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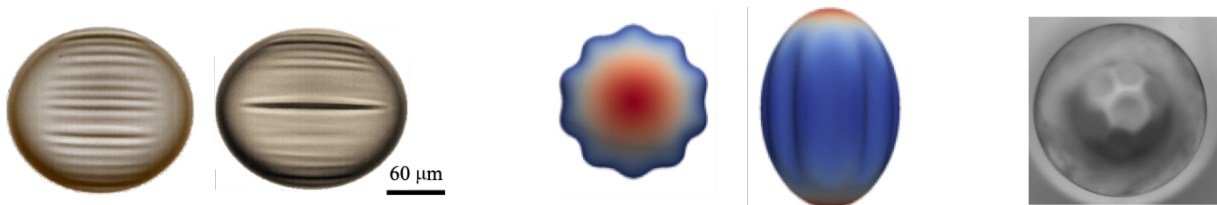
Internship location: Campus de Luminy, the south of Marseille

Thesis possibility after internship: YES

Funding: ANR, AMidex or ED

## Microcapsules under flow, from wrinkling to spatiotemporal dynamics

Capsules or microcapsules are everyday elastic particles consisting of a liquid core bounded by an elastic membrane: pharmaceuticals, cosmetics, nutrition and new materials in construction. They can either protect, transport and deliver active ingredients, or structure space and give the assembly new properties.



Capsules are deformable particles especially under hydrodynamic constraints: see figure for preliminary experimental and numerical studies. They can exhibit two types of instabilities under flow leading to a modulation of the shape at short wavelength (few results known whatever the methodology) or at wavelength close to the capsule size (known numerically but not experimentally). The former are reminiscent of wrinkling instabilities (figure) while the latter are spontaneous oscillations of the overall shape. In the literature, theoretical analyses are rare. Experimentally, the studies require capsules of a few tens to hundreds of micrometres that are reproducible in size with known mechanical properties: constitutive. Law, Young modulus, Poisson ratio and thickness. The laboratory has developed the know-how to overcome this problem. Theoretically, on the one hand, instabilities depend on the reference shape, a characteristic that does not exist in the case of drops or vesicles. On the other hand, the wrinkling instabilities develop on a stationary state in which the shape is ellipsoidal. Numerically, the team has developed an in-house code capable of tracking the emergence of wrinkles (figure). However, it remains a challenge to reach experimental wavelengths.

In the framework of the experimental course at the frontier between soft matter and non-linear physics, we propose to study by different methodologies the emergence of folds in a confined configuration, a capsule moving in a capillary. This is an "old" unsolved problem observed in 1970 by haematologists trying to understand the shape of cells in microcirculation and more precisely the inversion of curvature at the back of the cells. If the wrinkles are visible on the figures (balloon in a pipe), they are not mentioned in the few papers. An original high-speed imaging system will give access to the complete shape of the capsule.

The profile sought is that of a curious experimenter. Depending on the trainee's interest, he or she may participate in the theoretical development and numerical simulations that allow the limitation of the parameter space. The continuation of a thesis is desired.