Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Internship location: Luxembourg
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: University of Luxembourg

Dissipation-induced transitions in active matter

Active matter emerged in the last decade as the class of nonequilibrium systems where every constituent extracts energy from its environment to produce an autonomous directed motion [1]. Examples of active systems can be either biological, such as swarms of bacteria, or synthetic, such as self-catalytic colloids in a fuel bath. The combination of self-propulsion and interactions leads to collective effects without any equilibrium equivalent, where the details of microscopic interactions distinguish different classes of dynamics. For instance, a collective polar motion for aligning particles [2], and a phase separation for repulsive isotropic particles [3].

While phase transitions in active matter have already been studied extensively, the role of the dissipation of energy, at the basis of microscopic self-propulsion, has attracted attention only recently [4]. Interestingly, it has been shown that selecting a target dissipation, using a dynamical bias, is a generic route to unexpected phase transitions [5]. At variance with usual transitions, induced by varying the parameters of the dynamics, the *rules* of the dynamics now spontaneously vary to sustain the selected dissipation, yielding effectively novel interactions between the constituents. This generic mechanism opens the door to drawing unprecedented connections between different classes of active matter.

The aim of this project is to study dissipation-induced phase transitions in minimal models of active matter. The study will use both analytical and numerical methods of nonequilibrium statistical mechanics, which all rely on the connection between dynamical bias and large deviation theory [6]. The analytical descriptions will combine particle-based models and hydrodynamic theories. The numerical implementation of the dynamical bias will exploit a recent population dynamics algorithm [7]. Overall, the development of the project will largely build on the crosstalk between numerical and analytical results.

References

[1] Marchetti et al, Rev Mod Phys 85, 1143 (2013)
[2] Chaté, Annu Rev Condens Matter Phys 11, 189 (2020)
[3] Cates and Tailleur, Annu Rev Condens Matter Phys 6, 219 (2015)
[4] Tociu et al, Phys Rev X 9, 041026 (2019)
[5] Nemoto et al, Phys Rev E 99, 022605 (2019)
[6] Jack, Eur Phys J B 93, 74 (2020)
[7] Nemoto et al, Phys Rev E 93, 062123 (2016)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: YES
Quantum Physics: YES Theoretical Physics: YES