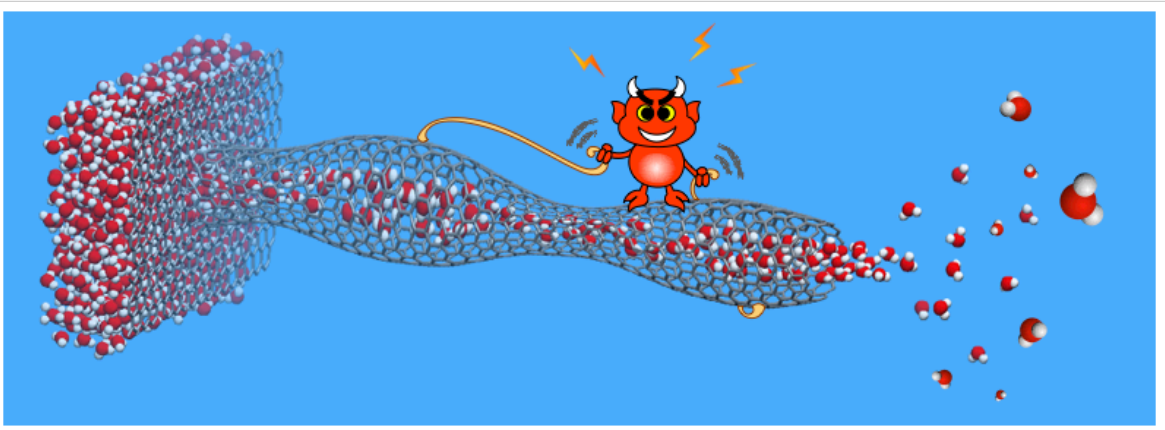
Out-of-equilibrium Transport of Particles within Fluctuating Nanotubes

S. Marbach[a], D. S. Dean[b] and L. Bocquet[a]
[a]*Laboratoire de physique statistique, Ecole Normale Supérieure, 75005 Paris, France*
[b]*Laboratoire Ondes et Matière d'Aquitaine, Université de Bordeaux, 33400 Talence, France*

Abstract

Filtering specific molecules is a challenge faced for several vital needs: from biomedical applications like dialysis to the intensive production of clean water. The domain has been boosted over the last decades by the possibilities offered by nanoscale materials [1]. Filtration is however always designed according to a passive sieving perspective: a membrane with small and properly decorated pores allows for the selection of the targeted molecules. This inevitably impedes the flux and transport, making separation processes costly in terms of energy.

In Nature however, exceptional permeability and selectivity properties are reached, for example ion channels are able to distinguish with high throughput very similar ions like Sodium and Potassium [2]. The paradigm change as compared to nanoscale technology is that these biological filters are **out-of-equilibrium**, submitted to either thermal or active fluctuations – for example of the pore constriction. Here we investigate how out-of-equilibrium fluctuations of a pore may affect the translocation dynamics, in particular dispersion coefficients. Our findings demonstrate a complex interplay between transport and surface wiggling and elucidate the impact of pore agitation in a broad range of artificial and biological porins, but also, at larger scales, in vascular motion in fungi, intestinal contractions and microfluidic surface waves. These results open up the possibility that transport across membranes can be actively tuned by external stimuli, with potential applications to nanoscale pumping, osmosis and dynamical ultrafiltration.



[1] "Materials for next-generation desalination and water purification membranes" Werber, J, Osuji, C. and Elimelech M., *Nature Rev. Mater.* (2016)

[2] "Control of ionic selectivity in potassium channels by electrostatic and dynamic properties of carbonyl ligands", Noskov, S.Y., Berneche, S., Roux, B. *, Nature.* (2004).