AKB 21 Intracellular Transport

Time: Thursday 10:45–12:30 Room: ZEU 260

AKB 21.1 Thu 10:45 ZEU 260

A stochastic model for intra-cellular transport of single-headed molecular motors — •Andreas Schadschneider[1], Philip Greulich[1], Katsuhiro Nishinari[2], Yasushi Okada[3], and Debashish Chowdhury[4] — [1]Institut für Theoretische Physik, Universität zu Köln, 50937 Köln — [2]Department of Aeronautics and Astronautics, University of Tokyo, Japan — [3]Department of Cell Biology and Anatomy, University of Tokyo, Japan — [4]Department of Physics, Indian Institute of Technology, Kanpur, India

Motivated by recent experiments on KIF1A, a representative member of single-headed kinesin motor proteins family, we develop a theoretical model of intra-cellular transport by mutually interacting molecular motors. It explicitly accounts not only for the hydrolysis of ATP, but also for the ratchet mechanism which is believed to drive each individual KIF1A motor. We study the model by a combination of analytical and numerical techniques. A remarkable feature is that all parameters can be completely determined from experimental data. Our results in the dilute limit are in excellent quantitative agreement with the empirical data from single molecule experiments. In the high density regime the predictions of the model also agree qualitatively with the corresponding experimental observations. We derive a phase diagram that shows the influence of hydrolysis and Langmuir kinetics on the collective spatio-temporal organization of the motors. Finally, we provide experimental evidence for the existence of domain walls in our in-vitro experiment with fluorescently labeled KIF1A; these domain walls correspond to the shocks observed in the density profiles of our theoretical model.

AKB 21.2 Thu 11:00 ZEU 260

Multicriticality in a driven transport process on two coupled lanes — •Tobias Reichenbach, Thomas Franosch, and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics and CeNS, Department of Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, D-80333 München, Germany

Intracellular transports constitute important examples of biological systems that exhibit interesting collective phenomena. Molecular motors, like myosin, kinesin, and dynein, move along cytoskeletal filaments. When considering a large assembly of such motors, their interaction gives rise to various phenomena.
One can study such transport processes on the basis of driven stochastic systems far from equilibrium. Boundary induced phase transitions and phase separation [1] are among the unexpected phenomena which arise. Here, we present a two-lane model that, incorporating these features, exhibits a rich variety of phases. Both first order and second order phase transitions arise. At their intersections, multicritical behaviour emerges. An analytical treatment is feasible via a mean field approach. We compare our results to Monte-Carlo simulations.
[1] A. Parmeggiani, T. Franosch, and E. Frey, Phys. Rev. Lett. 90, 086601 (2003)

AKB 21.3 Thu 11:15 ZEU 260

Traffic of molecular motors in the presence of obstacles — •Yan Chai, Stefan Klumpp, and Reinhard Lipowsky — Max Planck Institute for Colloids and Interfaces, Golm, Germany

The traffic of molecular motors along cytoskeletal filaments is studied theoretically using lattice gas models. These models describe the movements of a molecular motor along a filament as a biased random walk which is defined by a set of stepping probabilities for forward steps along the filament, binding to the filament and unbinding from the filament. We consider the case where obstacles such as lattice defects or additional proteins are present on the filament. We distinguish three basic types of defects, which differ from non-defect filament sites in only one of the motors' stepping parameters. We determine the motor current and density profiles using analytical calculations and Monte Carlo simulations.

AKB 21.4 Thu 11:30 ZEU 260

Traffic jams of molecular motors in tube-like compartments — •Melanie Müller, Stefan Klumpp, and Reinhard Lipowsky — Max-Planck-Institut für Kolloid- und Grenzflächenforschung, 14424 Potsdam

Processive molecular motors move along cytoskeletal filaments in a directed manner. However, even processive motors have only a finite walking distance after which they unbind from the filament and then undergo undirected diffusive motion in the surrounding aqueous solution. We consider theoretical models which map this interplay of directed and diffusive motion onto random walks on a lattice. Taking into account the mutual exclusion of the motors from the binding sites on the filament, this leads to variants of driven lattice gas models or exclusion processes, where the driving is localized to the filament.

Using analytical calculations and computer simulations, we obtain motor density and motor current profiles for several systems with different geometries. In particular, we study tube-like compartments which mimic the geometry of an axon. For high motor densities, the motors form traffic jams induced by their mutual exclusion, which leads to a reduction of the motor transport for high motor densities. The length of these traffic jams is determined as a function of the transport parameters of the motors.

AKB 21.5 Thu 11:45 ZEU 260

Driven diffusive gas of dimers: a model for molecular motors collective properties. — •Paolo Pierobon[1,2], Thomas Franosch[1,2], Mauro Mobilia[1], and Erwin Frey[1] — [1]Arnold Sommerfeld Center, Theresienstr.37, D-80333 Muenchen — [2]Hahn Meitner Institut, Glienicker str.100, D-14109 Berlin

One dimensional driven lattice gases have been extensively used to model traffic of molecular motors on microtubules. The standard model is the Totally Asymmetric Simple Exclusion Process (TASEP): a lattice gas model where particles move unidirectionally with a fixed rate and the flux depends on the entrance and exit rate. Inspired by recent models in intracellular transport, we discuss the properties of a TASEP of dimers (representing kinesins or dyneins) without particle conservation in the bulk (on/off kinetics). We investigate the phase diagram and the stationary average density profile by means of Monte Carlo simulations and rationalize the results through a refined mean field theory. We concentrate on experimentally measurable quantities and we investigate the effects of one defect in the lattice.

AKB 21.6 Thu 12:00 ZEU 260

Fluorescence Microscopy reveals the mechanistic details of nano-sized gene carrier transport in living cells — •Ralf Bausinger[1], Nadia Ruthardt[1], Karla de Bruin[1], Katharina von Gersdorff[2], Manfred Ogris[2], Ernst Wagner[2], Andreas Zumbusch[1], and Christoph Bräuchle[1] — [1]Department of Chemistry and Biochemistry, LMU München, Butenandtstr. 5-13, 81377 München — [2]Department of Pharmacy, LMU München, Butenandtstr. 5-13, 81377 München

Non-viral vectors consisting of the cationic polymer polyethyleneimine (PEI) and plasmid DNA are widely used for gene delivery into living cells. A detailed knowledge about the different stages which occur during the polyplex entry into the cell and its nucleus are prerequisite for further optimising the transfection process. We use highly sensitive fluorescence wide-field microscopy techniques to visualise the interaction of PEI/DNA polyplexes with the eGFP-labeled actin and tubulin cytoskeleton of living Huh-7 cells. Besides normal diffusion within the cell membrane we observe anomalous diffusion of the polyplexes due to their interaction with actin filaments as well as active directed transport along the microtubules [1]. In long-term experiments during mitosis we investigate the association of polyplexes to the spindle apparatus as a possible nuclear entry mechanism. We also compare the behaviour of these classical PEI/DNA polyplexes to more advanced non-viral vectors with polyethyleneglycol shielding and epidermal growth factor targeting.
[1] Bausinger et al., Angew. Chem., accepted

AKB 21.7 Thu 12:15 ZEU 260

Anomalous diffusion and viscoelasticity in living cells due to crowding — •Matthias Weiss and Gernot Guigas — Cellular Biophysics Group (BIOMS), Deutsches Krebsforschungszentrum, Im Neuenheimer Feld 580, 69120 Heidelberg

Using fluorescence correlation spectroscopy (FCS) we show that (inert) macromolecules and gold beads exhibit anomalous diffusion in the cytoplasm and nucleoplasm of living cells. By accompanying these observations with model simulations and in vitro experiments it is demonstrated that this behavior is a generic consequence of 'molecular crowding' [1].

In other words, the anomality of the diffusion yields a quantifiable measure for the 'crowdedness' of a fluid on the molecular scale. Based on the observation of anomalous diffusion, we determine experimentally the 'nanorheology' of the cell's interior, i.e. we find that the cytoplasm and the nucleoplasm are strongly viscoelastic for frequencies above 1 kHZ with a typical elasticity of about 100 Pa.

[1] Weiss, Elsner, Kartberg, Nilsson, Biophys. J. **87**, 3518 (2004).