Research Topic for the ParisTech/CSC PhD Program

Subfield: Applied Physics

ParisTech School: Ecole supérieure de physique et de chimie industrielles de la ville de Paris

Title: **Topological living matter**

Advisor(s): Teresa Lopez-Leon (teresa.lopez-leon@espci.fr, https://www.ec2m.espci.fr/home/people/teresa-lopez-leon.html). This project will be carried out in collaboration with the team of Pr. Ignés-Mullol and Pr. Sagués from the University of Barcelona (Spain)

Short description of possible research topics for a PhD:

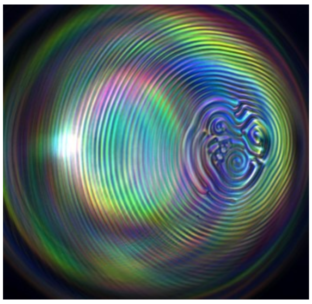

Figure 1. Topological defects in a chiral nematic spherical shell [1]

In cells, thousands of nanometre-sized molecular motors coordinate themselves to carry out mechanical tasks at much larger length scales, such as cell motility, division and replication. They do so by intertwining similar protein components that operate either as scaffold constituents or force-generators. The composite assembled in this way is a delicate, natural active material that exhibits sought-after properties such as autonomous motility, internally generated flows and self-organized beating. A replicated in-vitro active system has recently been developed by mixing bundled polymerized tubulin filaments (microtubules) with kinesin motors. When this biomimetic material is confined to a surface, the microtubules develop long range orientational order. That, coupled with the large-scale self-organized flows in the system, results in the formation of a two-dimensional active nematic material, whose fascinating properties have just started to be experimentally explored. At ESPCI, we have recently developed a rich platform where we produce complex molecular structures in passive nematic liquid crystals by confining the liquid crystal to complex geometries. The goal of this PhD is to extend these studies to active nematics. Confinement and curvature typically induce the formation of topological defects in the nematic material, which are singular points in the orientational field, see Fig.1 [1-5]. Unlike in equilibrium systems, where defects are largely static structures, in active nematics, defects move spontaneously and can be described as self-propelled particles. The combination of activity, topological constraints, and coupling between active and passive nematic materials is expected to produce a myriad of new dynamical states.

Required background of the student: Degree in physics or physico-chemistry. Experience in active matter/liquid crystals, although not necessary, will be appreciated. The student will do experimental research (optical microscopy, microfluidics, image analysis) while collaborate with theoreticians.

A list of 5 (max.) representative publications of the group:

[1] L. Tran, M. O. Lavrentovich, G. Durey, A. Darmon, M. F. Haase, N. Li, D. Lee, K. J. Stebe, R. D. Kamien, and T. Lopez-Leon, PRX, 2017(accepted). [2] A. Darmon, M. Benzaquen, S. Čopar, O. Dauchot and T. Lopez-Leon , Soft Matter, 12, 9280 (2016). [3] A. Darmon, M. Benzaquen, D. Seĉ, S. Čopar, O. Dauchot and T. Lopez-Leon, PNAS 113, 9469 (2016) [4] T. Lopez-Leon, A. Fernandez-Nieves, M. Nobili and C. Blanc, PRL,106, 247802 (2011). [5] T. Lopez-Leon, V. Koning, K. B. S. Devaiah, V. Vitelli, A. Fernandez-Nieves, Nature Phys.7, 391-394 (2011).