AKB 7 Biopolymers I

Time: Tuesday 09:45–11:30 Room: ZEU 255

Invited Talk AKB 7.1 Tue 09:45 ZEU 255

Cytoskeletal Polymerization Motors — •Marileen Dogterom — FOM Institute AMOLF, Amsterdam, Netherlands

Dynamic cytoskeletal polymers such as microtubules and actin filaments provide forces for various types of cellular and intracellular motility. To understand how these polymerization motors work we use optical tweezers-based techniques and microfabricated barriers that allow us to study both actin and microtubule force generation at a single polymer level. We can measure force-velocity relations and monitor how the polymer assembly dynamics responds to force, both in the absence and presence of relevant binding proteins. In addition, we use microfabricated devices to mimic the physical confinement of living cells and study, for example, the role of microtubule-based force generation in the positioning of microtubule organizing centers. In cells, this positioning results from a complex interplay between dynamic, force-generating microtubules, the cell cortex, the cell geometry, and regulatory proteins. In microfabricated chambers, we have previously shown that in simple cases the pushing of the growing microtubules on the chamber walls is enough to center the organizing center. We have now refined this type of experiment by adding specific biochemical activity to the chamber walls. This allows us to study the effect of localized motor proteins and cortical regulatory proteins on microtubule organization and the positioning of microtubule organizing centers.

AKB 7.2 Tue 10:15 ZEU 255

Polymers in Axially Symmetric Confining Geometries — •Frederik Wagner[1], Gianluca Lattanzi[2], and Erwin Frey[1] — [1]Arnold Sommerfeld Center and CeNS, Department of Physics, Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 München, Germany — [2]Department of Medical Biochemistry, Biology and Physics, TIRES-Center and INFN, Università di Bari, Piazza Giulio Cesare 11, 70124 Bari, Italy

The growing interest in understanding the constituents of the cell demands a rigorous analysis of its main structural components: polymers of different flexibilities (e.g. DNA, actin, microtubules) confined to a micrometer scale. In additon, confinement of polymers on micro- and nano-scales plays an important role in developing new devices for the visualization and manipulation of polymers. These recent advances require a careful analysis of the relevant accessible quantities and their dependence on the two main parameters of the system: the persistence length ℓ_p which entails the flexibility of the chain, and the Odijk deflection length l_d, which provides a measure of the confinement. We developed a Monte Carlo simulation to investigate the general features of the worm-like chain model in axially confining geometries. In particular, we have studied the case of harmonic potentials, which is amenable to analytic approximations. Our simulations critically assess the approximations used in analytical calculations, extend the range of parameters and the quantities that can be compared with experimental observables, and provide a deeper insight on scaling relations, the influence of boundary conditions and the details of the confining geometry.

AKB 7.3 Tue 10:30 ZEU 255

Actin Filaments Confined in Microchannels — •Patrick Levi and Klaus Mecke — Institut fuer Theoretische Physik I, Universitaet Erlangen-Nuernberg, Staudtstrasse 7, 91058 Erlangen, Germany

The statistical physics of semiflexible polymers in confined geometries faces the problem of treating bending modes in non-parabolic potentials. We present an analytic expression for the distribution of the end-to-end distance in a parabolic potential. Our result is in good agreement with experimental data for hard wall confinement in rectangularly shaped microchannels. For non-parabolic potentials we developed a selfconsistent ansatz for mapping the wall distance of a rectangular channel to an effective parabolic potential strength. Deviations from the Odijk result for the correlation function in a parabolic potential are discussed. The selfconsistent approach is also used to calculate forces on the filaments in inhomogeneous channel geometries.

AKB 7.4 Tue 10:45 ZEU 255

Entropic forces generated by grafted semiflexible polymers — •Azam Gholami[1], Jan Wilhelm[2], and Erwin Frey[2] — [1]Hahn-Meitner-Institut, Abteilung Theorie, Glienicker Str. 100, D-14109 Berlin, Germany — [2]Arnold Sommerfeld Center for Theoritical Physics and CeNS, Department of Physics, Ludwig-Maximilian-Universität München, Theresienstrasse 37, D-80333 München, Germany

We compute both numerically and by Monte Carlo simulations the average force exerted by a fluctuating grafted semi-flexible polymer upon a rigid smooth wall as well as the corresponding free energy. Both quantities are thought to be of interest for understanding the physics of actin-polymerization driven cell motility and movement of bacteria like Listeria monocytogenes. Depending on the angle between the constraining wall and the direction of the graft, two asymptotic regimes with different dependence of the force on the position of the wall can be discerned. The angle determining the position of the crossover varies as the square root of the ratio of the polymer's length to its persistence length. For angles larger than the critical angle, previous expressions are qualitatively valid but for smaller angles different behavior is found.

AKB 7.5 Tue 11:00 ZEU 255

The flexural rigidity of microtubules relates to a limited compliance of inter-protofilaments bonds — •Francesco Pampaloni[1], Gianluca Lattanzi[2], and Davide Marenduzzo[3] — [1]EMBL Heidelberg - Cell Biology and Biophysics Programme - Heidelberg (Germany) — [2]University of Bari - Faculty of Medicine (Italy) — [3]Mathematics Institute - University of Warwick (UK)

The structure of microtubules (MT) is highly optimized to a maximum of mechanical performance: the hollow tube shape allows high strength and stiffness combined with a minimum of structural elements (tubulin dimers). Moreover, MTs are anisotropic in their elastic properties: they are softer on basal plane than along the axial direction. Such unusual properties of MTs - light, flexible, stiff - make them very similar to composite materials designed by engineers. Remarkably, tiny structural variations in the MT lattice, like protofilaments torsion and shifting, are not confined locally, but propagate in a concerted way along the whole MT length. It is likely that the energy required by this deformation is very low, of the order of the thermal fluctuations. Sub-nanometer deformations of the lateral bonds produce a slight relative shift between protofilaments, that introduces a significant shear component to MTs deflection. Consequently, for MTs the shear modulus is small enough to produce a length dependence of the bending stiffness. We present a multi-scale approach to investigate the elastic properties of MTs based on Monte Carlo simulation and conformational analysis of tubulin dimers in typical MTs architecture and we provide an useful framework for the interpretation of experimental data.

AKB 7.6 Tue 11:15 ZEU 255

Elastic response, buckling and rupture of microtubules under radial indentation — •Iwan A.T. Schaap[1], Carolina Carrasco[2], Pedro J. de Pablo [2], Frederick C. MacKintosh[1], and Christoph F. Schmidt[1] — [1]Dept. Physics, Vrije Universiteit, Amsterdam, NL — [2]Departamento de Física de la Materia Condensada C-III, Universidad Autónoma de Madrid

We have tested the mechanical properties of single microtubules by lateral indentation with the tip of an atomic force microscope. Indentations up to ˜3.6 nm, i.e. 15 % of the microtubule diameter resulted in an approximately linear elastic response, and indentations were reversible without hysteresis. At an indentation force of around 0.3 nN we observed an instability corresponding to a ˜1 nm indentation step in the taxol-stabilized microtubules, which could be due to partial or complete rupture of a relatively small number of lateral or axial tubulin-tubulin bonds. These indentations were reversible with hysteresis when the tip was retracted and no trace of damage was observed in subsequent high-resolution images. Higher forces caused substantial damage to the microtubules, which either led to depolymerization or, occasionally, to slowly reannealing holes in the microtubule wall. We have modeled the experimental results using finite element methods and find that the simple assumption of a homogeneous isotropic material, albeit structured with the characteristic protofilament corrugations, is sufficient.