PhD in Statistical Physics 2025–2028

Exploring nonequilibrium activity and enhanced diffusion in living cells using experiment, theory, and machine learning

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Keywords : Statistical physics, physics of living systems, nonequilibrium fluctuations, stochastic thermodynamics, soft active matter, optical tweezers, microscopy, variational autoencoders.

Context : This PhD is part of a project that aims to uncover how energy-driven processes at the molecular scale influence the organization of living matter. By focusing on how molecular activity affects cellular properties, the project will explore how these processes scale up to impact tissues. Using a combination of experiments, physical modeling, and machine learning, this research seeks to deepen our understanding of how nonequilibrium activity drives organization in biological systems, offering new ways to study active matter.

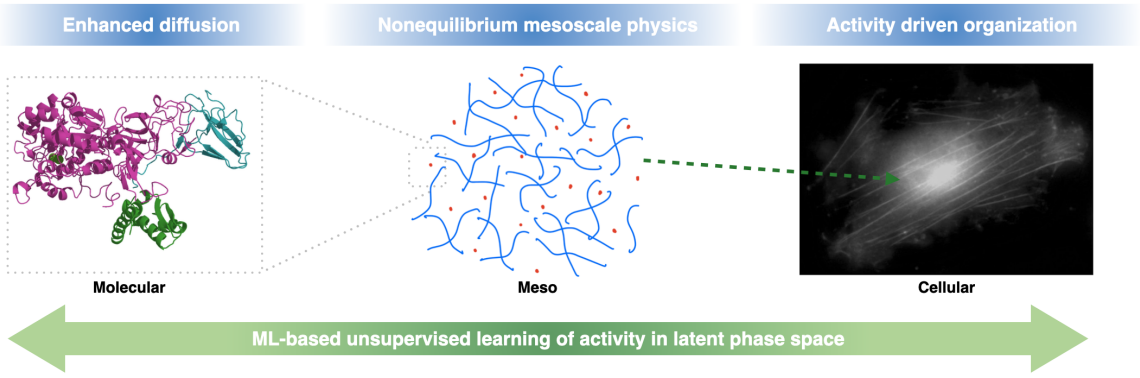

Figure 1: A combined approach using experiments, physical modeling, and machine learning will be used to study multi-scale nonequilibrium phenomena in living matter.

PhD work : The PhD project will focus on understanding how nonequilibrium molecular activity, such as enhanced diffusion, impacts cellular properties and organization. The student will combine experimental approaches with physical modeling to quantify activity and diffusion dynamics. By incorporating machine learning, the project aims to classify and analyze patterns of activity, providing deeper insights into the physical principles governing active matter at the cellular scale. This interdisciplinary approach will bridge data-driven analysis (variational autoencoders), experimental measurements (optical tweezers and microscopy), and theoretical models (stochastic thermodynamics) to elucidate the role of nonthermal fluctuations in shaping cellular behaviors.

Profile : The ideal candidate should have a Masters degree in physics (or equivalent), with experience in experiments, data analysis, and programming. Knowledge of machine learning or computational modeling is a plus. The student should be curious about biological systems, eager to explore nonequilibrium processes, and interested in using physical models to study active matter dynamics. A collaborative mindset and willingness to work across disciplines will be key.

Practical information : The doctoral student will work at both the LPT and CBI. The student will be enrolled in the Doctoral School of Matter Sciences. The 3-year contract is funded by the MESR/UT3 and will ideally start in October 2025. Interested candidates should send their CV and cover letter directly to W. Ahmed (wahmed@irsamc.ups-tlse.fr).

References :

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2. J. O'Byrne et al. (2020) Time irreversibility in active matter, from micro to macro, *Nature Reviews Physics.* 4
3. F. Cichos et al. (2020) Machine learning for active matter, *Nature Machine Intelligence.* 2