BP 9: Actin Dynamics

Time: Tuesday 10:45–13:15 Location: ZEU 260

BP 9.1 Tue 10:45 ZEU 260

Dynamics of the actin cytoskeleton in response to periodic stimuli — •Christian Westendorf[1], Eberhard Bodenschatz[1], and Carsten Beta[1,2] — [1]MPI für Dynamik und Selbstorganisation, Göttingen — [2]Institut für Physik und Astronomie, Universität Potsdam

The dynamic properties of the actin cytoskeleton provide the basis for motility, phagocytosis, and division of eukaryotic cells. Polymerization of actin fibers within the branched cortical network exerts a force at the membrane of the leading edge resulting in the formation of pseudopods and, finally, cell motion. A widely used model system for the study of actin dynamics in vivo is the social amoeba Dictyostelium discoideum. It is the aim of this study to characterize intrinsic time scales of the actin cytoskeleton in chemotactic Dictyostelium cells. We observe filamentous actin using a LimE-GFP construct in an AX-2 background. Microfluidic techniques, including laser-mediated uncaging of caged cAMP, are used to expose single Dictyostelium cells to periodic stimuli of cAMP. Responses of the actin cytoskeleton were recorded by fluorescence imaging of LimE-GFP using confocal laser scanning microscopy. Based on frequency analysis, we find an optimal response regime of the actin system around 20 sec. For longer forcing periods, a frequency doubled resonant response could be observed. For short forcing periods no entrainment was found. We also performed computer automated celltracking on the cells exposed to periodic stimuli.

BP 9.2 Tue 11:00 ZEU 260

Visco-Elasticity of Actively Deformed Actin Bundles — •Dan Strehle[1], Brian Gentry[1], Jörg Schnauss[1], Mark Bathe[2,3], Erwin Frey[2], and Josef Käs[1] — [1]Universität Leipzig — [2]LMU München — [3]MIT Boston

Actin, a highly conserved cellular protein, forms filamentous polymers under physiological conditions. In vivo these are organized into the networks and bundles that comprise the cytoskeleton, which is responsible for the cell*s morphology and is essential for cell locomotion. Cytoskeletal bundles also perform a variety of additional functions. In filopodia, for instance, they probe the extracellular environment and in stereocilia they serve as the signal transducing organelles of hair cells.

Cells can finely tune the mechanical properties of networks for various tasks by choosing from a variety of actin associated proteins to control growth, crosslinking and bundling of filaments. Dynamic crosslinkers such as alpha-actinin or fascin, for instance, create the possibility for a viscoelastic-like response to different stresses encountered in cellular conditions. This behavior is a well-known property of actin networks, but less is known about time-dependent responses of the bundles themselves.

In order to better characterize the mechanical properties of cytoskeletal F-actin bundles, we have actively deformed reconstituted bundles in vitro. We have seen clear evidence of plastic behavior in which bundles maintain their deformed shape after being bent for an extended time. On shorter holding times they response elastically, returning to their undeformed configurations.

BP 9.3 Tue 11:15 ZEU 260

Quantifying athermal fluctuations in active actomyosin complexes — •David Head[1] and Daisuke Mizuno[2] — [1]IFF Theorie II, Forschungszentrum Jülich, GERMANY — [2]Organization for the Promotion of Advanced Research, Kyushu University, Fukuoka, JAPAN

Active gels represent a class of non-equilibrium materials that are currently undergoing vigourous research due to their relevance to a range of important biomechanical processes. The motility, structural and mechanical properties of eukaryotic cells are determined in part by the interaction between protein filaments and motor proteins activated by a reservoir of energy transfer molecules such as ATP. Being athermal in origin, the pN-scale force impulses generated by motor activations violate the fluctuation-dissipation theorem, and first principles modeling is required to relate microscopic processes to macroscopically measurable quantities. Here we present the results of such calculations based on the two-fluid model, in which the active agents are spatially uncorrelated but their stress fields decay algebraically, generating long-range correlations that can and have been measured in 2-particle microrheology experiments. 1-particle results are also derived, and both sets of calculations are supported by zero-frequency elasticity calculations performed in real space. Beyond the obvious advantages of allowing direct comparison to experiment, these results can also be used to speculate about the early-time instability of isotropic networks in the absence of permanent crosslinks, leading to the well-known phenomenon of super-precipitation.

BP 9.4 Tue 11:30 ZEU 260

Filament turnover stabilizes contractile cytoskeletal structures — •Philip Guthardt Torres, Konstantin Doubrovinski, and Karsten Kruse — Universität des Saarlandes, Fachrichtung Theoretische Physik, 66041 Saarbrücken, Germany

Vital cellular processes depend on contractile stresses generated by the actin cytoskeleton. Commonly, the turnover of actin filaments in the corresponding structures is large. We introduce a mesoscopic theoretical description of motor-filament systems that accounts for filament nucleation, growth, and disassembly. To analyze the dynamic equations, we introduce an expansion of the filament densities in terms of generalized Laguerre polynomials. We find that filament turnover significantly stabilizes contractile structures against rupture. Finally, we relate the mesoscopic description to a phenomenological theory of cytoskeletal dynamics.

BP 9.5 Tue 11:45 ZEU 260

Polymerization forces of interacting filaments — •Jaroslaw Krawczyk and Jan Kierfeld — TU Dortmund, Fakultät Physik, 44221 Dortmund

Many cellular processes are driven by polymerization of filamentous proteins. Using stochastic simulations based on the Gillespie algorithm we investigate force-generation by polymerizing groups of filaments or protofilaments and study the influence of an attractive interaction between filaments on the polymerization dynamics. We find that the force-velocity characteristics, the stall force and maximal growth velocity of the filament assembly depend sensitively on the presence of interactions.

15 min. break

BP 9.6 Tue 12:15 ZEU 260

A realistic model for actin driven motility using homogenization techniques — •Karin John[1], Denis Caillerie[2], Philippe Peyla[1], and Chaouqi Misbah[1] — [1]Laboratoire des Spectrométrie Physique, UJF Grenoble I, BP 87 - 38402 Saint-Martin-d'Hères, France — [2]Laboratoire 3SR, INPG, BP 53 - 38041 Grenoble Cedex 9, France

Force generation by actin polymerization is an important step in cellular motility and can induce the motion of organelles or bacteria, which move inside their host cells by trailing an actin comet behind.

Biomimetic experiments on beads and droplets have identified the biochemical ingredients to induce this motion, which requires a spontaneous symmetry breaking in the absence of external fields.

We had shown previously, that the symmetry-breaking can be captured on the basis of a linear elasticity theory and linear flux-force relationships.

However, a deeper understanding of the process of symmetry-breaking and force generation necessitates a realistic description of the mechanics of the actin gel and its influence on the growth process.

Starting out from the filamentous structure of the actin gel we have derived a set of continuous constitutive equations using homogenization techniques, which takes into account the history of the gel growth.

This description allows us to capture basic phenomena like treadmilling, symmetry-breaking and comet formation without any ad hoc assumptions.

BP 9.7 Tue 12:30 ZEU 260

Cutting viscoelastic materials, the theoretical basis of orientation sensitive stress measurements — •Martin Depken[1], Mirjam Mayer[2], Justin Bois[1], Frank Jülicher[1], and Stephan Grill[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

Laser ablation is an important tool to analyze stress distributions in the cell cortex and in the tissues of developing organisms. To describe

the response of the cell cortex to such a perturbation, we utilize a hydrodynamic description of active viscoelastic materials. For these materials the initial velocity response is shown to be proportional to the local stress before ablation. This method provides a direction sensitive measure of stress differences, and applying this method to the C. elegans cell cortex we find that the stress can be both anisotropic and inhomogeneous. This constitutes a new tool for the studies of stress in active cellular systems.

BP 9.8 Tue 12:45 ZEU 260

Force Generation of Expanding Actin Gels — •Stephan Schmidt[1], Georg Freund[2], Walter Zimmerman[2], and Andreas Fery[1] — [1]Physikalsiche Chemie II, Universität Bayreuth,Universitätsstr. 30, 95440 Bayreuth Germany — [2]Theoretische Physik I, Universität Bayreuth,Universitätsstr. 30, 95440 Bayreuth Germany

Force generation in actin gels is mainly associated with directed polymerization of actin monomers into branched filaments that extend against the load. Its ability to generate forces by monomer insertion is appealing from a material science point of view. However, while the biochemical processes associated with the actin polymerization are well understood, the molecular scale mechanism of force generation is still matter of debate. We use a simplified in vitro assay composed of purified proteins and artificial colloidal probes to directly study the forces during actin network growth. Force measurements on actin networks are performed using colloidal probe AFM techniques. In our setup the actin gel is compressed between a colloidal probe and a solid substrate while it deflects an AFM cantilever during expansion. Using fluorescence microscopy we observe the gel extension in direct conjunction with the AFM measurement. Furthermore, we vary the actin density and crosslinking via drugs or proteinic constituents like ARP2/3 and gelsolin. Generally, we observe increasing stall forces as the gel density or crosslinking density is increased. Results also suggest that the forces are limited by tensile stress build-up as the gel extends outward. Understanding of the gel behaviour in the framework of linear elasticity theory is subject to ongoing modeling efforts.

BP 9.9 Tue 13:00 ZEU 260

Stress generation and polarity sorting in active filament bundles attached to a membrane — •Marc Neef and Karsten Kruse — Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken

During the late states of cell division, animal cells are cleaved into two by a contractile ring. It consists of a bundle of actin filaments and molecular motors, where the actin filaments are connected to the plasma membrane. We study the effects of this coupling between filaments and the membrane on the dynamics of the bundle. In our model, we assume that filaments are anchored to the membrane by proteins that are bound to the filament ends. We treat the membrane as a thin film of a viscous fluid and account for hydrodynamic interactions between the anchor proteins. These are included by application of the "method of reflections". Using a stochastic as well as a mean field version of this model, we calculate the stress in the membrane due to interactions between antiparallel filaments. Furthermore, we find polarity sorting within the bundle for sufficiently large interaction strengths. Both effects exist only in the presence of hydrodynamic interactions.