

# The Physics of Soft and Biological Matter

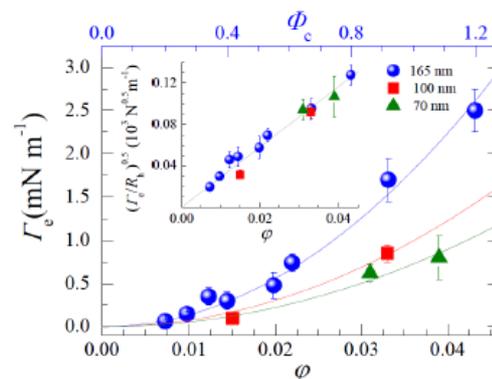
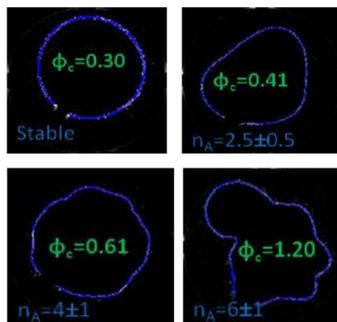
## Off-equilibrium surface tension in colloidal suspensions

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Surface tension between immiscible fluids is a well-understood and well-characterized phenomenon. By contrast, much less is known about the effective, off-equilibrium surface tension that arises when a (transient) interface is created between *miscible* fluids. This effective surface tension plays a key role in many phenomena, from jetting and drop formation and coalescence to precipitation and deposition, as it was already recognized more than 100 years ago by Korteweg [1], who first hypothesized that effective surface tensional stresses must be at work between two miscible fluids at contact. However, experimental investigations in this field remain scarce and the theoretical predictions by Korteweg have not quantitatively tested so far, to the best of our knowledge. We present a thorough experimental investigation of the Saffman-Taylor instability arising when a simple fluid (the solvent of a colloidal suspension) is pushed through a miscible, more viscous one (the colloidal suspension itself). We show [2] that the resulting interface pattern can be accounted for by the non-linear rheological properties of the suspension and an effective surface tension. By measuring the effective surface tension for suspensions at a variety of particle volume fractions, we successfully test Korteweg's theory.

We moreover find that the effective surface tension *increases* with the size of the colloidal particles, a surprising result at odd with the typical behavior in atomic or colloidal systems, where the surface tension usually *decreases* as the squared particle size [3]. We rationalize this finding by showing that for our particles, microgel spheres composed of cross-linked polymers, the surface tension is dominated by the entropic contribution associated with the internal degrees of freedom of the polymers



Left panel: Observed patterns in a Hele-Shaw radial experiment right after the onset of fingering instability at a fixed injection rate and different effective microgel volume fraction  $\Phi_c$  as indicated in the panels. The average number of observed fingers  $n_A$  is also shown [2]. Right panel: Effective interfacial tension  $\Gamma_e$  between the microgel suspensions and their solvent, as a function of colloid (resp., polymer) volume fraction (top, resp. bottom, axis). The lines are quadratic fits to the data for microgels with various hydrodynamic radii, as shown by the legend.

- [1] D. Korteweg, Arch. Neerlandaises Sci. Exactes Naturelles, 6, 1 (1901)
- [2] D. Truzzolillo, S. Mora, C. Dupas, L. Cipelletti, <http://arxiv.org/abs/1312.4427> (Submitted)
- [3] P.-G. de Gennes, F. Brochard-Wyart, and D. Queré, Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves (Springer-Verlag, Berlin, 2004)