Minicolloque n° 13 **x Oral** **☐ Poster**

Interfacial dynamics of a surfactant-laden drop flowing through a contraction

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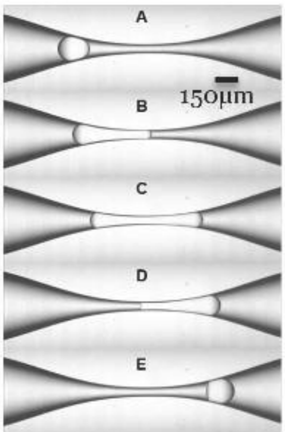
Practical situations in which soft objects suspended in a liquid pass through narrow pores are ubiquitous: crude oil emulsions in porous rocks, red blood cells in constricted arteries, droplets or capsules in lab-on-a-chip microfluidic devices… When these objects are drops, the presence of surfactants adsorbed at the surface modifies the interfacial tension. Thus, it is expected to favor the passage of the drop through a pore by reducing the Laplace pressures across the front curved interface. However, for drops much larger than the pore, the passage through the contraction induces a large deformation of the surface. Therefore, as the drop expands, surfactant concentration gradients are expected to develop at the surface. Although numerical studies [1,2] have evidenced the existence of such gradients, a clear understanding of the contribution of the phenomena at stake is missing.

Using a pressure controlled microfluidic set-up, we have experimentally studied surfactant-laden oil drops in a constricted capillary under an imposed pressure gradient (see figure). We use flowrate measurements to quantify the local surface tension at the front of the drop. We report a large increase of surface tension at the front up to a value close to the one for a bare interface (see figure). We suggest a description in which the increase in surface tension results from a balance between surface expansion and the adsorption of surfactant molecules from the bulk at the interface. The predicted value of surface tension is in excellent agreement with the experimental one.

[1] J. R. Gissinger, A. Z. Zinchenko and R. H. Davis, J. Fluid Mech. 878, 324-355 (2019)
[2] T.M. Tsai and M.J. Miksis, J. Fluid Mech. 337, 381-410 (1997)



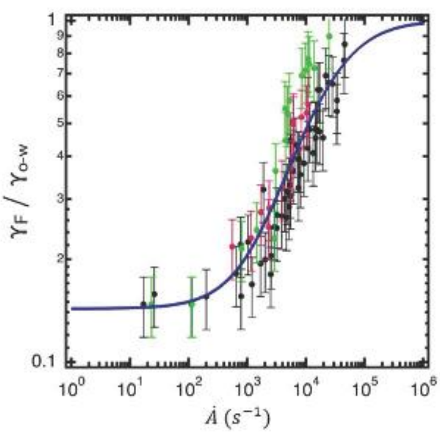


Figure 1: Left: Photographs of the key positions of the drop in the contraction. Right: Front surface tension of surfactant-laden droplets normalized by the surface tension of bare oil-water interface as a function of the expansion rate of the drop at the front.