# DY 25: Brownian Motion and Transport

Time: Thursday 9:30–13:30 Location: MA 004

**Invited Talk** DY 25.1 Thu 9:30 MA 004

**Through mountains high and valleys low: Ultracold atoms in random potentials.** — •Cord Müller — Centre for Quantum Technologies, National University of Singapore

Disorder and interaction are major challenges when it comes to understanding the transport properties of quantum matter. Experiments with ultracold atoms in optical speckle potentials have reached major milestones in the past few years: from 1D Anderson localization in 2008 to 3D localisation of both fermionic and bosonic matter in 2011. I will review these recent achievements in the light of our current theoretical understanding of quantum transport in random media. Perhaps more importantly, I will discuss open questions to be addressed in the future.

DY 25.2 Thu 10:00 MA 004

**Nonlinear electrocatalytic microswimmers** — •Benedikt Sabass and Udo Seifert — II Institut für Theoretische Physik, Universität Stuttgart

A small, bimetallic particle in hydrogen peroxide solution can propel itself by means of electrocatalytic surface processes. Due to the two different redox potentials, it constitutes a "short-circuited battery". An electric current passes through the particle. The compensating diffusive flux of cations in the solution around the particle drives it forward. We aim towards a theoretical understanding of this far-from-equilibrium swimming mechanism. A simplified, analytically tractable model is presented and the predictions from this model are compared with published experimental findings. We conclude with a brief discussion of generic principles which should be considered when an efficient use of these swimmers is envisaged.

DY 25.3 Thu 10:15 MA 004

**Biased and flow driven Brownian motion in periodic channels** — •Steffen Martens[1], Arthur Straube[1], Gerhard Schmid[2], Lutz Schimansky-Geier[1], and Peter Hänggi[2] — [1]Humboldt-University Berlin, Department of Physics, Newtonstr. 15, 12489 Berlin, Germany — [2]University Augsburg, Department of Physics, Universitaetsstr. 1, 86135 Augsburg, Germany

We investigate the role of the hydrodynamic flow field on the transport of a Brownian particle in a two-dimensional channel structure exhibiting smoothly varying periodic channel width. In particular, we will present an extension of the so-called Fick-Jacobs approximation [Zwanzig 1992] in order to describe the transport of point-size Brownian particles under the influence of an external force field $V(\mathbf{q})$ as well as an applied flow field $\mathbf{u}(\mathbf{q}, t)$. This is achieved by means of an asymptotic analysis [Martens et al., *Phys. Rev. E* 2011, Martens et al., *Chaos* 2011] to the components of the flow field and to stationary probability density for the particle's position within the channel. We demonstrate how the problem of biased Brownian dynamics in a confined 2D geometry can be reduced to the case of Brownian motion in an effective periodic one-dimensional potential $\Psi(x)$ which takes the external bias, the change of the local channel width, and the flow velocity component in longitudinal direction into account. The influence of the external bias and the pressure drop on the transport quantities like the averaged velocity and the effective diffusion coefficient are studied in detail. The analytic findings are confirmed by numerical simulations of the particle dynamics in a reflection symmetric sinusoidal channel.

DY 25.4 Thu 10:30 MA 004

**One-dimensional transport and control in an interacting colloidal system** — •Robert Gernert and Sabine H.L. Klapp — Institut für theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We consider a non-equilibrium system of interacting colloids driven by a constant force through a periodic, symmetric „washboard" potential[1]. As a framework for solving the overdamped equation of motion for the time-dependent density profile, we employ the Dynamical Density Functional Theory (DDFT), where the microscopic particle interactions enter via a free energy functional.

Transport properties such as density profiles, mean-squared displacement[2] and the diffusion coefficient are investigated in dependence of the interaction. In particular, we investigate the impact of interactions on the formation of plateaus in the mean-squared displacement and on the so-called „giant diffusion effect". Furthermore a feedback control is presented allowing the transport of particles in a package.

Our study shows that the DDFT is capable of describing cage effects as well as motion under driving forces and the impact of feedback control[3].

[1] Lichtner K. and Klapp S.H.L., *EPL* **92** (2010) 40007

[2] Reimann P., Van den Broeck C., Linke H., Hänggi P., Rubi J.M. and Pérez-Madrid A., *Phys. Rev. Lett.* **87** (2001) 010602

[3] Gernert R., Lichtner K., Schirok D. and Klapp S.H.L., in preparation

DY 25.5 Thu 10:45 MA 004

**Non-equilibrium effects on granular Brownian motors** — •Johannes Blaschke and Jürgen Vollmer — Max Planck Institute for Dynamics and Self Organization, Göttingen, Germany

It has been shown that an appropriately-shaped object, immersed in a Maxwellian gas and restricted to move only in one direction, released from rest will settle away from its point of release as it equilibrates with the gas.

When making the collisions between gas particles and motor inelastic, the device surprisingly acquires a finite steady state velocity. While this has been called a "Granular Brownian Motor", realistic granular gasses have finite particle-particle restitution coefficients leading to constant dissipation within the gas. As a consequence energy needs to be injected into the gas to keep it from freezing. This results in a system which is inherently not in equilibrium. Furthermore, energy generally cannot be injected homogeneously and instead is frequently injected at the walls, manifesting in a non-isotropic particle velocity distribution. This ultimately results in a particle velocity distribution that is both non-Maxwellian and appears as squeezed.

We have examined the motion of a Brownian motor in gases with realistic non-Maxwellian and squeezed particle velocity distribution.

DY 25.6 Thu 11:00 MA 004

**Active Brownian Particles with Active Fluctuations** — •Pawel Romanczuk[1], Robert Grossmann[2], and Lutz Schimansky-Geier[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden — [2]Institut für Physik, Humboldt Universität zu Berlin, 12489 Berlin

We study the effect of different types of noise on the dynamics of self-propelled agents with variable speed (active Brownian particles). We distinguish between passive and active fluctuations. Passive fluctuations are considered independent of the direction of particle's motion (e.g., thermal fluctuations). In contrast, active ones are assumed to be intrinsically connected with the propulsion mechanism of the agent and, as a result, correlated with its time-dependent orientation. We calculate the stationary speed and velocity probability density functions of non-interacting active Brownian particles in the presence of both fluctuation types and discuss the generic signature of active fluctuations [1]. Furthermore, we discuss swarming of active Brownian particles interacting via a velocity-alignment force [2]. We show, based on the results of a corresponding mean-field theory, how the type of fluctuations has a strong impact on the onset and stability of collective motion.

[1] P. Romanczuk and L. Schimansky-Geier, *Phys Rev Lett*, **106**, 230601 (2011)

[2] P. Romanczuk and L. Schimansky-Geier, *Ecol Compl*, in press, doi:10.1016/j.ecocom.2011.07.008 (2011)

**15 min. break**

DY 25.7 Thu 11:30 MA 004

**Entropic Splitter: Particle Separation by entropic rectification** — •Gerhard Schmid[1], David Reguera[2], Antoni Luque[2], Sekhar Burada[3], Miguel Rubi[2], and Peter Hanggi[1] — [1]University of Augsburg, Germany — [2]Universitat de Barcelona, Spain — [3]MPIPKS Dresden, Germany

Diffusive transport of particles or, more generally, small objects, is a ubiquitous feature of physical and chemical reaction systems. In configurations containing confining walls or constrictions, transport is controlled both by the fluctuation statistics of the jittering objects and the phase space available to their dynamics. In the talk I will report on recent advances in the theoretical and numerical investigation of stochastic transport occurring in geometries of varying cross sections.

In nanopores lacking mirror symmetry about a vertical axis rectification favoring transport in one pore direction occurs [1]. The combined action of a time-dependent driving force and this Entropic Rectification can be utilized for particle separation with respect to the particle size [2]. The mechanisms turned out to be very efficient and can be controlled by tuning the geometrical parameters of the pore leading to different velocities and directions of the particles.

[1] G. Schmid, P.S. Burada, P. Talkner, and P. Hänggi, Adv. Solid State Phys. 48, 317 (2009).
[2] D. Reguera, A. Luque, P.S. Burada, G. Schmid, J. M. Rubi, and P. Hänggi, to appear in Phys. Rev. Lett. (2012).

DY 25.8 Thu 11:45 MA 004

**Ratchet (re)loaded** — •Edward Goldobin[1], Martin Knufinke[1], Dieter Koelle[1], Reinhold Kleiner[1], Konstantin Il'in[2], and Michael Siegel[2] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, University of Tübingen, 72076 Tübingen, Germany — [2]Institut für Mikro- und Nanoelektronische Systeme, Karlsruhe Institute of Technology, 76187 Karlsruhe, Germany

We investigate experimentally a deterministic underdamped Josephson vortex ratchet – a fluxon-particle moving along a Josephson junction in an asymmetric periodic potential. By applying a sinusoidal driving current one can compel the vortex to move in a certain direction, producing an average dc voltage across the junction. Being in such a rectification regime we also load the ratchet, i.e., apply an additional dc bias current $I_{\rm dc}$ (counterforce) which tilts the potential so that the fluxon climbs uphill due to the ratchet effect. The value of the bias current at which the fluxon stops climbing up defines the strength of the ratchet effect and is determined experimentally. This allows us to estimate the loading capability of the ratchet, the output power and efficiency. For the quasi-static regime we present a simple model which delivers simple analytic expressions for the above mentioned figures of merit. [1]

[1] M. Knufinke et al., arXiv:1109.6507

DY 25.9 Thu 12:00 MA 004

**Thermodynamics, fluctuation relations and transport in presence of state-dependent diffusion** — •Ronald Benjamin — Institut fuer Theoretische Physik II, Universitaet Duesseldorf, D-40225 Duesseldorf, Germany

It is well known that inhomogeneous temperature or state-dependent diffusion can induce transport of a Brownian particle in one direction. In the presence of an external load the system can work as a heat engine or a refrigerator. We discuss the transport coherence and efficiency of this system, otherwise known as the Buettiker-Landauer motor. A recently derived fluctuation theorem for heat engines is also tested by applying it to this system.

DY 25.10 Thu 12:15 MA 004

**Directed Transport of Confined Brownian Particles with Torque** — •Paul Radtke and Lutz Schimansky-Geier — Institute of Physics, Humboldt University of Berlin, Germany

We investigate the influence of an external magnetic field (torque) on the motion of Brownian particles confined in a channel geometry with varying width. Furthermore, the particles are driven by random fluctuations modeled by the Ornstein-Uhlenbeck process (OUP) with given correlation time $\tau_c$. The latter is implemented as both as thermal and nonthermal process.

In contrast to the thermal OUP for the nonthermal process directed transport emerges, our setup now realizes a ratchet mechanism: Due to the assumed thermodynamic nonequilibrium situation random fluctuations are rectified. The transport quantities of the system are studied in detail with respect to the correlation time, the torque and the channel geometry. Eventually, the mechanism of the symmetry breaking is elucidated.

DY 25.11 Thu 12:30 MA 004

**Microrheological Characterization of Acrylic Thickener Solutions** — •Anne Kowalczyk and Norbert Willenbacher — Karlsruhe Institute of Technology (KIT), Institute of Mechanical Process Engineering and Mechanics, Gotthard-Franz-Str.3, 76128 Karlsruhe, Germany

The heterogeneous microstructure of three different acrylic thickeners with similar chemical composition but different molecular architecture has been characterized using 2D and 3D multi particle tracking (MPT). Thermal fluctuations of about 100 tracer particles are recorded at a time. We present a customized treatment of so-called tracing errors which occur in 2D tracking experiments which allows us to get physically meaningful results from statistical trajectory analysis for inhomogeneous fluids. We could show that tracer particles are homogeneously distributed and all show the same mobility for the thickener Viscalex HV30. For Sterocoll D the distribution of tracer particles is inhomogeneous, certain areas are not accessible, presumably due to a higher crosslink density, but all tracers exhibit similar mobility. Carbopol solutions show the highest degree of inhomogeneity, a substantial fraction of volume is inaccessible and in addition tracer mobility varies drastically in the remaining portion of the solutions, a fraction of particles is trapped in an elastic, gel-like environment, others can diffuse freely.

DY 25.12 Thu 12:45 MA 004

**Directional motion and anomalous diffusion of particles in viscosity landscapes** — •Alexei Krekhov, Markus Burgis, and Walter Zimmermann — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany

Anomalous diffusion of Brownian particles in inhomogeneous viscosity landscapes is analyzed in the framework of a Langevin equation and a complementary Fokker-Planck equation. In the case of an ensemble of particles starting at a spatial minimum (maximum) of the viscous damping, we find subdiffusive (superdiffusive) motion. Superdiffusion also occurs in the case of a monotonically varying viscosity profile. External forces cause a particle drift in viscous media. We find that an interplay between particle drift and diffusion in the fluid with a spatio-temporal modulated viscosity may lead to an effective particle separation. Different systems for experimental investigations are discussed.

**Topical Talk** DY 25.13 Thu 13:00 MA 004

**Transport beyond Brownian Motion – Persistent correlations** — •Thomas Franosch — Institut für Theoretische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Brownian motion is one of the pillars of statistical physics with applications ranging from astrophysics to biological physics. The theoretical foundation is well understood since Einstein and Smoluchowski introduced a probabilistic interpretation to derive diffusion as a macroscopic law. In modern language, the diffusion propagator follows from the central limit theorem.

Although the mean-square displacement is dominated by the linear increase for long times and finite diffusion constant, persistent correlation underlying the transport may be unraveled by studying the corresponding velocity autocorrelation functions (VACF). I will discuss recent theoretical, simulation, and experimental advances highlighting power-law tails in the VACF which correspond to a colored component in the power spectrum of the force correlator. In particular, I will focus on the effects of hydrodynamic backflow [1,2] and the repeated scattering from frozen obstacles [3,4] as paradigmatic mechanisms to generate persistent correlations.

[1] T. Franosch *et al.*, Nature **478**, 85-88 (2011)
[2] S. Jeney *et al.*, Phys. Rev. Lett. **100**, 240604 (2008)
[3] F. Höfling and T. Franosch, Phys. Rev. Lett. **98**, 140601, (2007)
[4] T. Franosch *et al.*, Chem. Phys. **375**, 530 (2010)