Proposal for a Master 2 intership

Nanopore and Polymer Feedback in Flow

with C. de Blois (**Charlotte.de-blois@universite-paris-saclay.fr**),
Laboratoire FAST, Université Paris-Saclay, CNRS 91405 Orsay, France

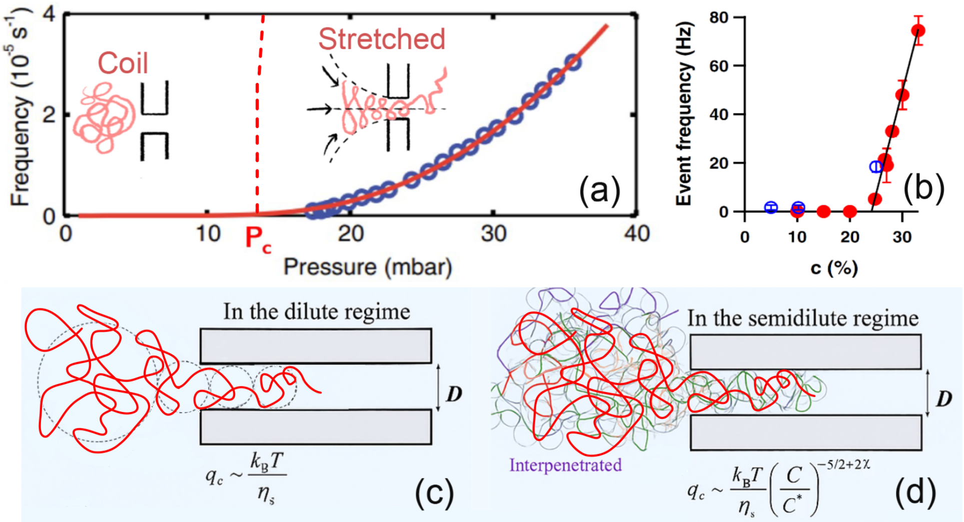

Figure 1: (a) Adapted from [1], onset of DNA translocation when the driving pressure exceeds the critical pressure P_c. (b) From [2], at a constant driving flow rate, increasing the concentration of long neutral polymers above a threshold leads to a concentration-dependent translocation frequency. (c,d) Adapted from [3], critical flow rate q_c predicted by the blob model in the semi-dilute regime.

Context: The behavior of complex fluids, such as polymer solutions, is usually studied at the bulk scale with rheometers that measure average viscoelastic properties. While this is useful for large-scale flows, it often misses the microscopic details that control how individual polymers move and interact-details that become crucial when the surrounding structures are of similar size to the polymers themselves. This situation is particularly relevant in biology, for example in mucus transport in the respiratory tract, where long mucin polymers interact with arrays of cilia at comparable length scales. To bridge this gap, new microrheological approaches are needed that can directly probe single-molecule dynamics in confined geometries. Nanopores offer such an approach, allowing individual DNA molecules-used as model polymers-to be observed as they translocate through nanometer-scale channels.

Principle: When a pressure difference is applied across a nanopore, a DNA molecule can stretch and pass through the channel. Using fluorescence microscopy, these single-molecule translocation events can be directly observed [4]. From these measurements, key quantities such as the number of events, translocation times, and the critical pressure required for passage can be extracted. These parameters reflect both the DNA dynamics and the rheological properties of the fluid.

Proposed work: The student will participate in the setup and calibration of a nanopore-based experimental system. After initial validation in simple fluids (water, then water-glycerol mixtures with controlled viscosity), experiments will focus on non-Newtonian solutions containing DNA or polyethylene glycol (PEG). The internship will involve preparing solutions, performing fluorescence microscopy experiments, and analyzing single-molecule translocation data as a function of viscosity and fluid rheology.

References:

[1] Auger, T. et al. Phys. Rev. Lett. 113, 028302 (2014)
[2] Oukhaled, A. G. et al. Phys. Rev. Lett. 108, 088104 (2012).
[3] He, J., Zheng, T. & Li, L. Macromolecules 52, 5679-5689 (2019).
[4] De Blois, C. et al. Nanoscale 16, 138-151 (2024).