DY 69: Complex Fluids and Soft Matter (joint session BP/DY/CPP)

Time: Friday 9:30–12:15 Location: H 1058

DY 69.1 Fri 9:30 H 1058

Anisotropic Diffusion of Macromolecules in the Contiguous Nucleocytoplasmic Fluid during Eukaryotic Cell Division — Nisha Pawar, Claudia Donth, and •Matthias Weiss — Experimental Physics I, University of Bayreuth, Bayreuth, Germany

Protein diffusion in intracellular fluids is a crucial determinant of many vital biochemical pathways. Frequently an anomalous diffusion of macromolecules in the cytoplasm and nucleoplasm of eukaryotic cells has been reported, and associated changes in biochemical reactions have been discussed in some detail. Here we show that the contiguous nucleo-cytoplasmic fluid in dividing cells features an anisotropically varying diffusion of macromolecules [1]. In metaphase, diffusion in the contiguous nucleo-cytoplasmic fluid appears less anomalous along the spindle axis as compared to perpendicular directions. As a consequence, the long-time diffusion of macromolecules preferentially points along the spindle axis, leading to a prolonged residence of macromolecules in the spindle region. An anisotropic diffusion may support the dynamic formation of a spindle matrix which guides later steps in mitosis.

[1] N. Pawar, C. Donth, and M. Weiss, Curr. Biol. 24, 1905 (2014).

DY 69.2 Fri 9:45 H 1058

Optical Shaking of Single Cells — •Carla Zensen[1,3], Isis E. Fernandez[2,3], Oliver Eickelberg[2,3], Theobald Lohmüller[1,3], and Jochen Feldmann[1,3] — [1]Chair for Photonics and Optoelectronics, Physics Department and CeNS, Ludwig-Maximilians-Universität, Munich, Germany — [2]Comprehensive Pneumology Center, Institute of Lung Biology and Disease, Ludwig-Maximilians-Universität and Helmholtz Zentrum, Munich, Germany — [3]Nanosystems Initiative Munich (NIM), Schellingstr. 4, Munich, Germany

We report on a new strategy to dynamically manipulate single cells by exposing them to an applied optical force field which varies periodically in time and space. The mechanical transient response of the cell is monitored both by optical imaging and by a microfluidic detector bead [1] positioned in the cell vicinity. These optical 'shaking' experiments give insight into the mechanobiological properties of single cells.

A predefined array of NIR laser beams is spatially varied with a periodic dynamics in order to optically 'shake' single cells. A detector bead, which is optically trapped with an independent laser beam, is used to simultaneously map the resulting microfluidic flow. We demonstrate a first application of this novel technique by resolving mechanobiological differences in the hypotonic state of individual human erythrocytes. By analyzing the Fourier spectra of cell and detector bead movements, we show that tracking a single detector particle is sufficient to distinguish between soft and hard cells.

[1] A. Ohlinger, A. Deak, A.A. Lutich, and J. Feldmann, Phys. Rev. Lett. 108, 018101 (2012)

DY 69.3 Fri 10:00 H 1058

***In vivo* mechanics measurements using ferrofluid droplets** — •Friedhelm Serwane, Alessandro Mongera, Payam Rowghanian, David Kealhofer, and Otger Campàs — Department of Mechanical Engineering, University of California, Santa Barbara, USA

The development of living tissues and organs depends on cell behavior strongly influenced by the mechanics of their microenvironment. A prime example is the ability of a tumor to spread which has been linked directly to the elasticity of the surrounding matrix.

This interplay between mechanical inputs and biological responses has remained poorly understood, mainly due to a lack of techniques to measure mechanical properties while characterizing the molecular signals *in vivo*.

Here we present a technique to measure the mechanics of cellular microenvironment within living tissues and organs. We use ferrofluid oil droplets as mechanical actuators. Once injected in developing zebrafish embryos, we obtain the mechanical properties by tracking the dynamical response of the droplet when actuated by an external magnetic field. In particular, this technique allows us to measure the changes in mechanical properties underlying zebrafish gastrulation.

This technique opens the door to experiments which uniquely relate biological signals to the underlying mechanical properties.

DY 69.4 Fri 10:15 H 1058

Biomolecule dynamics in microfluidic pH gradients and prebiotic FeS membranes — •Friederike M. Möller[1], Dominic Berchtold[1], Franziska Kriegel[1], Laura Barge[2], Michael Russell[2], and Dieter Braun[1] — [1]Systems Biophysics, LMU München, Germany — [2]Jet Propulsion Laboratory, Pasadena, USA

What are possible driving forces to reduce local entropy in early evolution? Early earth creates a marked redox potential of >600mV between the CO2-dominated atmosphere, creating an ocean around pH 6 and the alkaline outflow of geological serpentinization reactions at pH 10. A rocky FeS membrane forms upon contact from the sulfuric S– and the Fe++ ions. Its equilibrium version was studied by Huber and Wächtershäuser to form the first organic molecules starting from CO. The FeS clusters created in the membrane are central parts in ancient electron-transfer proteins.

What are the physical characteristics of this membrane? In a microfluidic replica, the pH gradient leaks through the membrane. However, we find yet unexplained attractive forces: hydrophobic and charged molecules are strongly attracted towards the membrane center. As reference system, we create pH gradients in water by uncaging of OH- or H+ ions. The phoretic motions and pH gradients are measured by fluorescence. The rich non-equilibrium dynamics are explained with finite element modeling. They offer a microscopic view back in time into the geological setting of early Earth.

DY 69.5 Fri 10:30 H 1058

Dynamics of biological membrane mimics - A combined QENS and MD simulation study — •Lisa Lautner[1], Martin Schmiele[1], Sebastian Busch[2], Michaela Zamponi[3], and Tobias Unruh[1] — [1]Chair for Crystallography and Structural Physics, FAU Erlangen-Nuremberg, Germany — [2]University of Oxford, United Kingdom — [3]Heinz Maier-Leibnitz Zentrum, Garching

Phospholipids are of high interest in the fields of biology and biophysics. As a main component of biological cell membranes the lipids are involved in lipid-lipid and lipid-protein interactions and therefore essential in a variety of cell functions. Many of these processes, e.g. binding to or transport through the membrane, are coupled to their structure and dynamics. Quasielastic Neutron Scattering (QENS) experiments and state-of-the-art Molecular Dynamics (MD) simulations yield a complementary view on these processes, with high spatial as well as temporal resolution.

A combination of QENS experiments and MD simulations was used to obtain a detailed understanding of the dynamics of biomimetic POPC (1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine) bilayers in the liquid crystalline ($L_{(}\alpha$)) phase. Special emphasis was thereby the study of the temperature dependent behaviour of the phospholipid dynamics. The results of both the QENS experiments and the MD simulations coincide nicely and confirm the benefit of the combination of these complementary methods. These results provide a basis for extended studies on more complex systems e. g. lipid mixtures and lipid-protein interactions. First results of such experiments will be presented as well.

15 min break

DY 69.6 Fri 11:00 H 1058

Bridging the scales: How is the large-scale deformation of a cellular network related to cell-scale processes? — •Matthias Merkel[1], Raphael Etournay[2], Suzanne Eaton[2], and Frank Jülicher[1] — [1]MPI for the Physics of Complex Systems, Dresden — [2]MPI of Molecular Cell Biology and Genetics, Dresden

We propose a method to study the deformation of two-dimensional cellular networks. To this end, we focus on biological tissues, which typically undergo large-scale deformations during the development of an organism. However, how these large-scale deformations correspond to the collective behaviour of individual cells is not fully understood yet. Today, experimentalists are able to image tissues with up to 10 000 cells at sub-cellular spatial resolution and at a time resolution of minutes. Nevertheless, there is still a lack of methods allowing us to exploit the full depth of this huge amount of information.

Here, we propose a geometrical framework that exactly decomposes large-scale deformations into contributions by different kinds of cellular processes, which comprise cell shape changes, cell rearrangements (T1 transitions), cell divisions, and cell extrusions (T2 transitions). As

the key idea, we introduce a tiling of the cellular network into triangles. This allows us to define the precise contribution of each of kind of cellular process to large-scale deformation. Additionally, our rigorous approach reveals subtle effects of correlated cellular motion, which constitute a novel source of large-scale tissue deformation. Finally, we demonstrate our new method on the wing of the fruit fly, which undergoes large-scale deformations during development.

DY 69.7 Fri 11:15 H 1058

Bridging from ionic to non-ionic thermophoresis — •Manuel Wolff, Michael Nash, and Dieter Braun — Center for Nanoscience, LMU, Munich, Germany

Thermal gradients drive molecules in solutions, an effect termed thermophoresis. Interest in aqueous thermophoresis was recently triggered by its widespread application in biomolecule affinity analysis using infrared-illuminated capillaries.

Theoretical models are debated, not least due to the fact that molecules in water seem to behave significantly different in non-aqueous fluids. By designing fluorescently labeled polymers that are either completely uncharged or whose charge can be tuned by a change in pH, we find that the temperature dependence of ionic and non-ionic polymers is very distinct. Building upon previous models, we find that increasing thermophoresis for rising temperature, often fitted by a heuristic formula proposed by Piazza and attributed to hydrophobic effects, can be fully explained by the Seebeck effect: the temperature dependence of ionic thermophoresis is dominated by the temperature dependent thermophoresis of the small ions in solution. While this dependence is not yet fully known for H^+ and OH^-, the thermophoresis of peptide nucleic acid (PNA) with its pH dependent charge is described well across a wide range of pH with reasonable assumptions. These findings offer a new bridge from aqueous thermophoresis to non-aqueous solutions.

DY 69.8 Fri 11:30 H 1058

How to regulate droplet position in a heterogeneous chemical environment? — •Samuel Krüger[1,2], Christoph Weber[1], Jens-Uwe Sommer[2,3], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]Leibniz Institute of Polymer Research Dresden e.V., Dresden — [3]Technische Universität Dresden, Institute of Theoretical Physics, Dresden, Germany

P granules are droplet-like structures consisting of RNA and proteins. They occur in Caenorhabditis elegans embryo and are known to determine its germ lineage. Interestingly, P granules are segregated to one side of the cell. There is evidence that the droplet position is regulated by a spatially inhomogeneous protein called Mex-5. Here we propose a model that simplifies the multicomponent nature of the cytoplasm as a ternary mixture: The P granule material, the background fluid, and a regulator mimicking Mex-5. Using our model we aim to understand the physical principles controlling the droplet position. To this end we consider lattice-based Monte Carlo simulations for a ternary mixture, where the microscopic interactions between the components are captured by three Flory-Huggins parameters. Considering a linear regulator gradient we observe two stationary states. Droplets localise in regions of lowest regulator concentration if the regulator exhibits a high affinity to the solvent, and vice versa. We present evidence that the transition between the localisation at highest and lowest regulator concentration can be regarded as a phase transition. Beyond biology, understanding how the droplet positions can be regulated offers the possibility to design switchable units for chemical computing.

DY 69.9 Fri 11:45 H 1058

Mechanical regulation of vein morphogenesis in plant leaves — •Jonathan E. Dawson[1], Franck A. Dintengou[2], Irina Kneuper[2], William Teale[2], Klaus Palme[2], and Eleni Katifori[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Insitute of Bioloy II, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Development of leaf veins is a highly dynamic and regulated process. However, mechanisms that regulate the formation of veins and vascular architecture are largely unknown. In a growing leaf, in addition to genetic regulation, cell mechanics must also play an important role in forming veins. To what extent cell mechanics and the interplay between mechanics and biochemistry plays a role in vascular patterning is not well understood. Using a cell based model in which cells are polygons, here we describe the vascular development in early stages of growing leaf primordia. We investigate the formation of leaf primary vein by simulating tissue growth driven by inter-cellular diffusion of the plant hormone auxin, from auxin synthesizing cells. We show that dynamic modulation of the cell mechanical properties based on cell auxin concentration can reproduce realistic primary vein as observed in growing leaf primordia. We further tested our model by comparing with experiments in which auxin transport in affected.

DY 69.10 Fri 12:00 H 1058

Osmolyte effects: Impact on the aqueous solution around charged and neutral spheres — •Jens Smiatek — Institut für Computerphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

We have performed atomistic molecular dynamics simulations to study the solvation characteristics of model spheres for low concentrations of urea and hydroxyectoine in aqueous solution. The spheres are either positively or negatively charged with a valency of one or charge neutral. Our results illustrate that the presence of osmolytes influences the solvation properties of the spheres significantly. We have conducted a detailed investigation of water properties like the mean dipolar relaxation times, water orientation parameters around the spheres, dielectric constants, preferential binding behavior, water self-diffusion coefficients, and free energies of solvation by thermodynamic integration to study the influence of osmolytes in detail. Our findings indicate that several factors like the charge of the spheres as well as the characteristics of the osmolytes significantly influence the thermodynamic and dynamic properties of the local water shell and the solvation process with regard to varying enthalpic and entropic contributions.