Master internship proposal – Soft Matter & colloidal physics

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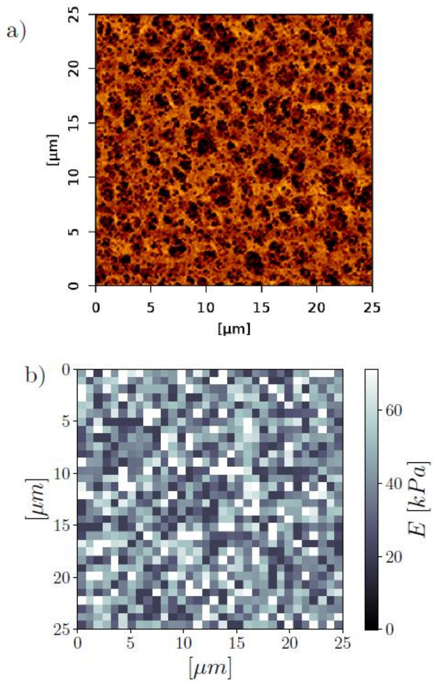
How tough is yogurt? *Local* viscoelastic properties of protein gels

Colloidal gels are crucial in biological networks, cell mechanics, food science, and building materials [1]. They result from the aggregation of sub-micron particles such as polysaccharide coils, actin filaments, attractive globular proteins, or cement particles, forming a percolated network (see Fig. a) that confers solid-like properties under small deformations. In addition, these gels display remarkable nonlinear behavior featuring stress- or strain-stiffening and fractures before irreversible rupture [2,3]. Recent experiments have shown that the frozen-in stresses that develop during the sol-gel transition strongly impact the nonlinear response of these gels [4]. However, these internal stresses were only evidenced indirectly at the macroscale. Moreover, there is no clear link between the microscale stress heterogeneities inside a colloidal gel and its macroscopic failure time.



(a) Topography map and (b) map of the local elastic properties of an agar gel determined over the same region by atomic force microscopy.

The internship, which is part of the MICROFAT ANR project led by S. Manneville, aims to make the handshake between the frozen-in stresses at the microscopic scale and the gel nonlinear mechanical response at the macroscale. In practice, the candidate will measure the local mechanical properties of colloidal gels composed of proteins [5] using atomic force microscopy and a state-of-the-art nano-indenter (PIUMA & CHIARO by Optics 11) to quantify the frozen-in stresses (Fig. b). Subsequent creep experiments conducted under a confocal microscope will allow the nonlinear gel response to be measured in regions of interest and link the frozen-in stresses with the failure scenario.

Skills – We are looking for a candidate trained in soft matter with a general background in physics, physical chemistry, or materials science. Previous knowledge of rheology and microscopy and data analysis (Matlab or Python) would be an asset.

Duration – Ideally, 4 to 6 months at Master 1 or 2 level (or 3A & 4A engineering schools) between April and December 2024. Send your application to Thibaut.Divoux@ens-lyon.fr.

[1] Zaccarelli, *J. Phys.: Condens. Matter* **19**, 323101 (2007)
[2] Leocmach, Perge, **Divoux** & S. Manneville, *Phys. Rev. Lett.* **113**, 038303 (2014) [link]
[3] B. Keshavarz, **T. Divoux**, S. Manneville & G.H. McKinley, ACS Macro Letters **6**, 663 (2017) [link]
[4] Pomella, Cipelletti & Ramos, *Phys. Rev. Lett.* **125**, 268006 (2020)
[5] J. Bauland, G. Manna, **T. Divoux** & T. Gibaud, arXiv:2403.10176 (2024)