Colloidal particles at fluid interfaces: the effects of curvature on capillary interactions

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If colloidal particles get trapped at fluid-fluid interfaces they interact effectively via deformations of the interface. These so-called capillary interactions can easily be tuned by changing external fields and they depend sensitively on the shape of the particles. This makes them good candidates for designing self-assembling systems and provides a convenient experimental playground for studying basic issues of statistical mechanics in two dimensions in the presence of long-ranged interactions [1]. On the other hand, recent experiments [2] show that capillary forces between elongated particles floating on spherical interfaces can have important consequences for stabilizing so-called Pickering emulsions, which are formed by particle-covered droplets (e.g., oil) in a solvent (e.g., water).

Whereas considerable theoretical progress has been made in understanding capillary interactions at flat interfaces, basic issues such as the balance of forces acting on the interface and the influence of the incompressibility of the liquid enclosed by spherical interfaces have not yet been fully resolved. We calculate analytically the effective capillary interaction potentials for small colloidal particles trapped at the surface of liquid droplets [3-5]. Pair potentials between capillary monopoles and dipoles, corresponding to particles floating on a droplet with a fixed center of mass and subjected to external forces and torques, respectively, exhibit a repulsion at large angular separations and an attraction at smaller separations, with the latter resembling the typical behavior for flat interfaces. This change of character is not observed for quadrupoles, corresponding to free particles on a mechanically isolated droplet. The analytical results are compared with the numerical minimization of the surface free energy of the droplet in the presence of spherical or ellipsoidal particles.

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