BP 19: Semiflexible Polymers and Networks

Time: Wednesday 17:30–19:30 Location: PC 203

BP 19.1 Wed 17:30 PC 203

Orientational order in two-dimensional random networks of semiflexible polymers — •Martin Kiemes[1], Panayotis Benetatos[2], and Annette Zippelius[2] — [1]Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Germany — [2]Institut für Theoretische Physik, Universität Göttingen, Germany

It has recently been shown that in a 3D melt of semiflexible polymers random permanent cross-links that fix the corresponding segments to align give rise to orientationally ordered gels [1]. In the current work, using a similar semimicroscopic replica field-theoretic approach, we focus on the 2D case which allows us to consider cross-links that prescribe a finite angle between the corresponding segments. We discuss the resulting phase diagram in terms of the cross-link density, the polymer stiffness, and the crosslinking geometry.

[1] P.Benetatos and A.Zippelius, PRL 99, 198301 (2007)

BP 19.2 Wed 17:45 PC 203

A Stiff Rod in Dense Environments: A Paradigm for Translation–Rotation Coupling — •Tobias Munk, Felix Höfling, Erwin Frey, and Thomas Franosch — Arnold Sommerfeld Center and CeNS, Ludwig-Maximilians-Universität München, Germany

Everybody who once observed a long lorry trying to turn in a small street knows of the consequences of the coupling of translational and rotational motion in the macroscopic world. On the micro scale, similar things happen to anisotropic objects diffusing in a crowded environment. This is found for example in biological cells: their interior is enormously crowded by huge amounts of proteins and other complexes, thus diffusing anisotropic objects are largely constricted by their surroundings. This happens e.g. to free actin filaments moving in the cytoskeleton.

We have set up a simple two-dimensional model in order to examine the Brownian motion of a stiff rod in a sterically hindered medium on all physically relevant timescales. A theoretical description of the unobstructed motion is developed by mapping the corresponding anisotropic diffusion equation to the Smoluchowski-equation. This, however, is not sufficient to grasp the translation–rotation coupling induced by the obstacles. By means of molecular dynamics simulations we point on these coupling effects and demonstrate that the motion is non-gaussian at intermediate times.

BP 19.3 Wed 18:00 PC 203

Stretching of buckled filaments by thermal fluctuations — •Krzysztof Baczynski, Reinhard Lipowsky, and Jan Kierfeld — Max Planck Institute of Colloids and Interfaces, Department of Theory & Bio - Systems, Science Park Golm, 14424 Potsdam, Germany

We study the buckling instability of filaments or elastic rods in two spatial dimensions in the presence of thermal fluctuations. We present an analytical solution based on a renormalization-like procedure where we integrate out short wavelength fluctuations in order to obtain an effective theory governing the buckling instability. We calculate the resulting shift of the critical force by fluctuation effects and the average projected filament length parallel to the force direction as a function of the applied force and of the contour length of the filament. We find that, in the buckled state, thermal fluctuations lead to an increase in the mean projected length of the filament in the force direction. As a function of the contour length, the mean projected length exhibits a cusp at the buckling instability, which becomes rounded by thermal fluctuations. Our analytic results are confirmed by Monte Carlo simulations.

BP 19.4 Wed 18:15 PC 203

Misfits never yield – A microscopic approach to the nonlinear rheology of biopolymer solutions — •Pablo Fernández[1] and Klaus Kroy[2,3] — [1]E22 Biophysik, Technische Universität München, James Franck Straße 1, D-85748 Garching, Germany — [2]Institut für Theoretische Physik, Universität Leipzig, Postfach 100920, D-04009 Leipzig, Germany — [3]Hahn-Meitner Institut, Glienicker Straße 100, D-14109 Berlin, Germany

We propose a nonlinear extension of the standard tube model for semidilute solutions of semiflexible polymers. Non-affine filament deformations at the entanglement scale, the renormalisation of direct interactions by thermal fluctuations, and the geometry of large deformations are systematically taken into account. The analysis of the shear response of a simplified unit cell sheds light onto fundamental issues in cytoskeletal mechanics. The strong geometric stiffening predicted for purely enthalpic networks is found to be thermally suppressed. Instead, we obtain a broad linear response regime covering typical physiological mesh sizes. Surprisingly, we discover a destabilizing effect of large strains ($\sim$ 100%). The theory thus provides a novel perspective at the widely observed catastrophic collapse of *in-vitro* sheared biopolymer solutions, usually attributed to irreversible network damage. It moreover supports the interpretation of shear stiffening at finite frequencies as indicative of adhesive polymer interactions. In combination with such friction-type interactions, our analysis provides an analytically tractable framework to address the nonlinear viscoplasticity of biological tissue on a molecular basis.

BP 19.5 Wed 18:30 PC 203

Accessory contribution of actin binding proteins to the viscoelastic properties of composite actin-networks — •Kurt Schmoller, Oliver Lieleg, and Andreas Bausch — Lehrstuhl E22 für Biophysik, Physik Department, TU München, Garching, Deutschland

Cell shape, mechanics and motility are mainly determined by crosslinked and bundled actin-networks. As in living cells many different actin binding proteins (ABPs) are used simultaneously, it is necessary to study their mechanical function in well-defined in vitro systems where the type and concentration of the ABP can be controlled. By rheological methods we determine the viscoelastic properties of bundled and crosslinked actin networks. The ABPs filamin and fascin are both known to bundle actin filaments. However, the bundle networks formed exhibit pronounced differences in their viscoelastic properties. We investigate composite networks tuning the concentration of either fascin or filamin in the presence of the other ABP. Interestingly, the concentration dependence of the viscoelastic network response is only slightly modified by the presence of the second ABP. These findings suggest that a combination of these two ABPs does not lead to a phase separation, but to an accessory contribution to the viscoelastic properties of the composite network. Further we find networks with a frequency response resembling that of living cells. These findings underline that in vitro actin networks with only a few combined ABPs might be sufficient to rationalize main aspects of the mechanical properties of cells.

BP 19.6 Wed 18:45 PC 203

Semiflexible Polymer Conformations in Entangled Networks — •Hauke Hinsch and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics, LMU München, Germany

Biopolymers are ubiquitous in nature and play a crucial role for cell mechanics and motility. One prominent example is the semiflexible filamentous actin that constitutes the cytoskeleton by forming large networks. In the absence of cross-links the network's polymers are mutually constrained only by entanglements. We report on theoretical work and simulations on various distribution functions, investigate the implications for the network's equilibrium configuration and compare our findings to recent experimental observations. Particularly, we challenge the assumption that for large ensembles in the absence of any other interactions than topology the behavior of free polymers is recovered.

BP 19.7 Wed 19:00 PC 203

Conformations of zipped filaments — •Petra Gutjahr[1], Reinhard Lipowsky[1], and Jan Kierfeld[2] — [1]Max Planck Institute of Colloids and Interfaces, Theory & Bio-Systems, 14424 Potsdam, Germany — [2]Technical University of Dortmund, Theoretical Physics I, 44221 Dortmund, Germany

We study the zipping of two filaments with an attractive interaction and pinned filament ends based on experiments using microscopic pillar arrays. For the cases of weak and strong attraction between filaments, we analyze the influence of the filaments' stiffness and thermal fluctuations on the zipped equilibrium shape. Thereby we propose a scheme, by which the magnitude of the attraction between the filaments can be deduced from experimentally observed conformations.

Our results should be applicable to actin filaments bundles induced by various crosslinker proteins and multivalent cations, but also to bundles formed by other types of semiflexible polymers.

BP 19.8 Wed 19:15 PC 203

Semiflexible chains in disordered media — •Abigail Klopper[1], Sebastian Schoebl[2], and Klaus Kroy[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [2]Institut für Theoretische Physik, Universität Leipzig, Leipzig

Cellular function is intimately connected with the mechanical and dynamical properties of an underlying cytoskeletal structure, which can be described as a random network of stiff polymers. One attempt to understand this relationship involves determining how these properties are influenced by the conformational statistics of *single* polymers within the network. This calls for shrewd modeling of the polymers' immediate environment - capturing the spatial confinement caused by cellular crowding within a simplified theoretical framework. In this spirit, the problem may be recast in terms of a wormlike chain embedded within a matrix of quenched random obstacles. Despite the prolific attention paid to the analogous problem in flexible polymer networks in recent years, little is understood about how their stiffer counterparts respond to such an environment. This can be partly attributed to the difficulties encountered when stiffness and inextensibility criteria are imposed simultaneously with quenched disorder constraints. With the view to circumvent these problems, we use a weakly bending rod formalism and employ replica theory to calculate disorder-averaged equilibrium properties of a stiff biopolymer in a quenched random environment.