AKB 25 Active Networks and Cell Motility

Zeit: Freitag 15:30–17:30 Raum: TU H2013

AKB 25.1 Fr 15:30 TU H2013

Molecular motors in cells: A rapid switch of biopolymer organization — •David Smith[1], Falko Ziebert[2], Walter Zimmermann[2], and Josef Käs[1] — [1]Institute for Soft Matter Physics, University of Leipzig, Linné Str. 5, D-04103 Leipzig, Germany — [2]Theoretical Physics, University of the Saarland, D-66041 Saarbrücken, Germany

All eukaryotic cells rely on the self-assembly of protein filaments to form a cytoskeleton. Motility and reaction to stimuli require pathways to reversibly change cytoskeletal organization. We report a mechanism whereby the molecular motor myosin II induces order-disorder transitions in actin-myosin networks. Bulk activity of the motors, which causes sliding on an individual filament level, maintains a dynamically disordered network. During depletion of ATP, an increasing fraction of molecular motors becomes inactive, crosslinking actin filaments to small clusters. The remaining active motors combined with continually increasing crosslinking foster further growth of these clusters, resulting in a variety of ordered macro-molecular structures such as asters, networks resembling neuronal architectures, and condensed super-precipitates. Experiments with photo-activated motors demonstrate the quick reversible restoration of the disordered state. This nonequilibrium pathway to switch between order and disorder is much faster than any structural changes driven by Brownian motion in thermodynamic equilibrium. This ability for rapid, isothermal motor-induced transitions between different degrees of self-organization indicates that molecular motors, in general, may substantially contribute to dynamic cellular organization.

AKB 25.2 Fr 15:45 TU H2013

Polymerization-Forces in Cell-Motility — •Cosima Koch, Claudia Brunner, Allen Ehrlicher, and Josef Käs — Universität Leipzig, Physik der weichen Materie

Over the last decade cell motility has been a subject of major research in cell biology, bio-medicine and biophysics. However, even up to date the detailed mechanisms of cell translocation are not completely understood. To tackle this problem we explore the effects of the actin-polymerization-disrupting drug cytochalasin D on the locomotion of fish epidermal keratocytes. The actin polymerization is essential for the protrusion of the cell's leading edge, the lammelipodium, which is elongated by the new polymerization of actin filaments. Nevertheless it is known that there are other mechanisms involved, like the rotation of the cell body and the generation of substrate traction forces. To gain insight into the interplay of the different processes we use substoichiometric concentrations of cytochalasin D which disrupts the lammelipodial protrusion by inhibiting the actin polymerization. The time dependence of the velocity and the area of fish keratocytes for different concentrations of cytochalasin D will be evaluated and discussed.

AKB 25.3 Fr 16:00 TU H2013

Simulation of collective filament dynamics in motility assays for motor proteins — •P. Kraikivski, R. Lipowsky, and J. Kierfeld — MPI für Kolloid- und Grenzflächenforschung, 14424 Potsdam

We present a model for the simulation of filament dynamics in two-dimensional motility assays of motor proteins and cytoskeletal filaments. The model contains deformable filaments that move under the influence of forces from molecular motors and thermal noise. Motor tails are attached to the substrate and modeled as elastic springs, motor heads perform a directed walk with a given force-velocity relation. Filament interactions are repulsive and characterized by a crossing probability. We study the collective filament dynamics and pattern formation as function of the motor and filament density, the force-velocity characteristics and detachment rate of motor proteins and the filament interaction. In particular, we investigate the formation and statistics of filament clusters due to blocking effects if filament crossing is inhibited.

AKB 25.4 Fr 16:15 TU H2013

Self-organization of cytoskeletal systems: formation of contractile rings and mitotic spindles — •Alexander Zumdieck, Karsten Kruse, and Frank Jülicher — Max-Planck-Institut für Physik komplexer Systeme, Dresden

The cytoskeleton is a complex network of protein filaments. Driven by active processes such as filament polymerization and depolymerization and the action of molecular motors it represents an active, soft material. It is intrinsically dynamic and able to generate mechanical stress and flow of filaments.

We discuss the self-organization of filament motor systems in the presence of filament polymerization and depolymerization. Starting from a microscopic picture, we develop a coarse grained theory for the dynamics of the system [1]. We apply these theories to systems of filaments representing stress fibers or contractile rings in linear and cylindrical geometry and find that contractile rings could form on a cell membrane by self-organization phenomena. We furthermore discuss the contraction dynamics of the contractile ring. Application of these theories to mitotic spindles reveals conditions for spindle formation and stability.

[1] K. Kruse, A. Zumdieck and F. Jülicher, Europhys. Lett. 64, 716 (2003)

AKB 25.5 Fr 16:30 TU H2013

The Bipolar Mitotic Kinesin Eg5 Moves on Two Microtubules — •Lukas C. Kapitein[1], Erwin J.G. Peterman[1], Benjamin H. Kwok[2], Jeffrey H. Kim[2], Tarun M. Kapoor[2], and Christoph F. Schmidt[1] — [1]Dept. Physics, Vrije Universiteit, Amsterdam, NL — [2]Lab. Chem. Cell Biol., The Rockefeller University, New York, NY, USA

During cell division mitotic spindles dynamically self-assemble with the help of microtubule-based motor proteins. The bipolar organization of spindles is essential for proper segregation of DNA and in eukaryotes requires BimC motor proteins, a family of homotetrameric kinesins. Hypotheses for bipolar spindle formation include the "push-pull mitotic muscle" model in which BimC and opposing motor proteins act between overlapping microtubules. The mitotic spindle is, however, very different from skeletal muscle in that it is a very dynamic structure which turns over its components within minutes while maintaining its shape and exerting forces. We have shown using in vitro assays with single-molecule fluorescence microscopy and optical tweezers that the BimC kinesin Eg5 drives sliding of microtubules dependent on their relative orientation at speeds comparable to spindle pole separation rates. Additionally, we found that Eg5 can tether microtubule plus-ends, suggesting an additional microtubule-binding mode for Eg5. Based on these data we suggest a physical model in which BimC kinesins contribute to mitotic spindle assembly by aligning and pushing apart microtubules.

AKB 25.6 Fr 16:45 TU H2013

Optical Deformability as an Intrinsic Differentiation Marker for Stem Cells — •Stefan Schinkinger, Falk Wottawah, Bryan Lincoln, Frank Sauer, and Jochen Guck — Universität Leipzig, Abteilung Physik der Weichen Materie, Linnéstr. 5, 04103 Leipzig

Despite major efforts in stem cell research, there is no unequivocal molecular marker available for characterization and sorting of stem cells or their state of differentiation. We use a microfluidic Optical Stretcher to determine the material properties of individual cells as a non-invasive cell marker. The mechanical properties measured are mainly influenced by the cytoskeleton, a polymeric protein network in the cell. Because the cytoskeleton also plays a major role in the function of cells, with this technique we are able to follow cell progression through the various stages of differentiation. Experiments were performed with a promyelocytic leukemia cell line called HL-60. Comparison with mature neutrophils and experiments with different precursor cells support our hypothesis. As no labeling is required, preparation time of samples is reduced and the risk of activation or differentiation due to stress can be kept minimal. Especially for therapeutic applications of stem cells where labeling of any kind is prohibitive, characterization by optical deformability as an intrinsic marker provides a reasonable alternative.

AKB 25.7 Fr 17:00 TU H2013

Resolving the Cell Cycle by Measuring Optical Deformability with a Microfluidic Optical Stretcher — •Bryan Lincoln, Maren Romeyke, Frank Sauer, Stefan Schinkinger, Falk Wottawah, and Jochen Guck — Universität Leipzig, Abteilung Physik der Weichen Materie, Linnéstr. 5, 04103 Leipzig

The Optical Stretcher is a dual-beam optical trap capable of measuring the deformability of suspended biological cells. Previous measurements with this system have shown relevant differences between various cell types and have supported the idea that there is a strong correlation between a cell's cytoskeletal structure and its deformability. A microfluidic delivery system has been developed in order to measure cells at a high enough rate to acquire the necessary statistics to resolve elasticity changes within a single cell type. The cytoskeleton reorganizes as a cell grows and divides, so we find changes in deformability during various phases of the cell cycle as well. These various stages are identified by quantitative single-cell fluorescent DNA analysis. Results are presented using a three-element viscoelastic model and implications for deformability as a cell marker are discussed. Additional experiments using Laser Scanning Cytometry are presented that correlate position in the cell cycle with amount of F-actin in both the adhered and suspended state.

AKB 25.8 Fr 17:15 TU H2013

Dynamics of Cilia and Flagella — •Andreas Hilfinger[1], Ingmar Riedel[2], Amit Chattopadhyay[1], Karsten Kruse[1], Jonathon Howard[2], and Frank Jülicher[1] — [1]Max-Planck-Institute for Physics of Complex Systems, D-01187 Dresden, Germany — [2]Max-Planck-Institute of Molecular Cell Biology and Genetics, D-01307 Dresden, Germany

Directed motion on the level of single cells is in many cases achieved through the beating of whip like appendages (cilia or flagella). These organelles contain a highly conserved structure called axoneme, whose characteristic architecture is based on a cylindrical arrangement of elastic filaments (microtubules). In the presence of ATP, molecular motors (dynein) exert shear forces between neighbouring microtubules, leading to a bending of the axoneme through structural constraints.

We describe the axoneme as an elastic filament, driven by internally generated stresses. Bending waves emerge from a non-oscillatory state via a dynamic instability. The corresponding beat patterns are solutions to a non-linear wave equation with appropriate boundary conditions. Focusing on beats confined to a surface we compare our results to recent data from bull sperm flagella. Our approach can be generalised to three dimensions enabling us to discuss helical and rotary wave patterns.