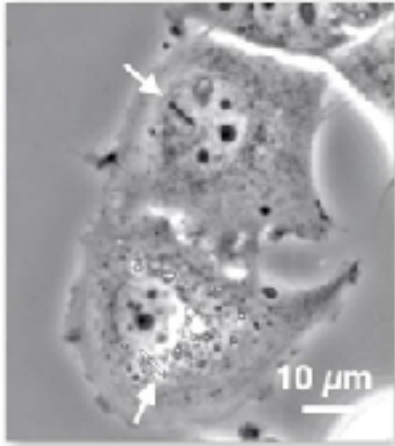


M2 Internship

How cytoskeleton structure and dynamics impact cellular viscosity in cancer cells

The mechanical properties of cancer cells, and in particular their intracellular viscoelasticity, are increasingly recognised as important indicators of cell physiology and cancer progression. While cell stiffness has been extensively investigated, intracellular viscosity remains much less explored. The experimental team of JF Berret at the UPCité use magnetic rotational spectroscopy (MRS) to measure the viscoelastic properties of living cells at the intracellular scale. The method relies on magnetic wires internalised by cells (see Figure). When an external magnetic field is applied, the rotation of these wires probes the mechanical resistance of their local intracellular environment, allowing us to quantify both viscous and elastic contributions [1]. Our preliminary results across



several cancer types indicate that intracellular viscosity is typically 5–10 times lower in cancer cells than in their healthy counterparts [2,3]. This finding suggests that intracellular viscosity could provide a new biophysical readout of cancer cell metastatic potential. An important challenge is to understand the physical mechanisms underlying these differences and how they influence the rotation of magnetic wires inside cells.

Computational approaches based on multi-scale simulations [4,5] combining particle and fluid dynamics can provide a direct *in silico* quantification of the intracellular viscosity, and therefore explain the systematic drop observed in cancer cells. Our inspiring idea is that the viscosity accessed by magnetic wires originate from the heterogeneity of the cellular environment sampled at the characteristic length scale of the probe (micrometers), and therefore reflects the dynamical microstructure of the cell: the cytoskeleton.

In this master, we aim to create an elastic dynamic model for the cytoskeleton components and observe how its disordered connectivity -and dynamics- impacts the dynamic of the surrounding cytoplasmic components (proteins and other macromolecules) [6] and hence the associated viscosity.

The master candidate will work and will be directly supervised by F. Sterpone at the Laboratoire de Biochimie Théorique at the IBPC in Paris. The work will advance in tight collaboration with the experimental teams of JF Berret and M. Reffay at the Laboratoire Matière et Systèmes Complexes at UPCité.

Candidates must sent a letter to Fabio STERPONE (fabio.sterpone@ibpc.fr)
<https://sites.google.com/site/sterponefabio/home>

References

- [1] J.-F. Berret, Local viscoelasticity of living cells measured by rotational magnetic spectroscopy, *Nature Communications* 7, 10134 (2016) <https://doi.org/10.1038/ncomms10134>
- [2] M. Dessard J.-B. Manneville and J.-F. Berret*, Cytoplasmic Viscosity is a Potential Biomarker for Metastatic Breast Cancer Cells, *Nanoscale Advances* 6, 1727-1738 (2024). <https://doi.org/10.1039/D4NA00003J>
- [3] Anja M. Markl, Daniel Nieder, Anna Taubenberger, Jean-François Berret, Artur Yakimovich, Eduardo Sergio Oliveros-Mata, Larysa Baraban, Anna Dubrovskaya*, Heterogeneity of Tumor Biophysical Properties and their Potential Role as Prognostic Biomarkers, *Cancer Heterogeneity and Plasticity* 1(2), 0011 (2024), <https://doi.org/10.47248/chp2401020011>
- [4] E. Laborie, S. Melchionna, F. Sterpone, "Cilia beating misalignment, immotility or death pathologically affect the efficiency of mucus-clearance", *Comm. Phys.* (2025), 8, 109.
- [5] F. Sterpone, P. Derreumaux, S. Melchionna «Protein simulations in fluids: coupling the OPEP coarse-grained force field with hydrodynamics», *J. Chem. Theory Comput.* (2015) 11, 1843-1853.
- [6] B. Caviglia et al. "Cytoplasmic fluidity and the cold life: proteome stability is decoupled from viability in psychrophiles", *Nature Comm.* (2025), 16, 10345.