Master 2: *Systèmes Biologiques et Concepts Physiques*

INTERNSHIP PROPOSAL

Laboratory name: **Laboratory of Condensed Matter Physics**
CNRS identification code: **UMR7643**
Internship director'surname: **Denis GREBENKOV**
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Internship location: **Laboratory of Condensed Matter Physics, Ecole Polytechnique, Palaiseau, France**
Thesis possibility after internship: YES
Funding: NO (but it is possible to apply for a scholarship from Ecole Polytechnique)

Theory and modeling of diffusion in heterogeneous media, with applications to single-particle tracking in living cells

The transport of macromolecules and organelles inside living cells is a complicated phenomenon with various regimes (sub-diffusive, super-diffusive, intermittent, transitory…) whose physical origins remain poorly understood. New optical microscopy techniques for single-particle tracking have been recently applied in microbiology in order to study cellular transport, as well as structural and functional properties of living cells. Since these techniques typically acquire a small number of random trajectories (generated by an unknown stochastic process), the problem of the best statistical analysis of acquired data and their most reliable biophysical interpretation becomes fundamental. In fact, one faces a very general question: How can one characterize a stochastic process from its single random trajectory?

The internship focuses on theoretical and numerical study of random trajectories in spatio-temporal heterogeneous media. We will explore recently developed models of both annealed and quenched random disorder and analyze the related first-passage phenomena. The first goal consists in extending the model of diffusing diffusivity to a more realistic description of diffusion-controlled reactions, in particular, to account for (anti)-cooperativity effects in reactions with multiple particles. The second goal is to develop new statistical tools for model selection and calibration of parameters from both simulated and experimental data from living cells. This systematic study should help to identify spatial and temporal heterogeneities of disordered cytoplasmic media and to distinguish different regimes of intracellular transport. The ultimate goal of this research is a better understanding of cellular transport and its biophysical origins.

The candidate is expected to have a solid background in statistical/theoretical physics, be skilled in numerical simulations (e.g., in Matlab), and strongly motivated for biology-oriented research. The internship can potentially be continued as a PhD thesis under the condition of obtaining a PhD scholarship (in order to be able to apply for such a scholarship at Ecole Polytechnique, the candidate should have excellent notes).

Bibliography

Y. Lanoiselée, N. Moutal, and D. S. Grebenkov, *Diffusion-limited reactions in dynamic heterogeneous media* Nature Comm. **9**, 4398 (2018) [online: https://pmc.polytechnique.fr/pagesperso/dg/publi/2018_10.pdf]

D. S. Grebenkov, et al., *Towards a full quantitative description of single-molecule reaction kinetics in biological cells*, Phys. Chem. Chem. Phys. 20, 16393 (2018) [online: https://pmc.polytechnique.fr/pagesperso/dg/publi/2018_06.pdf]

Y. Lanoiselée and D. S. Grebenkov, *A model for non-Gaussian diffusion in heterogeneous media*, J. Phys. A 51, 145602 (2018) [online: https://pmc.polytechnique.fr/pagesperso/dg/publi/2018_04.pdf]

Y. Lanoiselée and D. S. Grebenkov, *Unravelling intermittent features in single particle trajectories by a local convex hull method*, Phys. Rev. E 96, 022144 (2017) [online: https://pmc.polytechnique.fr/pagesperso/dg/publi/2017_07.pdf]