Active colloid at a fluid interface

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The last years have witnessed the growing interest on active colloids, i.e., of colloids made of particles that exhibit chemical activity: this activity induces gradients in the ambient fluid and thus drives a self-induced colloidal dynamics. This kind of systems have attracted attention both as a paradigm of nonequilibrium physics and for its potential applications.

Some recent theoretical work has focused on the case of a monolayer of active colloidal particles at a fluid interface [1, 2, 3]. A new phenomenology arises which is exclusive to the combination "activity + interface", because the interface is also responsive to chemical gradients: the spatial variations of the surface tension induce Marangoni flows in the ambient fluids that manifest themselves as an effective interaction between the colloidal particles and between these and the interface (see Fig. 1).

The most relevant prediction is the existence of "pseudoequilibrium" particle distributions in the monolayer [4]: in these states, the colloidal particles remain at rest although there exist an ambient flow in the embedding fluids. At the mean–field level, the effective interaction due to the Marangoni flow is analogous to two-dimensional Newtonian gravity, and the corresponding "pseudoequilibrium" states describe the coexistence of thermodynamic phases of the monolayer in a layered structure much like in a planet (see Fig. 2). These states, involving many particles, would represent the experimental signature of the Marangoni flows induced by the activity, which are otherwise too weak to be directly observable at the single–particle level [4].

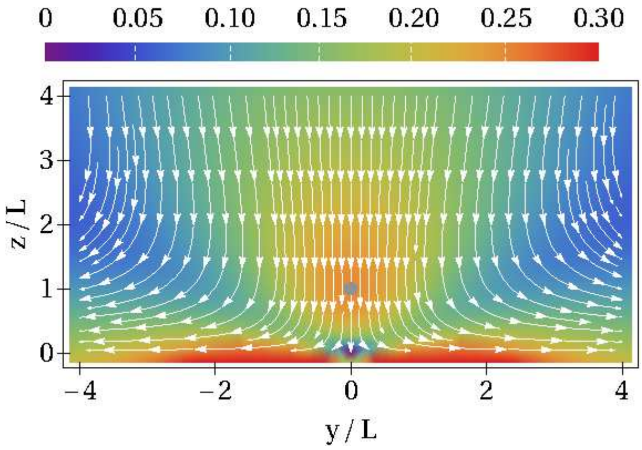

Fig. 1. Marangoni flow induced by the activity of a particle located at the position of the grey dot. The fluid interface is located at the plane $z = 0$. The color scale encodes the magnitude of the flow.

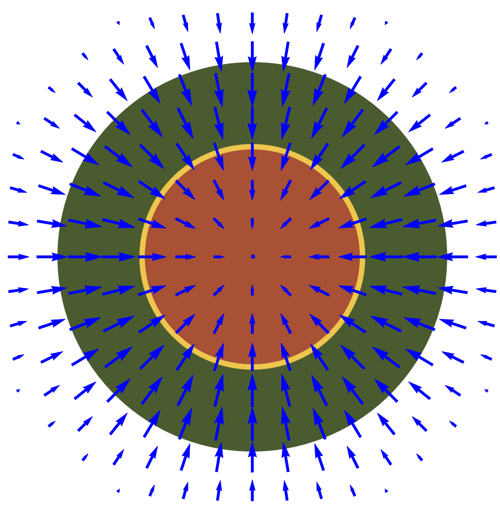

Fig. 2. The predicted structure of a cluster in the monolayer which is confined by its own Marangoni flow (blue arrows), and which exhibits a layered structure of different phases: crystal (brown), hexatic (yellow), and liquid (green). These phases correspond to a mutual interparticle repulsive force decaying like $1/r^4$ with separation r, and have been observed for colloids of ionizable particles [5] or of paramagnetic particles in an external magnetic field [6].

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