M2 internship: Growth of a living nematic phase on a curved surface

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Subject

The anisotropic, elongated shape of bacteria such as *Bacillus subtilis* plays an important role in the spatial organization of dense bacterial suspensions. Indeed, the rod-like shape of individual bacteria induces an alignment between neighbors, ultimately leading to the formation of larger spatial domains characterized by a local orientational order. When bacteria are on a 2D plane surface, ordered domains appear reminiscent of a ferromagnetic phase (Fig. 1a). However, in contrast with non-living passive systems, these domains evolve in time as bacteria grow and divide [2].

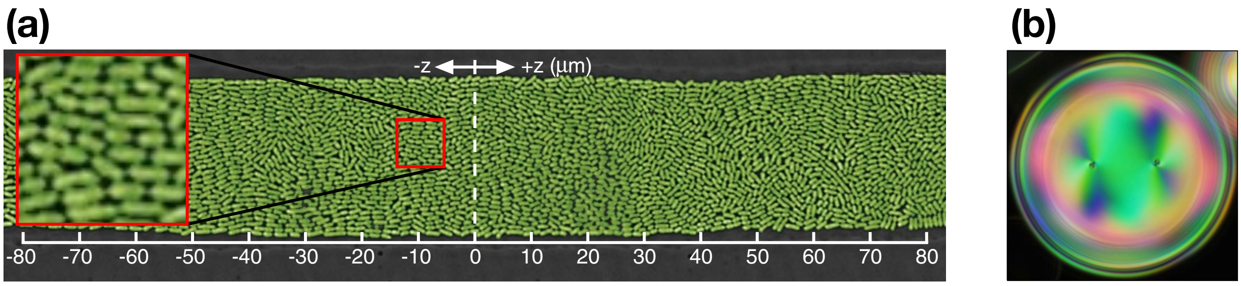

Figure 1: (a) Bacteria on a flat 2D surface, showing local orientational order [2]. (b) Liquid crystals on a spherical shell. The color depends on the local orientation of the molecules. Two topological defects are observed (black circles) [1].

When constrained on the curved surface of a sphere, anisotropic shapes such as rods cannot be perfectly aligned and defects appear, corresponding to singularities of the orientational order. These defects are clearly visible when making shells of liquid crystals [1], which are rod-like molecules, see Fig. 1b. When the passive, immobile liquid crystals are replaced by a rod-like, active system of microtubules that are able to propel themselves, defects start moving and evolving on the surface of the sphere.

In this internship, we ask how topology influences the dynamics of defects in a system of bacteria constrained to living on the surface of a sphere. Bacteria will not necessarily be able to swim at the surface of a sphere, but will grow and divide, which will influence the dynamics of defects. The internship will have both an experimental and theoretical component. On the experimental side, the intern will adapt a microfluidic setup to produce air bubbles in water, and add bacteria at the air/water interface. On the theoretical side, we shall compute and analyze the phase transition point when evolving from a low bacterial density isotropic phase to the high density nematic phase. Combining experiments and theory will help understand how topological defects smoothly arise in a geometrically frustrated medium.

References

[1] A. Darmon, O. Dauchot, T. Lopez-Leon, and M. Benzaquen, *Elastic interactions between topological defects in chiral nematic shells*, Physical Review E, 94 (2016), pp. 1–5.

[2] D. Volfson, S. Cookson, J. Hasty, and L. S. Tsimring, *Biomechanical ordering of dense cell populations*, Proceedings of the National Academy of Sciences, 105 (2008), pp. 15346–15351.