Internship and thesis proposal

Laboratory name: **PHENIX** (UMR 8234)
Internship/thesis director : **Pierre ILLIEN**
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Internship location: **Sorbonne Université, place Jussieu, Paris 5ème**
Thesis possibility after internship: **YES (funding: ANR)**

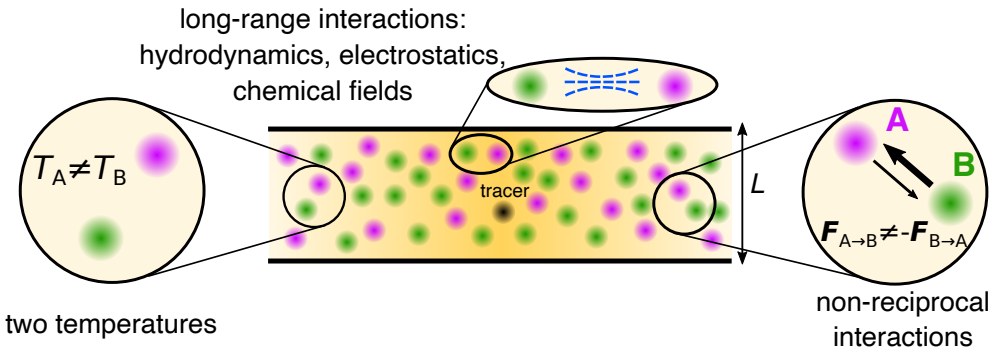
Statistical physics of nonequilibrium mixtures: tracer diffusion and long-range interactions

Transport of soft matter at small scales is at the heart of many modern scientific challenges, such as the design of new nanomaterials or nanofluidic devices, or the understanding of intracellular self-organization. The hallmarks of these systems are their strong **heterogeneity**, and their **nonequilibrium** nature. From a theoretical perspective, the interplay between these two features makes the **analytical description** of such systems particularly difficult, and the available models are generally restricted to single species systems, with simple pair interactions between the constituents.

Recently, we focused on properties associated with **tracer particles** in model nonequilibrium mixtures, that include **multi-temperature thermostats**, or **non-reciprocal interactions**. These models were introduced recently and have received a lot of attention in the community. Analytical calculations, relying on linearized **stochastic field theories**, coupled with Brownian dynamics simulations, revealed how the nonequilibrium nature of the mixtures could lead to **enhanced diffusion** and to the formation of pairs of particles that self-propel [1, 2].

The goal of the master internship (and of the associated thesis project) is two-fold: (i) the student will first extend the analytical results to **confined geometries** and to **long-range interactions**, such as chemotactic [3] or electrostatic [4] interactions; (ii) in parallel, the student will work on more fundamental aspects of the stochastic field theory that was employed: the objectives will be to go **beyond the Gaussian approximation** that was used so far, and to incorporate the effect of **hardcore** repulsive interactions.

The work will essentially be **analytical**: the candidate must have a taste for stochastic processes, statistical field theory and perturbative methods. Funding for a **PhD starting in 2025** is available.



[1] M. Jardat, V. Dahirel, P. Illien, *Phys. Rev. E* **106**, 064608 (2022). arXiv:2209.00929.
[2] A. Benois, M. Jardat, V. Dahirel, V. Démery, J. Agudo-Canalejo, R. Golestanian, P. Illien, *Phys. Rev. E.* **108**, 054606 (2023). arXiv:2307.05408.
[3] P. Illien, R. Golestanian, *J. Chem. Phys.* **160**, 154901 (2024). arXiv:2402.09775.
[4] P. Illien, A. Carof, B. Rotenberg. arXiv:2407.17232.