DY 43: Statistical Physics of Biological Systems II (joint session BP/DY)

Time: Wednesday 15:00–17:30 Location: ZEU 250

Invited Talk DY 43.1 Wed 15:00 ZEU 250

Eavesdropping on fluctuation-driven transport in living matter — •Matthias Weiss — Experimental Physics I, University of Bayreuth, Gemany

The interior of eukaryotic cells is crowded on several length scales by a plethora of macromolecules and membrane-enveloped subcompartments. Self-organization of this complex environment eventually involves fluctuation-driven transport on many scales. Due to a vast number of active processes, living cells are in a genuine non-equilibrium state, endowing fluctuation-driven transport also with a non-thermal noise character.

Using different model systems, from culture cells to developing embryos, we have analyzed fluctuation-driven transport of cell constituents to eavesdrop on the ambient non-equilibrium noise of living matter. In particular, we have used single-particle tracking to quantify the heterogeneous and driven, yet often anomalous diffusion of cellular constituents under varying physiological conditions. Based on a thorough analysis of the experimental data, e.g. in terms of correlation functions and power spectra, and comparison to model simulations, our data provide deep insights into the physics of fundamental steps in cellular self-organization.

DY 43.2 Wed 15:30 ZEU 250

Control of droplet kinetics in active emulsions — •Jacqueline Janssen[1], Marta Tena-Solsona[2,3], Caren Wanzke[2], Fabian Schnitter[2], Hansol Park[4], Benedikt Riess[2], Julianne M. Gibbs[4], Job Boekhoven[2,3], and Christoph A. Weber[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Department of Chemistry, Technical University of Munich — [3]Institute for Advanced Study, Technical University of Munich — [4]Department of Chemistry, University of Alberta

Living cells host many membrane-less organelles which originate via liquid-liquid phase separation in both the cytoplasm and the nucleoplasm. Liquid phase separated droplets are crucial in living cells to spatially control chemical reactions. Recent experimental work revealed a new class of active emulsions where the lifetime and the rate of droplet growth can be controlled. This class of active emulsions involves fuel-driven chemical reactions from thermodynamically stable precursor molecules to metastable building blocks. At large enough concentration of building block material, the liquid droplets can form and undergo an anomalously fast ripening towards fewer droplets of larger size. Up to date, there is no theoretical model which would describe such anomalous ripening kinetics of active emulsions. We have derived a theoretical model which quantitively coincides with the experimental measurements conducted in the Boekhoven Laboratory. Our theory allows to understand how the metastable building blocks determine the lifetime and accelerate the droplet kinetics in this new class of phase separated, active systems.

DY 43.3 Wed 15:45 ZEU 250

Plasticity in vertex model of epithelial tissues — •Marko Popović, Valentin Druelle, and Matthieu Wyart — Institue of Physics, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

In order to properly develop and function living organisms are required to change and maintain shape. This can be achieved by reshaping a liquid-like tissue and then changing its material properties to stabilize the final shape. Alternatively, if the tissue is plastic it will respond elastically to stresses below some critical value but higher values of stress will produce a plastic flow leading to a permanent plastic shape change, allowing it to retain the memory of stresses that have acted on it. Plasticity is exhibited by a wide class of amorphous solids such as: colloidal gels, emulsions and foams where it corresponds to a yielding transition. Are there features of yielding transition, such as strong dependence on system preparation and collective particle rearrangements leading to non-linear rheology, that are relevant during biological morphogenesis? Motivated by similarities of disordered tissues and amorphous solids we study plastic properties of vertex model of epithelial tissues, where mechanical properties of individual cells are prescribed and emerging tissue mechanics is obtained from their collective behaviour. We study mechanical properties of elementary plastic event in epithelial tissues, a so called T1 transition, in which two pairs of cells exchange neighborship. We demonstrate that interactions between T1 transitions are analogous to those of particle rearrangements in amorphous solids and that vertex model belongs to the same class of universality.

DY 43.4 Wed 16:00 ZEU 250

Selection via phase separation — •Giacomo Bartolucci[1,2], Yash Rana[1,2], Alexandra Kühnlein[3], Christof Mast[3], Dieter Braun[3], and Christoph A. Weber[1,2] — [1]Max Planck for the Physics of Complex Systems, Dresden — [2]Center for Systems Biology Dresden — [3]Ludwig Maximilian University, München

Living cells and pre-biotic systems are complex aqueous mixtures composed of thousands of different heteropolymers. In such multi-component mixtures, enrichment and selection of a small set of components are important to achieve biological function. However, when the number of components increases, each of them becomes more diluted impeding a significant enrichment of selected components. Here, we propose a selection mechanism relevant for prebiotic mixtures based on cycles of phase separation combined with material exchange of the dense phase with a reservoir. We find a selective enrichment of components up to two orders of magnitude coinciding with a growth of the dense phase up to the system volume. Such enrichment of selective components is robust also in mixtures composed of a large number of components. For a prebiotic soup, our findings indicate that cycles of phase separation and material exchange with a reservoir, e.g. the accumulation DNA gel in rock pores periodically filled with DNA rich aqueous solution, could provide a mechanism for the selection and enrichment of specific heteropolymers sequences in a multi-component mixture at the origin of life.

15 min. coffee break

DY 43.5 Wed 16:30 ZEU 250

Sperm chemotaxis in external flows — •Steffen Lange[1,2] and Benjamin Friedrich[1,2,3] — [1]Center for Advancing Electronics Dresden (cfaed) — [2]Cluster of Excellence Physics of Life (PoL) — [3]Institut Theoretische Physik (ITP), TU Dresden, 01062 Dresden, Germany

Chemotaxis - the navigation of biological cells guided by chemical gradients - is crucial for bacterial foraging, immune responses, and guidance of sperm cells to the egg before fertilization.

Previous work on chemotaxis focused predominantly on idealized conditions of perfect chemical gradients. However, natural gradients are subject to distortions, e.g. by turbulent flows in the ocean.

Recent experiments with bacteria [1] and sperm cells from marine invertebrates [2] have surprisingly revealed the existence of an optimal turbulence strength at which the chemotaxis is more effective than for still water conditions with perfect gradients.

Using sperm chemotaxis in shear flow as a prototypical example, we reproduce an optimal turbulence strength in numerical simulations. We can understand the origin of this optimum and quantify it:

For this we apply a theory of sperm chemotaxis to the concentration filaments, which are typical for scalar turbulence. We explain how external flows distort sperm swimming paths and concentration gradients, but at the same time extend the spatial range of these gradients. Together, these two competing effects set the optimal turbulence strength. We compare our theoretical results to previous experiments and find good agreement.

[1] Taylor, Stocker; Science 2012 [2] Zimmer, Riffell; PNAS 2011

DY 43.6 Wed 16:45 ZEU 250

Extracting the degree of order in the bacterial chromosome using statistical physics — •Joris Messelink[1], Jacqueline Janssen[2], Muriel van Teeseling[3], Martin Thanbichler[3], and Chase Broedersz[1] — [1]Arnold Sommerfeld Center for Theoretical Physics, LMU München — [2]Max Planck Institute for the Physics of Complex Systems, Dresden — [3]Faculty of Biology, Philipps University Marburg

Elucidating the three-dimensional spatial organization of the bacterial chromosome is essential to understand how genomic processes are spatially regulated inside the cell. Recent Hi-C chromosome conformation capture experiments provide contact frequency maps of the chromosome. These experiments reveal structural organization beyond that of an amorphous polymer. However, despite such experimental advances,

the degree of spatial organization of the bacterial chromosome remains unclear. To investigate this, we develop a maximum entropy approach to extract the three-dimensional structure of the bacterial chromosome from such data. Using this approach, we obtain a coarse-grained model for the full distribution of chromosome configurations for the bacterium C. crescentus. We validate the predictive power of our model by experiments on the localization of chromosomal loci in the cell. Our model reveals novel features of spatial chromosome organization on various length scales. Our approach is not organism-specific, and opens up a new way of analyzing spatial chromosome organization.

DY 43.7 Wed 17:00 ZEU 250

Rewarding cargo-carrier interactions: cell-mediated particle transport — •Valentino Lepro[1,2], Robert Grossmann[1], Oliver Nagel[1], and Carsten Beta[1] — [1]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [2]Max Planck Institute of Colloids and Interfaces, 14476 Potsdam, Germany

As society paves its way towards devices miniaturization and precision medicine, micro-scale actuation and guided transport become increasingly prominent research fields, with high potential impact in both technological and clinical contexts. To accomplish directed motion of micron-sized cargos towards specific target sites, a promising strategy is the usage of living cells as smart biochemically-powered carriers, developing so-called *bio-hybrid systems*. In this talk, we discuss eukaryotic active particle transport, using *Dictyostelium discoideum* as a model organism. We shed light on the underlying mechanics and the emerging dynamics governing such cell-mediated transport. A simple yet powerful model is proposed which reproduces the observed phenomenology and, moreover, elucidates the role of cell-cargo interactions for the long-time mass transport efficiency.

DY 43.8 Wed 17:15 ZEU 250

Effective spin glass theories for gene regulatory networks — •Fabrizio Olmeda[1] and Steffen Rulands[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Center for Systems Biology Dresden, Dresden, Germany

The development and maintenance of complex organs relies on precisely regulated cell fate decisions. Understanding the molecular mechanisms underlying these decisions is one of the central questions in stem cell biology.

The primary layer of regulation is the expression of genes and their interaction in gene regulatory networks. Here, by rigorously mapping the stochastic dynamics of gene regulatory networks to bipartite spin glasses, we develop an effective theory for describing fluctuations in gene regulatory networks during cellular decision making.

Performing a replica calculation, we describe the phase diagram that emerges in terms of the parameters of the gene network and demonstrate the existence of a spin glass phase.

In addition to the highly efficient simulation of gene networks our work, for the first time, allows using single-cell sequencing experiments to link fluctuations in gene expression to mechanisms of cellular decision making.