INTERNSHIP PROPOSAL

Laboratory name: **PHENIX**
CNRS identification code: **UMR 8234**
Internship supervisor: **Pierre Illien**
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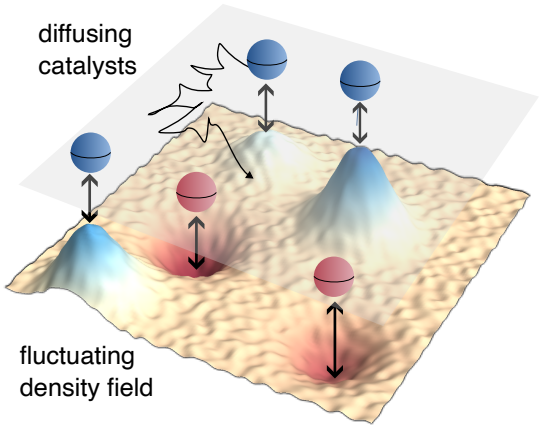
Internship location: **Sorbonne Université, place Jussieu, Paris 5ème**
Thesis possibility after internship: **YES**
Funding: **to be discussed**

Statistical physics of chemically active mixtures

Near criticality, binary mixtures exhibit large composition fluctuations with **spatial correlations**. Introducing **mobile catalysts** that promote interconversion between the two components is expected to drive the system **out of equilibrium**, potentially altering its **fluctuation spectrum**. Understanding how such diffusing reactive agents, whose dynamics and coupling to the underlying fields can be represented explicitly, modify spatial correlations is the central objective of this project.



The internship will focus on constructing and analyzing a **theoretical model** describing a near-critical binary mixture coupled to mobile catalysts. The mixture will be represented by continuous concentration fields obeying model B (conserved) stochastic dynamics derived from a **Gaussian free energy** [1]. Catalysts will be modeled as **diffusing sources and sinks** that locally bias the A ↔ B conversion reaction.

Analytical methods (such as stochastic field theories, Langevin equations, perturbative expansion) will be used to determine how catalyst motion modifies the two-point correlations of the fields. Particular attention will be paid to identifying possible **long-range, non-equilibrium correlations** emerging from the interplay between diffusion and reaction, and to investigating their consequence on **tracer diffusion** [2] and **fluctuation-induced forces**, like the one evidenced recently in externally driven systems [3].

This project will provide quantitative insight into fluctuation mechanisms in reactive mixtures and may help interpret simulations and experiments on **enzyme-driven or catalytic colloidal systems** [4]. The work will essentially be **analytical**: the candidate must have a taste for stochastic processes, field theories, and perturbative methods. Depending on the advancement on the project, the candidate could benefit from a collaboration with J. Diaz and I. Pagonabarraga (Univ. Barcelona), who specialize on numerical simulations on this topic.

[1] D. Venturelli et al., Phys. Rev. E **105**, 054125 (2022). arXiv:2203.06001.
[2] A. Benois et al., Phys. Rev. E **108**, 054606 (2023). arXiv:2307.05408.
[3] S. Mahdisoltani & R. Golestanian, Phys. Rev. Lett. **126**, 158002 (2021). arXiv:2011.12821.
[4] J. Fries et al., J. Roy. Soc. Interface. **22**, 20240803 (2025). arXiv:2411.11696.

Condensed Matter Physics: **NO**	Soft Matter and Biological Physics: **YES**
Quantum Physics: **NO**	Theoretical Physics: **YES**