Flow driven jamming of viral particles in narrow channels

Léa Chazot-Franguiadakis[1]*, Fabien Montel[1]

[1]Laboratoire de Physique, UMR CNRS 5672, ENS de Lyon, Université de Lyon, Lyon, France
*lea.chazot-franguiadakis@ens-lyon.fr

The human cell is organized into compartments. The transport of biomolecules between them is an essential step in order to maintain cell function. Among the cell's communication pathways, the nuclear pore complex (NPC), which regulates transport between the cell nucleus and the cytoplasm [1], is certainly the most complex. This pore has exceptional adaptability and selectivity properties, due to the presence of a network of dynamic polymers inside its central channel. Many viruses (adeno-associated virus, hepatitis B virus, HIV, ...) must transport their genetic material across the nuclear membrane, via the NPC to replicate inside the cell nucleus.

Our project addresses the issue of virus transport through the NPC in a biomimetic environment, i.e. simplified and controlled, in order to facilitate the study. To this end, we mimic the nuclear pore by grafting nanoporous membranes with hydrophobic artificial polymers. We then use a highly sensitive optical system, developed within our team, which allows us to detect in real time and at the level of a single pore the transport of a single viral particle [2,3].

Using this device, we measure the translocation frequency of viruses (labeled with a fluorophore) through the pores as a function of a control parameter (pressure, concentration). We reveal a jamming phenomenon caused by the confinement of the viruses under flow. We study the determinants (physical, chemical) of this effect and propose a physical model of the phenomenon seen as a phase transition under flow. Extracted parameters are related to the interaction of the viruses with the pore. They can be used to study subtle structural and geometrical modifications of the viruses induced by topological defect modulators.

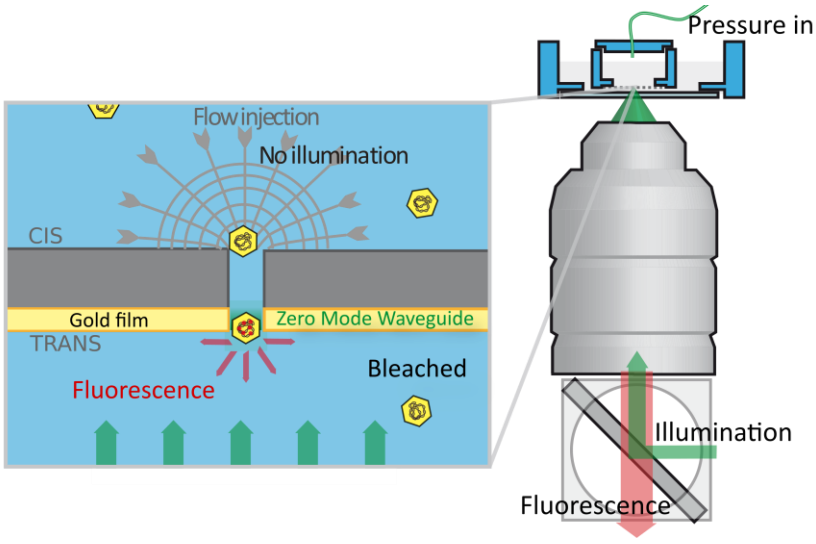

Figure 1: Experimental setup for translocation of (fluorescently labeled) viral particles through a synthetic nanoporous membrane.

References

[1] Wente S.R, et al. The nuclear pore complex and nuclear transport. Cold Spring Harb Perspect Biol.2, (2010).

[2] Auger T, et al, Zero-Mode Waveguide Detection of Flow-Driven DNA Translocation through Nanopores. Phys Rev Lett, Vol 113 (2), p028302-07, (2014).

[3] Chazot-Franguiadakis L., et al., Optical Quantification by Nanopores of Viruses, Extracellular Vesicles and Nanoparticles. Nano Letters, 22, 9, 3651–3658 (2022).