Master 2 Internship

Title: Interface dynamics of complex fluids at the nanoscale: the puzzling role of local rheology and thermal fluctuations

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Project: The spreading dynamics of a droplet on a substrate is an important scientific issue with numerous practical implications. The underlying principles on simple non-evaporating liquids are now well-established [1]. This spreading dynamics has also strong incidence on more complex or evolving liquids, in particular in soft matter. How they flow or deform at very small scales leave a lot of open applied and fundamental questions in out-of-equilibrium conditions such as the evolving rheology (viscosity/visco-elasticity) during solvent evaporation for ink (coffee ring effect) and paint deposition, or the spreading or the evaporation towards the nanofluidics regime (reached before the end, by definition) where continuum fluid dynamics becomes debatable and surface fluctuations become increasingly important [2]. Investigation of these effects remains very challenging since classical rheometry is no more adapted in scale and in dynamics and fluidics at the nanoscale, in particular in non-equilibrium conditions (spreading/evaporation), still deserves the setting of new means of investigation. In order to overcome these difficulties, we propose to implement a promising contactless strategy that uses the optical radiation pressure to deform interfaces and detect these deformation by interferometry with nanometric resolution [3].

This M2 project focuses experimentally and theoretically on an almost uncovered situation, the out-of-equilibrium rheology of solvent evaporating inks and paints when their thickness varies from the micrometric range to total drying, since rheology plays a major role in the quality of the covering and its properties. Do rheology and continuous fluid mechanics continue to be at work? And is there a crossover to a thermal fluctuation regime? Asymptotic and/or numerical solutions of stochastic lubrication models [4] will be constructed and compared quantitatively to experimental results.

Considering the novelty of this contactless optical approach, we plan developing this work within the frame of a PhD generalizing investigations to out-of-equilibrium wetting droplets in near-critical phase separated mixtures where density fluctuations, associated to critical opalescence, play an increasing role. Experimentally, the radiation pressure at a near-critical liquid-liquid interface allows to produce such out-of-equilibrium droplets [5], whose physical properties vary with the proximity to the critical point. We plan to investigate the near-critical deviations from a fluctuation-free situation (far from the critical point), and their relations with the increasing roles of density fluctuations, gravity and evaporation. The overall goal is to establish for the first time on solid grounds the fundamental crossover between the capillary-dominated and fluctuation-dominated regimes in presence of evaporation, since evaporation is at the heart of printing mechanisms and is an intrinsic component of the stochastic fluid dynamics involved in nanofluidics.

[1] L. H. Tanner, The spreading of silicone oil drops on horizontal surfaces, J. Phys. D Appl. Phys., 12, 1473 (1979)
[2] B. Davidovitch *et al*. Spreading of viscous fluid drops on a solid substrate assisted by thermal fluctuations, Phys. Rev. Lett. 95, 244505 (2005)
[3] G. Verma, *et al*. Contactless thin-film rheology unveiled by laser-induced nanoscale interface dynamics. Soft Matter, 16, 7904 (2020)
[4] C. Pedersen *et al.* Asymptotic regimes in elastohydrodynamic and stochastic leveling on a viscous film, Phys. Rev. Fluids 4, 124003 (2019)
[5] J. Petit, *et al.* Break-up dynamics of fluctuating liquid threads, Proc. Nat. Ac. Sci. USA 109, 18327 (2012)