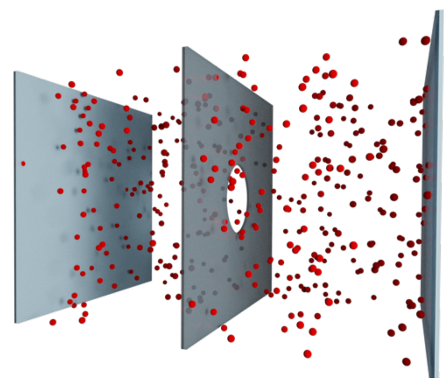
Fluctuations in Nanopores
Unravelling hidden traces of interfacial phenomena

Nanoscale pores are essential tunnels that organize the traffic of ions and molecules. Nanopores are found in numerous biological contexts (in between cells, to guide material to the nuclei,…) but also in industrial applications, for filtering water and other liquids.

Fluctuations are ubiquitous in bio or artificial nanopores. These fluctuations have subtle and highly intricate origins due to a diversity of effects: the number of particles within the pore is small and hence fluctuates, the structure of the pore has important mechanical fluctuations, and also the physical chemistry properties of the surface fluctuate, due to rapid binding and unbinding of molecules. Fluctuations have dramatic consequences on transport: the noise on current measurements through pores is often very large, reducing the sensitivity. Yet, biological systems are still able to achieve complex tasks relying on these nanopores and in spite of fluctuations.

To investigate the riddle of fluctuations in nanopores, during this internship we will explore fluctuations in a minimal system with binding and unbinding at the surface of the pore. In fact, adsorption is believed to play a key role in such systems [1,2]. We will study the stochastic properties of the number of particles that are free or bound to the surface. In some limit regimes, we expect exotic behaviors to arise, such as fractional Brownian noise [3]. We will characterize these different regimes. The intern will be able to relate their findings to experiments that are underway (Alice Thorneywork, UK), and to collaborate with Benjamin Rotenberg (Phenix lab) on simulations.
The results could open new avenues in artificial designs, where fluctuations are harnessed to improve transport and sensing.



Artistic representation of a pore within a membrane (gray) and molecules (in red) passing through.

The internship can lead to a PhD, with a focus on understanding how to extract bound ions from narrow constrictions. This has applications in the extraction of heavy metal ions which are of utmost concern in polluted soils.

Tools used: Analytical work in Stat Phys and/or stochastic simulations, depending on preferences

A few references

[1] S. Gravelle, R. Netz, L. Bocquet, Nano Lett. 2019, https://doi.org/10.1021/acs.nanolett.9b02858
[2] S. Knowles, … A. Thorneywork, Phys. Rev. Lett. 2021, https://doi.org/10.1103/PhysRevLett.127.137801
[3] S. Marbach, J. Chem. Phys. 2021, https://doi.org/10.1063/5.0047380

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