

Twist-bend coupling in helical polymers

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Actin is an element of the cell cytoskeleton and plays a large role in cellular mechanics and transport. It forms networks of filaments connected by a variety of proteins. Actin filaments themselves are polar polymers. Their structure resembles a double helix, in which the two strands are out-of-register by a half monomer.

Because of their helical structure, such polymers are expected to exhibit twist-bend coupling. However, the magnitude of this effect is hard to establish. Indeed, the pitch of actin filaments is around 72nm , well below the optical resolution limit. Because of this, the relevance of the twist-bending coupling on real actin networks remains unknown.

However, it is possible to indirectly measure filament deformation by measuring the binding of shape-sensing proteins to actin filaments. This can be performed while deforming filaments through various experimental methods (optical tweezers, magnetic tweezers, microfluidic flow). As a result, the sensitivity of binding to filament deformation can now be assessed experimentally.

Project

In this internship, we aim at understanding the magnitude and relevance of twist-bend coupling in actin filaments under stress. For this, we will use theory and simulation to decypher the experimental results obtained by our collaborators (Cecile Leduc and Hugo Wioland, Institut Jacques Monod, Paris).

To bridge the scales between experimental measurements and analytical theory, we will be able to use a recently-developed numerical simulation of actin filament. This new implementation allows the simulation of much larger time- and lengthscales than that usually accessible by coarse-grained model, while keeping essential actin features such as chirality and twist-bend coupling.

Methods

The student need to be familiar with at least some of the physical concepts required for this project (i.e. semi-flexible filaments, elasticity, physical chemistry...). The student should be willing to interact with experimentalists and develop a workings understanding of actin biochemistry. Basics in Python scripting are recommended for simulation analysis.

Mentoring

The student will be mentored by Serge Dmitrieff (Institut Jacques Monod, Paris), a theoretical physicist specialized in cytoskeleton mechanics using theory and simulations. The student will be hosted in the team "Cellular Spatial Organization", an interdisciplinary team that hosts both theoreticians and experimentalists. The student will interact with Cecile Leduc and Hugo Wioland, in the team of Antoine Jégou and Guillaume Romet-Lemonne, in the same institute.

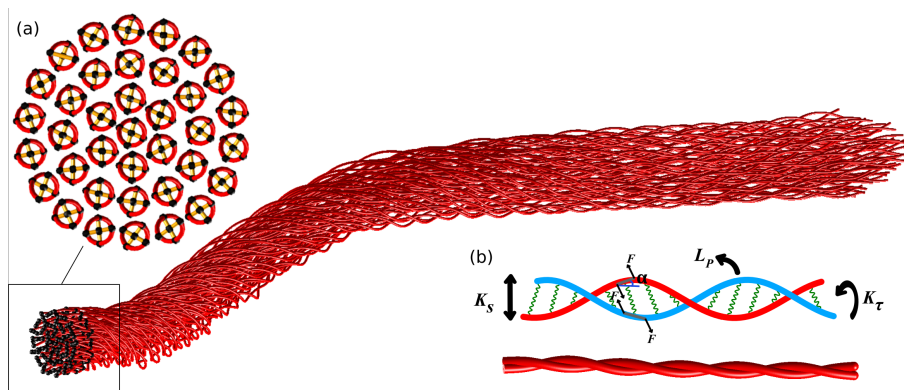


Figure 1: (a) Overdamped Langevin simulation of a bundle of helical filaments. Filaments ends are placed on a hexagonal lattice. (b) Schematic of the implementation of a helical filament as two protofilaments connected by springs and torques.