induced phase separation, Ann. Rev. Cond. Mat., 6, 219, 2015
- G. Gommper et al., The 2020 motile active matter roadmap, Journal of Physics: Condensed Matter 20, 193001, 2020

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# Controlling phase separation in active systems

**Abstract:**
Active systems, from flocks of birds to self-propelled colloids, show fascinating collective behaviors crucial both in biology and for the future engineering of a new class of soft materials. We will study, and hopefully control, one of the most important of these both computationally and analytically by using techniques from non-equilibrium statistical mechanics.

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