université de BORDEAUX

UMR5798 Laboratoire Ondes et Matière d'Aquitaine

# M2 Internship

**Title:** Rheology of air/water interface using thermal capillary fluctuations

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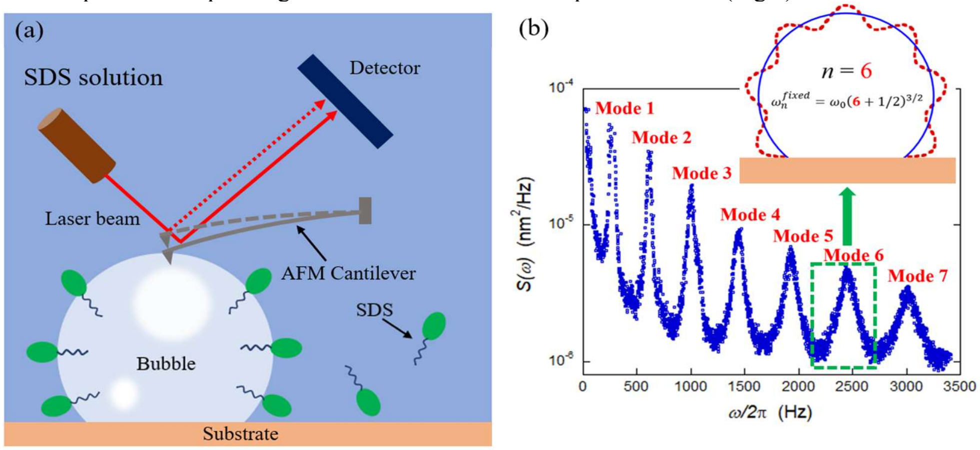
**PhD funding (if any): yes**

**Project:** Interfacial rheology of fluids interfaces decorated by surface-active species such as surfactants, proteins, or particles has many importance since it controls foams and emulsion stability, and it has many applications such as for oil recovery, microelectromechanical system as well as biomedical. Interfacial rheology deals with the response of interfaces against deformations, it has been the subject of research interest during the last decades. A range of devices and methods have been developed to measure the rheological interface properties, such as Langmuir troughs, various rheometers and oscillating drop or bubble . Despite the development of these different, we still face specific challenges to quantifying the interfacial properties; some of this techniques are limited to static measurements and rheological properties are only probed at low frequencies (a few tens of Hz).
The dynamic atomic force microscope (AFM) is a powerful tool to investigate structure and rheology of confined liquids, and its dynamic mode allows to separate viscous and elastic forces [1]. Recently we have used an atomic force microscope to probe the thermal capillary oscillation of a hemispherical bubble or drop deposited on polystyrene surface [2-4]. In this method, the nano-metric thermal vibration of the bubble drives the motion of the cantilever (Fig.a). We have shown that the spectrum of the thermal oscillations of the bubble surface presents several resonance peaks corresponding to the different mode of shape oscillations (Fig.b) .




In this project, we intend to probe the rheology of the air/water interface formed by an air bubble immersed in a solution containing ionic surfactants (examples: sodium dodecyl sulfate SDS and cetrimonium bromide CTAB). The movement of the bubble interface will be probed using an AFM cantilever which measures the amplitude of the vibration as a function of frequency. The damping and resonance frequencies of thermal fluctuations will be used to measure the surface tension and surface elasticity of the bubble surface. During the project, we will determine the resolution of the method and the range of parameters for which it works effectively, and compare with existing techniques. The solubility of surfactant molecules could be an important parameter distinguishing amphiphilic molecules, soap molecules from phospholipids or steroidal alcohols, and it will be studied in detail. The surface charge of the air/water interface which creates electrostatic barriers and controls adsorption will be studied in detail. We will vary the salt concentration (example NaCl) in the solutions, to understand the role of electrostatic screening on the adsorption dynamics of surfactants.

References:

[1] A. Maali, R. Boisgard, H. Chraibi, Z. Zhang, H. Kellay, A. Würger, “Viscoelastic drag forces and crossover from no-slip to slip boundary conditions for flow near air-water interfaces” **Phys. Rev. Lett**. 118, 084501 (2017)

**[2]** Z. Zhang, Y. Wang, Y. Amarouchene, R. Boisgard, H. Kellay, A. Würger, A. Maali "Near-field probe of thermal capillary fluctuations of a hemispherical bubble" **Phys. Rev. Lett**. 126, 174503, (2021).

**[3]** H Zhang, Z Zhang, C Grauby-Heywang, H Kellay, A Maali,"Air/Water Interface Rheology Probed by Thermal Capillary Waves", **Langmuir** , 39, 3332,(2023).

**[4]** H. Zhang,B. Gorin, H. Kellay, A. Maali,"Viscoelastic rheology of polymer solution probed by resonant thermal capillary fluctuation",**Phys. Fluids** 35, 121706 (2023).