DY 4: Brownian motion and transport

Time: Monday 14:00–17:00 Location: MA 004

Invited Talk DY 4.1 Mon 14:00 MA 004

Entropic particle transport — •Gerhard Schmid, P. Sekhar Burada, and Peter Hänggi — Institut für Physik, Universität Augsburg, D-86135 Augsburg

We show that transport in the presence of entropic barriers exhibits peculiar characteristics which makes it distinctly different from that occurring through energy barriers. The constrained dynamics yields a scaling regime for the particle current and the diffusion coefficient in terms of the ratio between the work done to the particles and available thermal energy [1]. The problem is analyzed under the perspective of the Fick-Jacobs equation which accounts for the effect of the lateral confinement by introducing an entropic barrier in a one dimensional diffusion. The validity of this approximation, being based on the assumption of an instantaneous equilibration of the particle distribution in the cross-section of the structure, is analyzed by comparing the different time scales that characterize the problem. A validity criterion is established in terms of the shape of the structure and of the applied force [2].

[1] D. Reguera, G. Schmid, P. S. Burada, J. M. Rubi, P. Reimann, and P. Hänggi, Phys. Rev. Lett. **96**, 130603 (2006)
[2] P. S. Burada, G. Schmid, D. Reguera, J. M. Rubi, and P. Hänggi, Phys. Rev. E **75**, 051111 (2007)

DY 4.2 Mon 14:30 MA 004

Active Brownian particles and Nosé-Hoover thermostats — •Rainer Klages — School of Mathematical Sciences, Queen Mary, University of London, UK

Active Brownian particles refer to a theory that is used in order to model the self-propelled motion of biological entities such as, for example, cells migrating on substrates. For this purpose the friction coefficient of ordinary Langevin dynamics is assumed to be velocity dependent, representing the take-up of energy from some external reservoir and its conversion into kinetic energy. Other well-known generalizations of Langevin equations are deterministic thermal reservoirs for which the Nosé-Hoover thermostat is a simple example. I will show that these two seemingly different concepts are quite related to each other. Particularly, I will focus onto the origin of crater-like velocity distributions, which are produced by both types of generalized Langevin dynamics. Starting from Nosé-Hoover thermostats, I will argue that the crater-like shapes can be understood in terms of a combination of canonical with microcanonical distributions.

Ref.: R.Klages, Microscopic chaos, fractals and transport in nonequilibrium statistical mechanics (World Scientific, Singapore, 2007), Chapter 16.

DY 4.3 Mon 14:45 MA 004

Conformational Subdiffusion in Peptides — •Thomas Neusius[1], Igor M. Sokolov[2], and Jeremy C. Smith[3] — [1]Interdisziplinäres Zentrum für wissenschaftliches Rechnen (IWR), Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 368, D-69120 Heidelberg — [2]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, D-12489 Berlin — [3]Center for Molecular Biophysics, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge TN 37831-6164, USA

There has been recent interest in the dynamics of both folding and folded proteins and the relation of protein dynamics to biological function. Among the dynamical aspects of biomolecules anomalous conformational diffusion, in particular subdiffusion, has attracted a lot of attention both in experimental [1] and theoretical [2] works. Subdiffusion can be seen in relativly small molecules such as peptides. Molecular dynamics simulation of peptides extending to several microseconds can provide the basis for a better understanding of conformational subdiffusion and the underlying mechanisms.

[1] S. C. Kou and X. Sunney Xie, Phys. Rev. Lett. **93**, 180603 (2004); W. Min, G. Luo, B. J. Cherayil, S. C. Kou, and X. Sunney Xie, Phys. Rev. Lett. **94**, 198302 (2005); G. Luo, I. Andricioaeli, X. Sunney Xie and M. Karplus, J. Phys. Chem. B **110**, 9363 (2006).

[2] G. R. Kneller and K. Hinsen, J. Chem. Phys. **121**, 10278 (2004); G. R. Kneller, PCCP **7**, 2641 (2005); R. Granek and J. Klafter, Phys. Rev. Lett. **95**, 098106 (2005).

DY 4.4 Mon 15:00 MA 004

The diffusion coefficient of nonlinear Brownian motion — •Benjamin Lindner — Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

Nonequilibrium biological systems like moving cells or bacteria have been phenomenologically described by Langevin equations of Brownian motion in which the friction function depends on the particle's velocity in a nonlinear way. In my talk I present an exact result for the diffusion coefficient of such a nonlinear Brownian motion for simple cases (Rayleigh friction, SET model, and powerlaw friction). I discuss under which conditions the diffusion can be minimized at a finite noise intensity. REFS: Lindner New J. Phys. 9 , 136 (2007); Lindner J. Stat. Phys. (in press, 2007)

DY 4.5 Mon 15:15 MA 004

Random walks with random velocities — •Vasily Zaburdaev, Michael Schmiedeberg, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

We consider a random walk model that takes into account the velocity distribution of random walkers. Random motion with alternating velocities is inherent to various physical and biological systems. Despite the obvious importance and potential applications, such a model has not been considered before. Here, we derive transport equations describing the dispersal process in the model and solve them analytically. The asymptotic properties of solutions are presented in the form of a phase diagram that shows all possible scaling regimes, including superdiffusive, ballistic and superballistic motion. Theoretical results of this work are in excellent agreement with accompanying numerical simulations.

DY 4.6 Mon 15:30 MA 004

Branched Flow and Caustics in Random Media — •Jakob J. Metzger, Ragnar Fleischmann, and Theo Geisel — Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany

Classical particles as well as quantum mechanical waves exhibit complex behaviour when propagating through random media. One of the surprising features of the dynamics in correlated, weak disorder potentials is the appearance of branches in the flow. This can be observed in several physical systems, most notably in the electron flow in two-dimensional electron gases [1].

We show that the branching is due to the formation of caustics and present advances in the theoretical understanding and numerical simulation of the caustics. We compare our results to existing theoretical models. In particular, we study the statistics of the first appearance of a caustic along a trajectory.

[1] e.g. Topinka, M. A. et. al. Nature, 2001, 410, 183-186; Jura, M. P. et. al. Nat Phys, advanced online publication, Nov. 2007

DY 4.7 Mon 15:45 MA 004

Diffusive Processes on Fractals — •Janett Prehl[1], Do H. N. Anh[1], Karl Heinz Hoffmann[1], and Sujata Tarafdar[2] — [1]Institut für Physik, Technische Universität Chemnitz, D-09107 Chemnitz — [2]Condensed Matter Physics Research Center, Jadaypur University, Kolkata 700 032, India

Anomalous diffusion processes are of great interest in natural science as well as in many applications, like diffusion in disordered media such as porous rocks, cements, or biological tissues. In order to model anomalous diffusion random walks on regular fractals or the master equation approach are usually used. Describing diffusion phenomena in porous material the complex structure of these media has to be taken into account. As an appropriate model for the observed material structure we apply Sierpinski carpets with finite iteration depth [1] and we attempt to capture the randomness of the material by mixing Sierpinski carpet generators randomly [2,3]. Besides we consider biased diffusion of charged particles in an external field in such models. Analyzing the diffusive process we utilize different methods to determine important quantities as e.g. the random walk dimension d_{w}. We find that this exponent d_{w} shows a strong dependence on the mixture composition and on the structural features of the carpets analyzed.

[1] S. Tarafdar, et al., *Physica A*, **292**, 1 (2001)
[2] D. Anh, et al., *Europhys. Lett.*, **70**, 109 (2005)
[3] D. Anh, et al., *J. Phys. A: Math. Theor.*, **40**, 11453 (2007)

DY 4.8 Mon 16:00 MA 004

Anomalous escape kinetics due to thermal 1/f noise — •Igor Goychuk and Peter Hänggi — Institut für Physik, Universität Augsburg, Germany

We present an analytic study for subdiffusive escape of overdamped particles out of a cusp-shaped parabolic potential well which are driven by thermal, fractional Gaussian noise with a $1/\omega^{1-\alpha}$ power spectrum. This long-standing challenge becomes mathematically tractable by use of a generalized Langevin dynamics via its corresponding non-Markovian, time-convolutionless master equation: We find [1] that the escape is governed asymptotically by a power law whose exponent depends *exponentially* on the ratio of barrier height and temperature. This result is in distinct contrast to a description with a corresponding subdiffusive fractional Fokker-Planck approach; thus providing experimentalists an amenable testbed to differentiate between the two escape scenarios.

[1]I. Goychuk and P. Hänggi, Phys. Rev. Lett. **99**, 200601 (2007).

DY 4.9 Mon 16:15 MA 004

Realization of a Brownian ratchet based on a ferrofluid sample — •Thomas John and Ralf Stannarius — Otto-von-Guericke-Universität Magdeburg

We demonstrate an experimental ratchet system where thermal fluctuations plays a necessary role. The system is a suspension of nano-sized ferrite particles (ferrofluid) in a time dependent magnetic field. We use the sensitivity of this suspension to magnetic fields and construct a system where the ratchet is a time periodic, orientational asymmetric magnetic potential. This potential rectifies the stochastic motion of the ferrite particles. Depending on the shape of the potential a macroscopic torque is measured on the sample. Results of our measurements are compared with a microscopic model (Engel et al.).

[1] A. Engel et al., PRL 91, 060602 (2003).
[2] A. Engel and Peter Reimann, PRE 70, 051107 (2004).

DY 4.10 Mon 16:30 MA 004

Ratchet effect caused by internal degree of freedom — •Sebastian von Gehlen, Mykhaylo Evstigneev, and Peter Reimann — Universität Bielefeld, Universitätsstraße 25, 33615 Bielefeld

A dimer consisting of two dissimilar components is considered. It is assumed that the two dimer components are in contact with the same heat bath and find themselves in periodic potentials of the same wavelength but different amplitudes modulated synchronously in time. It is shown that this model exhibits the ratchet effect, i.e., directed transport in the absence of any external bias. An accurate analytic approximation for the dimer's velocity and diffusion coefficient is obtained. The system exhibits phenomena similar to stochastic resonance and resonant activation: its velocity is maximized by adding an optimal amount of noise and by tuning the driving frequency to an optimal value. Furthermore, there exists an optimal coupling strength at which the velocity is the largest.

DY 4.11 Mon 16:45 MA 004

Deterministic Relativistic Josephson vortex ratchet: new results — •Edward Goldobin, Reinhold Kleiner, and Dieter Koelle — Physikalisches Institut – Experimentalphysik II and Center for Collective Quantum Phenomena, University of Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

We investigate a deterministic relativistic Josephson vortex ratchet[1,2] — a fluxon in an asymmetric periodic potential driven by a deterministic force with zero time average. Our previous experiments[3] showed that such a ratchet exhibits several non-adiabatic effects such as quantized rectification, fractional dynamics, and voltage reversal. We also observed an anomalously high average fluxon velocity which, up to now, could not be explained theoretically.

In this talk we present new results in the non-adiabatic regime and also investigate efficiency and loading capability of this kind of deterministic relativistic Josephson vortex ratchet.

[1] E. Goldobin et al. Phys. Rev. E **63**, 031111 (2001).
[2] G. Carapella, Phys. Rev. B **63**, 54515 (2001).
[3] M. Beck et al., Phys. Rev. Lett. **95**, 090603 (2005).