DY 36: Brownian Motion and Transport

Time: Thursday 15:00–17:15 Location: ZEU 160

DY 36.1 Thu 15:00 ZEU 160

Statistical mechanics of stochastic ratchets far from equilibrium — •Johannes Blaschke and Jürgen Vollmer — Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Stochastic ratchets (such as the Brownian motor, or the asymmetric adiabatic piston) deliver important insights into the statistical mechanics of non-equilibrium systems.

We examine the motion of an anisotropic particle encountering collisions with a gas far from equilibrium. Contrary to what is observed for a dissipative Maxwell-Boltzmann gas, vanishingly small perturbations to the gas velocity distribution (e.g. via shaking) result in a steady-state drift velocity independent of particle mass in the limit of a massive particle [1].

Inspired by an interesting breakdown of equipartition and linear response theory, here we build on this finding by exploring the statistical mechanics of a gas even further from equilibrium: that of self-propelled swimmers. The kinetic theory shows a rich and surprising behaviour. Furthermore, we show to what extend stochastic thermodynamics and the appropriate fluctuation theorem can account for this behaviour.

[1] J. Blaschke and J. Vollmer, Phys. Rev. E 87, 040201R (2013)

DY 36.2 Thu 15:15 ZEU 160

Resonant Optical Tweezers with Anti-Reflection Coated Titania Microspheres — •Mohammad Kazem Abdosamadi, Anita Jannasch, and Erik Schäffer — Nanomechanics Group, ZMBP - Center for Plant Molecular Biology, University of Tübingen, Auf der Morgenstelle 2, 72076 Tübingen, Germany

Brownian motion is exhibited by an optically tapped particle due to the thermally driven molecules of the surrounding medium. This motion is often considered to be a frequency-independent phenomenon which is known as a white noise process. However, fluid entrainment influences the particle in the trap and results in a frequency-dependent motion. Therefore, the power spectral density (PSD) of the noise that drives the motion is “colored”. The “colored noise” of the Brownian motion can change the behavior of an optical trap from an overdamped oscillator to a resonant one. Here, our goal was to amplify this resonance. Theoretical calculations predict that particles with a large diameter and a high trap stiffness enhance the resonance effect. Therefore, we synthesized large anti-reflection coated titania microspheres. These microspheres have a high trap stiffness in the optical trap. In comparison to our previous work [Jannasch, Phys. Rev. Lett. 2011], the results showed a roughly 4 times enhancement of the resonance in acetone. The resonant behavior could be used as a sensor in analogy to other resonant probes such as an atomic force microscope cantilever.

DY 36.3 Thu 15:30 ZEU 160

Hydrodynamically enforced entropic trapping of Brownian particles — •Steffen Martens[1], Gerhard Schmid[2], Arthur Straube[3], Lutz Schimansky-Geier[3], and Peter Hänggi[2] — [1]Technische Universität, Berlin, Deutschland — [2]Universität Augsburg, Augsburg, Deutschland — [3]Humboldt-Universität zu Berlin, Berlin, Deutschland

In small systems spatial confinement causes entropic forces that in turn implies spectacular consequences for the control for mass and charge transport. In view of its importance, recent efforts in theory triggered activities which allow for an approximate description that involves a reduction of dimensionality; thus making detailed predictions tractable. Up to present days, the focus was on the role of conservative forces and its interplay with confinement. Within the presented work, we overcome this limitation and succeeded in considering also “magnetic field” like, so termed non-conservative forces that derive from a vector potential [S. Martens et al., *Phys. Rev. Lett.* **110**, 010601 (2013)]. A relevant application is the fluid flow across microfluidic structures where a solute of Brownian particles is subject to both, an external bias and a pressure-driven flow. Then a new phenomenon emerges; namely, the intriguing finding of identically vanishing average particle flow which is accompanied by a colossal suppression of diffusion. This entropy-induced phenomenon, which we termed *hydrodynamically enforced entropic trapping*, offers the unique opportunity to separate particles of the same size in a tunable manner [S. Martens et al.,*Eur. Phys. J. ST* **222**, 2453-2463 (2013)].

DY 36.4 Thu 15:45 ZEU 160

Computersimulation of colloidal particles in channel geometries — •Ullrich Siems and Peter Nielaba — University of Konstanz

This talk presents the results of Brownian Dynamics Simulation of paramagnetic particles confined to two-dimensional micro-channels under the influence of external forces. Two-dimensional colloidal dispersions are well known model systems for a variety of problems on different length scales and have also some applications to microfluidic devices. Confinement into channels can have a great influence on diffusion and transport properties in such systems. A good agreement of Brownian Dynamic Simulation with experiments has been found in the past.

DY 36.5 Thu 16:00 ZEU 160

Calculation of the waiting time distribution with a Fokker Planck equation: hopping in a one-dimensional periodic potential — •Robert Gernert[1], Clive Emary[2], and Sabine H.L. Klapp[1] — [1]Institut für theoretische Physik, Technische Universität Berlin — [2]Department of Physics and Mathematics, University of Hull, United Kingdom

“How long will a complex stochastic process take?” The waiting time distribution (WTD) gives us the answer. The question is important in Brownian as well as in quantum transport [1,2], because it allows to identify the, possibly several, relevant time scales of non-equilibrium motion and to get these single-particle resolved.

Recent developments in quantum transport[2] have shown that the WTD is (especially for short times) more detailed than full counting statistics, i.e. than the cumulants of motion like mean position, mean squared displacement or non-Gaussian parameter.

A way to calculate the WTD directly with a Fokker-Planck equation is presented. As an example the one-dimensional overdamped motion of one Brownian particle in a washboard potential is investigated.

We also present a Master equation approach, based on [3], which gives analytic access to the WTD. Both approaches are verified by comparison to Brownian dynamics simulations.

[1] R.D.L. Hanes, C. Dalle-Ferrier, M. Schmiedeberg, M.C. Jenkins, S.U. Egelhaaf, Soft Matter 8, 2714 (2012)

[2] M. Albert, C. Flindt, M. Büttiker, PRL 107, 086805 (2011)

[3] C. Emary, R. Gernert, S.H.L. Klapp, PRE 86, 061153 (2012)

15 min break

DY 36.6 Thu 16:30 ZEU 160

Convex Hulls of Random Walks: Large-Deviation Properties — •Gunnar Claussen[1], Satya N. Majumdar[2], and Alexander K. Hartmann[1] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg — [2]Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud

We numerically consider two-dimensional time-discrete random walks of length T represented through sets $\{\vec{\delta}_i\}$ of vectors denoting the steps $i \leq T$. Motivated by modeling animal home ranges [1], we are interested in area A and perimeter L of the convex hull over the trajectory $\vec{x}(t)$ of this walk. As previous studies determined the analytical averages $\langle A\rangle$ and $\langle L\rangle$ [2], we aim at the according distributions $P(A)$ and $P(L)$ by application of a Monte Carlo method [3] which allows us to sample within ranges of particularly rare values of A and L, leading to probabilities such as 10^{-300}. The resulting distributions can be compared with respect to their scaling behaviour, their rate functions $\Phi(s) = -T^{-1} \cdot \log P(s)$ (with $s = A/A_{\mathrm{max}}$ or $s = L/L_{\mathrm{max}}$, respectively) and standard analytical distribution functions $p(A)$ and $p(L)$ like the Gumbel distribution. Our analyses of these properties resulted in the obtaining of asymptotic values for the corresponding parameters and exponents for $T \to \infty$. A multitude of walk lengths T, open and closed walks and various types of step displacements $\vec{\delta}_i$ have been covered by our simulations.

[1] L. Giuggioli et al., PLoS Comput. Biol. 7 (2011) e1002008

[2] S.N. Majumdar et al., J. Stat. Phys. 138 (2010) 995-1009

[3] A.K. Hartmann, Eur. Phys. J. B 84 (2011) 627-634

DY 36.7 Thu 16:45 ZEU 160

Multi-terminal Thermoelectric Transport in a Magnetic

Field: Bounds on Onsager Coefficients and Efficiency — •Kay Brandner[1], Julian Stark[1], Keiji Saito[2], and Udo Seifert[1] — [1]II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart — [2]Department of Physics, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Japan 223-8522

Thermoelectric transport in non-interacting systems involving an arbitrary number of terminals is discussed in the presence of a magnetic field breaking time-reversal symmetry. We derive a universal bound on the Onsager coefficients that depends only on the number of terminals [1,2]. This bound implies bounds on the efficiency and on efficiency at maximum power for heat engines and refrigerators. To illustrate our results, we introduce a simple classical model using four terminals for a thermoelectric engine based on the Nernst effect [3]. Within this setup, the predicted bound on the efficiency can indeed be saturated for large magnetic fields and small fugacity in the thermochemical reservoirs.

[1] K. Brandner, K. Saito and U. Seifert, Phys. Rev. Lett. **110** 070603 (2013)
[2] K. Brandner and U. Seifert, New J. Phys. **15** 105003 (2013)
[3] J. Stark, K. Brandner, K. Saito and U. Seifert, arXiv:1310.1195v1 (2013)

DY 36.8 Thu 17:00 ZEU 160

Advanced data analysis by the distribution of diffusivities — •Michael Bauer and Günter Radons — Technische Universität Chemnitz, Germany

Single-particle tracking (SPT) provides a useful approach to observe individual tracers and characterize transport processes in physical and biological systems. However, an analysis based on well-established quantities, such as mean squared displacements (msd), often obscures the interesting properties of complex systems. To improve the interpretation of SPT experiments we introduced the distribution of diffusivities. We demonstrated its applicability to heterogeneous diffusion in a two-layer system and showed its relation to ensemble-based methods such as pulsed field gradient nuclear magnetic resonance (PFG NMR) [1]. Furthermore, we analyzed processes with direction-dependent diffusion coefficients [2], which are of great interest for anisotropic diffusion, e.g., of elongated molecules or in porous media. Additionally, our new method was extended to the distribution of generalized diffusivities to characterize data from anomalous diffusion processes [3]. In our contribution we will explain the properties and features of the distribution of diffusivities. We apply our method to different systems and show the advantages over conventional analysis methods.

[1] M. Bauer et al., J. Chem. Phys. 135, 144118 (2011)
[2] M. Heidernätsch et al., J. Chem. Phys. 139, 184105 (2013)
[3] T. Albers and G. Radons, EPL 102, 40006 (2013)