« PROPOSITION DE STAGE ET DE THESE »

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Profil recherché :	theoretical biophysics

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"Flow localization on active nematic surfaces"

Experiments have recently shown that morphogenesis — the formation of shape and structure in living systems — can involve an interplay between surface curvature change, material flow, and orientational (nematic) order of the surface constituents. A striking example is found in the small sea animal *Hydra* [3]. In this system, supra-cellular actin-myosin fibers exhibit nematic order, and because of myosin-generated active stress, the *Hydra* boundary is an active nematic surface. Topological defects in the nematic director field are focal points of actively driven flows and deformations ; the tentacles, feet, and mouth coincide with +1 charge defects.

The goal of the M2 internship and the PhD will be to understand **how curvature and in-plane order can localize active flows in the surfaces** of developing organisms. The ability to spatially control flows is also of importance in the design of synthetic active matter systems. During the internship you will study a problem motivated by morphogenesis of ordered surfaces, and specifically tubular epithelial tissues, which we will model as an active nematic fluid surface. These tubes, found in a number of developing organs, are distinguished by the shapes at their tips. It is known that in certain tissue types, the cells at the tip rotate about the tube axis [7], but are static away from the tip. How curvature and orientational order interact to localize this flow is not understood.

Nematic order on the tube means that there is a topological defect in the director field of charge +1 as one circles the tube tip. Dynamics of active integer defects have recently attracted interest in cellular systems on *flat*, *rigid* surfaces [2, 8], but only a few, and mainly numerical, studies have considered defects on *curved, deformable* surfaces [1, 4]. Using covariant surface theory [6, 5], you will calculate the curvature-dependent activity threshold at which a +1 defect spontaneously rotates. For now, we will assume the defect is centered on a rigid, axisymmetric surface. By considering an aster defect, with angle $\psi = 0$ (see Fig. 1) in the base state, you will try to map the eigenvalue problem for the instability threshold to a time independent Schrödinger equation for a particle in a potential with wavefunction ψ. A first outcome of the internship will be this mapping and relating the effective potential V to the curvature of the axisymmetric surface. A second outcome will be to identify conditions for the existence of *bound states*, corresponding to order change, $\psi \neq 0$, and flow localized near the tube tip.

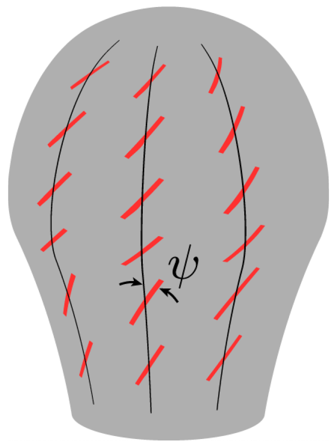

FIGURE 1 – Schematic of nematic order on an axisymmetric surface.

During the PhD, together we will pursue three directions. First, we will relax the above assumption of a rigid surface, and explore how surface deformation and flow localization influence each other. Next, while the above description is certainly valid for an active *polar* system, the condition under which integer defects in active nematics are stable is not well understood. This question has been addressed for flat surfaces [8], but not yet on curved ones. Along these lines, we will pursue a stability analysis of integer defects with respect to non-axisymmetric modes in ψ and in the flow $\mathbf{v}$ on a rigid, curved axisymmetric surface. Finally, we will relax the above constraint of a rigid surface, with the aim of identifying principles that affect the shape of the tips of active nematic tubes.

Références

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