

The Topological Glass: A Network Phase Transition?

A Mini project proposal offered by Prof Matthew Turner & Davide Michieletto

Understanding the static and dynamic properties of linear, closed rings (e.g. ring polymers in solution) has been a long-unresolved problem in physics. Ring shaped objects have a closed topology and therefore lack ends. This has profound consequences for the configurations that they can explore at equilibrium and for how they move. Recently, most of the theoretical and computational effort has been focused on dense, flexible rings. These studies have revealed (i) the emergence of an unusual state of matter and (ii) deep connections with DNA organization during the stage at which chromosomes de-condense and form a largely entangled state of looped DNA [1]. Recently, it has also been shown that confining dense rings into a gel (or other porous medium) results in the proliferation of inter-ring penetrations or “threadings”. Such a state has been found to possess novel physical properties, which may be intimately related with the rings closed topology [2]. These threadings represent strong constraints on diffusion. In the thermodynamic limit this could drive the emergence of a new, highly entangled state of matter with exponentially slow dynamics, which we term a “topological glass”.

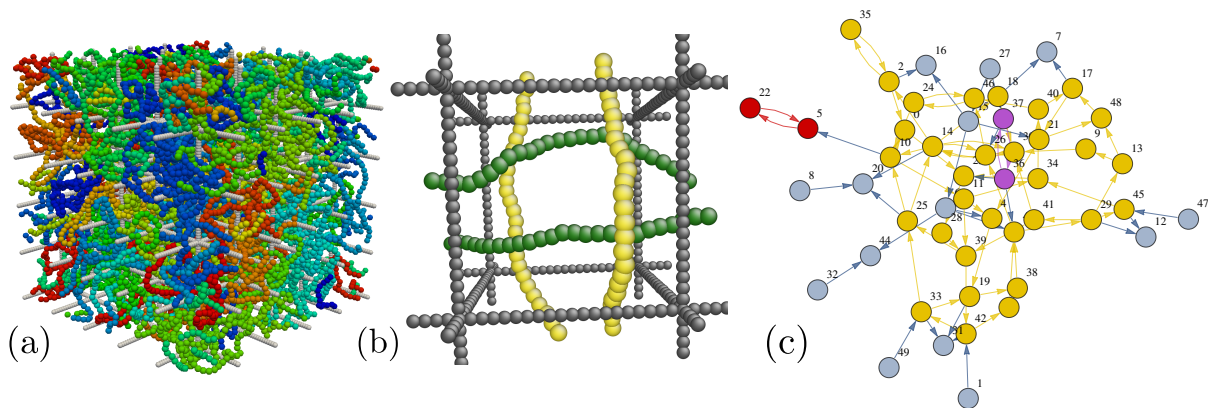


Figure 1: (a) Snapshot of inter-threading rings confined in a gel. (b) Detail of the system, where the green ring is threading through the yellow one, and hence hindering its diffusion (both ends of the rings close on themselves far away from the cell): the yellow ring cannot ‘slither’ up or down so as completely leave this lattice volume until it is first unthreaded by the green one. (c) Snapshot of the network of inter-threading rings. Each node represents a ring and an arrow from i to j is pictured if i is threading through j . The largest strongly connected component is highlighted in yellow.

In this project the student should aim to (i) study the evolution of the network of inter-threading rings, which has been suspected of undergoing a phase transition as a function of the solution density or the rings length and (ii) to investigate the slowing down (jamming) in the dynamics, which may be intimately related to a network phase transition in the network of inter-ring threadings. The student will use data that we have already obtained from detailed computer simulations of this system to characterise the nature of the transition in this network and, secondly, design a model that couples the change in the network topology with the dynamics of the rings themselves, *e.g.* by using a ring diffusion coefficient that depends on its in-degree in the network. This work would require some familiarity with network analysis and some familiarity with stochastic processes or monte carlo techniques would be advantageous. The student will be supported by a current Ph.D. student, working on a related subject (D. Michieletto). There is a good chance that a committed student could contribute to a publication in a peer-reviewed journal.

References

- [1] Rosa A. and Everaers R., PLoS 4,8 (2008)
- [2] Michieletto D., Marenduzzo D., Orlandini E., Alexander G., Turner M., arXiv preprint arXiv:1306.4965