Master 2 Internship

Title: Tracking mechanical and dynamic transitions within living cell compression

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PhD funding (if any): proposal to ANR for PhD funding

Project:

It is increasingly recognised that the proliferation (cell division), migration and mechanics of eucaryote cells is an inherently collective and multi-scale problem. Our understanding of cell behaviour at the genetic and molecular level has improved dramatically over the past two decades, but we recognise that this is necessary but not sufficient to capture the behaviour of cells in real situations. In particular, the mechanical response of cells must also be taken into account to understand collective behaviour. Much like glassy, granular and colloidal materials, cells are fascinating to physicists and biologists because they can undergo individual or collective phase transitions between states that resemble the material phases of solid, liquid and gas. In particular, the transformation of a living cell upon compression can be captured in real time using single-cell manipulation techniques such as atomic force microscopy. Depending on the rate of compression, the cell may undergo what is known as a phase transition, for example from a 'rigid-like' to a 'liquid-like' gel in response to the external deformation.
Detecting the transition and characterising the change in mechanical properties of the cell during compression challenges both our analysis and modelling methods. Breaks in the mechanical behaviour (either sudden in the case of a first order transition, or progressive in the case of a second order transition) must be properly detected. More interestingly, it may also happen that the cell undergoes a dynamic response to the stress by adopting a non-stationary behaviour (oscillatory dynamics or amplification of fluctuations), which is typical of a non-linear system close to non-equilibrium phase transitions.
What we propose for this internship: To implement fracture detection methods from atomic force microscopy force-displacement curves and test them on both experimental data from living cells and model equations that mimic the mechanical transitions.

The project has two parts:
I. Static hypothesis: the compression characteristic time is less than the time for the cell to undergo an active reorganisation of its components (the cell is frozen and not active). The mechanical transition that occurs is that of a glassy material that reorganises passively its network in response to compression.
II. Dynamic hypothesis. The compression time is of the same order of magnitude as the cell internal dynamics. The cell uses its active mechanisms, it reacts to the compression by reorganising its filament networks in real time, or even migrates during the compression.

Techniques, 'savoir faire' : Computational and mathematical tools: Identification methods for multi-parametric systems. Minimisation functions to address the transition points. Numerical simulations and computations will be done in either Matlab, Julia or Python.
Candidate profile: Physicist with background in complex systems - nonlinear science, interested in transdisciplinary work (biology).
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