BP 27: Nonequilibrium Processes and Self-Organisation

Time: Friday 10:30–12:45 Location: H43

Invited Talk BP 27.1 Fri 10:30 H43
From target search to travel bugs: scale free motion in biology — •Dirk Brockmann — MPI for Dynamics and Self-Organization, Göttingen, Germany

Numerous physical, biological and social systems exhibit anomalous diffusion, i.e particles or mobile agents perform stochastic motion that violates the key features of ordinary Brownian motion. Superdiffusion is typically a consequence of a lack of scale in the spatial increments, the distribution of which follows an inverse power-law with divergent second moment. For these processes the term Lévy flight has been coined and the utilisation fractional diffusion equations turns out to be a key theoretical framework to describe these systems. Lévy flights exhibit particulary interesting behavior when they evolve in heterogeneous environments and when superdiffusion is a consequence of the topological complexity of the system. I will give an overview of recent discoveries of this type of topological superdiffusion and similar processes in a variety of biological systems ranging from facilitated target location of proteins on folding heteropolymers, optimal saccadic scanpaths in human eye-movements, the geographic trajectories of banknotes to current research on the dispersal of travel bugs. These are tagged items that are part of geocaching, a worldwide kind of GPS treature hunt. I will allude to similarities between these systems, discuss there differences and provide a general theoretical framework for the description of topologically superdiffusive systems.

BP 27.2 Fri 11:00 H43
Dynamics of rod-like macromolecules — •Felix Höfling[1,2], Erwin Frey[1], and Thomas Franosch[1] — [1]Arnold Sommerfeld Center for Theoretical Physics (ASC) and Center for NanoScience (CeNS), Department für Physik, Ludwig-Maximilians-Universität München, Theresienstraße 37, 80333 München — [2]Hahn-Meitner Institut, Abteilung Theorie, Glienicker Straße 100, 14109 Berlin

Nature as well as modern technology presents us a variety of heterogeneous materials ranging from porous rock over gels to the inner structure of eukaryotic cells. Macromolecules being immersed in such materials exhibit a host of phenomena including Brownian motion, anomalous diffusion, fractal dynamics and a peculiar zig-zag motion.

The emergence of anomalous transport can be understood as a consequence of spatial heterogeneities and excluded volume within a minimal model [1]. We have extended this model to capture essential properties of the dynamics of a rod moving between randomly distributed, fixed rods. For long rods, strong entanglement effects lead to a suppression of rotational diffusion, while at the same time, they enhance center-of-mass diffusion [2].

Our results from Molecular Dynamics simulations allow for a detailed comparison with the tube model. Further, they give insight into the origin of the zig-zag motion and the effect of enhanced diffusion.

[1] F. Höfling, T. Franosch, E. Frey, *Phys. Rev. Lett.* **96,** 165901 (2006).

[2] F. Höfling, Ph. D. thesis, Ludwig-Maximilians-Universität München (2006).

BP 27.3 Fri 11:15 H43
Directed Brownian motion of non-spherical particles — •Susan Sporer, Christian Goll, and Klaus Mecke — Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudtstrasse 7, 91058 Erlangen

Mesoscopic particles, such as molecular motors, embedded in a fluid are expected to perform symmetric thermal fluctuations around a mean position. A net transport in a preferred direction is not possible in thermal equilibrium without applying a temperature gradient or an external force which breaks the spatial symmetry. However, directed Brownian motion is possible if the particle is a-symmetric and the system is prohibited from relaxation in thermal equilibrium. A non-equilibrium state can be sustained by stopping the particle at periodic sites along a filament. After releasing the relaxation process towards a Maxwellian velocity distribution has a preferred direction which causes a directed motion due to the particle asymmetry. Even motion against a small fluid drift is possible. The relaxation process, the directed motion and its dependence on the particle shape are analyzed analytically. The results are compared to molecular dynamics simulations.

BP 27.4 Fri 11:30 H43
The Einstein relation generalized to non-equilibrium — •Valentin Blickle[1], Thomas Speck[2], Christoph Lutz[1], Udo Seifert[2], and Clemens Bechinger[1] — [1]2. Physikalisches Institut, Universität Stuttgart — [2]II. Institut für Theoretische Physik, Universität Stuttgart

Thermodynamics and classical statistical mechanics are not able to describe processes far from equilibrium. Recently, several exact theoretical relations, e.g. Jarzynski equation [1] and other fluctuation theorems were derived for this regime. We focuss on the Einstein relation, a prominent example of the fluctuation dissipation theorem, connecting the diffusion constant and the mobility which is violated beyond linear response. In our experiment we test its recent theoretical generalization [2] to the non-equilibrium regime. With video microscopy we observe the motion of a driven Brownian colloidal particle trapped within a torroidal 3d laser trap. Additionally we can modulate the laser intensity, imposing a stationary potential onto the torus. Using the measured particle trajectory we determine an integral over velocity correlation functions which quantifies the violation of the Einstein relation. The fact that this integral cannot be neglected demonstrates that in our experiment we are probing a regime which is far from thermal equilibrium and beyond linear response.

[1] C. Jarzynski, *Phys. Rev. Lett.* **78**, 2690 (1997).

[2]T. Speck, U. Seifert, *Europhys. Lett.* **74**, 391 (2006).

BP 27.5 Fri 11:45 H43
Optimal finite-time processes in stochastic thermodynamics — •Tim Schmiedl and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

For a small system like a colloidal particle or a single biomolecule embedded in a heat bath, we ask for the optimal protocol of an external control parameter minimizing the mean work required to drive the system from one given equilibrium state to another in a finite time. The emphasis on a finite time is crucial since for infinite time the work spent in any quasi-static process is equal to the free energy difference of the two states. For finite time the mean work is larger and will depend on the protocol. Knowing the optimal protocol could inter alia improve the extraction of free energy differences from finite-time path sampling via the Jarzynski relation both in numerical schemes and in experimental studies.

In general, the optimal protocol obeys an integro-differential equation. We derive explicite solutions both for a moving harmonic laser trap and a time-dependent strength of such a trap. In both cases, the optimal protocol exhibits finite jumps both at the beginning and the end of the process. We expect such jumps to be generic even for nonharmonic potentials.

BP 27.6 Fri 12:00 H43
Self-organization in systems of treadmilling filaments — •Konstantin Doubrovinski and Karsten Kruse — Universität des Saarlandes, Postfach 151150, D-66041, Saarbrücken

The polymerization and depolymerization of cytoskeletal filaments plays an important role in many subcellular processes. It can produce forces and lead to effective filament transport. An example of the latter is provided by treadmilling, which occurs when subunits are added one end at the same rate as they are removed at the other. Addition and removal of subunits is influenced by a large number of proteins. In fish melanophores such porteins are coupled to color pigments. There, treadmilling filaments and polymerization affecting proteins can self-organize into states of agglomerated or dispersed pigments which allows the fish to change color. A theoretical treatment of such systems is difficult as distributions of filaments lengths must be taken into account. We present a new mesoscopic approach which allows for numerical as well as analytical analysis. We find a multitude of patterns such as asters, traveling fronts and solitary waves. We apply this formalism to melanophores and point out possible implications for cell locomotion.

BP 27.7 Fri 12:15 H43
Mean-field transition in two dimensional self-propelled particle systems with different alignment mechanisms — •Fernando Peruani[1,2], Andreas Deutsch[1], and Markus Baer[3]

— [1]Technische Universitaet Dresden, Dresden, Germany — [2]Max Planck for the Physics of Complex Systems, Dresden, Germany — [3]Physikalisch-Technische Bundesanstalt, Berlin, Germany

We study the emergence of collective effects in two-dimensional systems of self-propelled particles interacting locally through a liquid crystal-based alignment mechanism. In the model particles are driven with a constant absolute velocity and align their direction of motion to the local director. We show through extensive simulations that there is a continuous kinetic phase transition for sufficient low directional noise and high enough density. Moreover, we propose an effective mean-field equation and show that this approach correctly describes the the scaling of the order parameter vs. noise intensity. Similar arguments follow for the ferromagnetic alignment. These findings strongly suggest that self-propelled particles exhibit kinetic mean-field-type transitions in which the critical noise depends explicitly on the density and the alignment mechanism.

BP 27.8 Fri 12:30 H43

Cell morphology in growing tissues — •Reza Farhadi Far[1], Jens-Christian Röper[2], Suzanne Eaton[2], and Frank Jülicher[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, Dresden — [2]Max-Planck-Institute for Molecular Cell Biology and Genetics, Pfotenhauer Straße 108, Dresden

We present a theoretical study of the morphology and topology of cell packing in a two dimensional tissue. Using a vertex model, we represent each cell by a polygon and take into account cell elastic properties, line tension due to adhesion with neighboring cells as well as contractility of the cell. We present a phase diagram of the model and study the topology and morphology of the cell packing in the presence of cell division. We find three distinct types of tissue morphology, depending on parameter values. We compare our calculations to observed cell packings in the wing-disc of the fruit fly *Drosophila*.