UNIVERSITÀ DI TRENTO | Department of Physics

A Quantum of Matter

Mixing topology and activity in polymeric materials

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Polymers, which are large molecules made of repeating units, permeate our world, with plastic being in almost all of our modern appliances, and macromolecules such as DNA being at the basis of life as we know it. Thanks to their high aspect ratio and flexibility, polymers show a wide variety of shapes: they can be linear, have branches, be circularized into rings, or stem from a central core. Starting from these configurations, their topological complexity can be further increased, as polymers can be tied into knots, form loops, be mechanically linked together and at high density become entangled melts. When we investigate such structures in the frame of biological systems, we incur into another layer of complexity, as we step out of equilibrium; in fact, biological mechanisms are defined by their out-of-equilibrium nature, relying on the extraction of energy from the environment. In many cases, this energy extraction takes place in the form of "activity", that is, the production of directed motion: examples of active polymers can be considered actin, moving thanks to kinesin, and the DNA, moving during replication and protein production. If we generalize the idea of polymer from molecules to filaments, also cilia, flagella, bacteria, and even worms share similar characteristics and can be studied within the active polymer framework. Our research employs coarse-grained molecular dynamics simulations to study how activity and complex topologies interact with each other in polymer systems, especially in highly entangled melts [1] and tied knots [2], revealing that in one case activity renders topology irrelevant, while in the other it makes topology a determining factor.

[1] *Breoni, D. et al., Giant activity-induced elasticity in entangled polymer solutions. Nature Communications 16, 5305 (2025)*
[2] *Breoni, D. et al., The effects of knot topology on the collapse of active knots. arXiv:2507.08391 (2025)*

Who is Davide Breoni?
Davide is a Postdoctoral researcher at the University of Trento, where he has worked in the group of Prof. Luca Tubiana since 2024. He obtained his PhD at the University of Düsseldorf (Germany) under the guide of Prof. Hartmut Löwen on the topic of active matter in complex environments. His current interests are in the field of polymer physics, active matter, and topology.

A Quantum of Matter is a series of events dedicated to the research in Physics of Matter that is carried out in the **Physics Department of the University of Trento**. The goal of **A Quantum of Matter** is to develop synergies and collaborations between research groups: for this reason, the seminars will focus not only on the results obtained, but also on the techniques employed by the groups and on the possible research themes that could be developed in partnership, leaving plenty of room for exchange of opinions and discussion.

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