DY 61: Brownian Motion and Anomalous Transport

Time: Friday 9:30–11:15 Location: ZEU/0118

DY 61.1 Fri 9:30 ZEU/0118

Quantifying non-Markovianity via entropy production in rotational Brownian motion — •Felix Hartmann[1], Finja Tietjen[2], Matthias Geilhufe[2], and Janet Anders[1,3] — [1]University of Potsdam, Institute of Physics and Astronomy, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Department of Physics, Chalmers University of Technology, 412 96 Göteborg, Sweden — [3]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

Magnetization dynamics is commonly modeled by the stochastic Landau-Lifshitz-Gilbert (LLG) equation, which describes the rotational Brownian motion of a magnetization vector on a spherical surface, and successfully explains and predicts magnetization experiments. On ultrashort timescales ($\sim$ a few picoseconds) an extension of the LLG by an inertial term has been theoretically predicted and experimentally measured. More generally ultrafast magnetization experiments are modeled by an open-system LLG equation, which includes a memory kernel and colored noise. It has previously been reported that if classical entropy production rates become negative, the underlying dynamical evolution is non-Markovian. In this talk we employ this to detect and measure non-Markovianity in the evolution of the magnetization dynamics. We analytically show that the inertial LLG and open-system LLG equation may have temporarily negative entropy production rates. We highlight our findings by numerical calculations of the entropy production rates for the three different LLG equations under different initial conditions and field orientations.

DY 61.2 Fri 9:45 ZEU/0118

Resolving hidden barriers and states form time series of projected observables — •Francesco Malcangi and Aljaz Godec — Mathematical Physics and Stochastic Dynamics, Institute of Physics, University of Freiburg

Single molecule experiments, such as FRET, plasmon ruler, and optical tweezers, probe a low- (often one-) dimensional projection of a higher dimensional dynamics. Unless the hidden degrees of freedom relax faster then the observed ones or they are uncoupled, projection induces memory and hides features of the full dynamics, like the presence of hidden states or energy barriers. In this study we show that the higher-order statistics of appropriately chosen functionals of projected paths can reveal some hidden features directly from the time series. In particular, they can unravel and resolve hidden barriers or states.

DY 61.3 Fri 10:00 ZEU/0118

Intensity countoscope: Quantifying dynamics from intensity correlations in real space — •Sophie Hermann and Sophie Marbach — PHENIX, Sorbonne Université/CNRS, Paris, France

Quantifying the dynamics of particle suspensions is of widespread interest in soft matter, including crystalline aggregates and bacterial colonisation. Here, we develop a new technique to learn about these dynamics directly from microscopy images. The intensity countoscope is based on the analysis of intensity correlations in virtual observation boxes of images. Through colloidal experiments, simulations, and theory, we demonstrate how this method determines equilibrium motion properties, such as self-diffusion coefficients and particle drift. By varying the size of the observation boxes, we can probe dynamics across length scales, disentangling contributions of the particle shape and the point spread function (PSF) from those of the particle motion. The intensity countoscope complements the broad range of existing techniques on interpreting images, such as particle tracking, sitting right in between dynamical differential microscopy (DDM), and particle number fluctuations (Countoscope). One strength is its applicability to situations where particle tracking is difficult, e.g. at high densities, with fast dynamics or with poor image resolution. Additionally, the entire analysis is performed in real space, which makes the technique computationally cheap as it does not require Fourier transformations. This also enables to find more intuitively physical meaning behind the obtained signals. This simplicity opens up broad perspectives on the study of collective phenomena and of interparticle interactions.

DY 61.4 Fri 10:15 ZEU/0118

Leveraging Interactions for Efficient Swarm-Based Brownian Computing — •Alessandro Pignedoli, Atreya Majumdar, and Karin Everschor-Sitte — University of Duisburg-Essen, CENIDE Center for Nanointegration Duisburg-Essen

Brownian particles naturally explore a system's configuration space through thermal fluctuations, requiring no external energy input. This intrinsic property makes them an energy-efficient basis for addressing optimisation problems [1]. Inspired by swarm intelligence [2], we show that short-range interactions between Brownian quasiparticles induce dynamic clustering around the global minimum of a complex temperature landscape [3,4]. By varying the interaction strength and particle density, we identify a broad range of physical conditions in which collective behaviour enhances optimization accuracy. Our results highlight that the emergent collective dynamics of interacting Brownian particles provide a scalable, energy-efficient framework for unconventional computing.

[1] C. H. Bennett, Int. J. Theor. Phys. 21, 905 (1982);
[2] Bonabeau, et al, Oxford University Press (1999);
[3] German Patent Application DE 10 2023 131 171, K. Everschor-Sitte, A. Pignedoli, B. Dörschel (2023);
[4] German Patent Application DE 10 2023 131 706, K. Everschor-Sitte, A. Pignedoli, B. Dörschel (2023);

DY 61.5 Fri 10:30 ZEU/0118

Current reversals in periodically driven many-particle colloidal ratchet — •Seemant Mishra[1], David Vorac[2], Artem Ryabov[2], and Philipp Maass[1] — [1]Universität Osnabrück, Institut für Physik, Germany — [2]Charles University, Faculty of Mathematics and Physics, Czech Republic

We study a many-particle colloidal ratchet and demonstrate the occurrence of current reversals under a symmetric, time-periodic driving force. An overcrowding of particles in the potential wells of the ratchet causes the current to be mediated by propagating solitary waves [1,2]. The current reversals arise from distinct modes of these waves. By a mapping onto a quasiparticle dynamics [3] and applying a unit-displacement law [4], we develop an analytic theory for the particle currents as function of the driving parameters and explain the occurrence of the current reversals. We further examine the role of hydrodynamic interactions in the system.

[1] A. P. Antonov, A. Ryabov, P. Maass, Phys. Rev. Lett. 129, 080601 (2022).
[2] E. Cereceda-López, A. P. Antonov, A. Ryabov, P. Maass, and P. Tierno, Nat. Commun. 14, 6448 (2023).
[3] S. Mishra, A. Ryabov, P. Maass, Phys. Rev. Lett. 134, 107102 (2025).
[4] A. P. Antonov, A. Vonhusen, A. Ryabov, P. Maass, Nonlinear Dyn. 113, 31529 (2025).

DY 61.6 Fri 10:45 ZEU/0118

Advection-diffusion processes of Brownian particles in a long corrugated channel: mean first passage time approach — •Xiaohan Huang, Paolo Malgaretti, and Jens Harting — Helmholtz Institute Erlangen-Nürnberg for Renewable Energy, Cauerstr. 1, 91058 Erlangen, Germany

Transport of particles in porous media in micro- and mesoscopic scales is of interest in many applications, such as the catalytic transport and nanoparticles separations. In such scenarios, the time that a particle takes to reach a target for the first time, namely the mean first passage time (MFPT), represents a standard indicator. We model the advection-diffusion of a finite size particle in a diluted suspension through a corrugated channel of N varying cross sections elements. Under the fast transverse equilibrium and the slow longitudinal transport, we encode the geometric effect to an effective entropic potential via the Fick-Jacobs approximation [1]. Together with the lubrication approximation, the 2D equation is reduced to 1D, allowing us to solve the moments of MFPT. The resulting data collapse onto a master curve, enabling us to identify the relevant dimensionless numbers: the MFPT without advection and the particle-sensitive effective advection $\tilde{v}$. $\tilde{v}$ is the average velocity of a particle in a single element, accounting for advection, geometry and particle-wall interactions. Thus, 1^{st} and 2^{nd} moment of MFPT are expressed as $f(Pe)$, $Pe = \frac{\tilde{v}NL}{D}$ [2]. The model predicts the particle transport in a long channel, enabling fast parameter studies in porous media design.[1] P. Malgaretti et al. Entropy 2023. [2] X.Huang et al. in preparation.

DY 61.7 Fri 11:00 ZEU/0118

Anomalies in first-passage times and survival profiles of the critical Lorentz gas — •Giorgia Marcelli and Felix Höfling — Institute of Mathematics, Freie Universität Berlin

We investigate the non-equilibrium transport in the three-dimensional Lorentz gas, which is a paradigm of tracer motion in crowded environments and heterogeneous porous media [1]. The model exhibits critical slowing down and the emergence of anomalous diffusion as the porosity approaches the percolation threshold, where the void space loses connectivity [2,3]. Based on large-scale molecular dynamics simulations for transport across a finite sample, we discuss the statistics of first-passage times (FPT) covering a wide dynamic window [4]. Upon decreasing the porosity, the tail of the FPT density $p(\tau)$ broadens beyond the diffusive law, $p(\tau) \sim \tau^{-3/2}$, and attains a critical power law.

The picture is complemented by a discussion of the spatially resolved survival probability $\rho(x,t)$, which, at low obstacle densities, varies almost linearly in the distance x to the finish line, as expected for normal diffusion, but develops a broad interior plateau near the threshold.

The hazard rate, quantifying the likelihood of an arrival to occur at the next moment, becomes strongly time dependent, signalling a non-Poissonian statistics. We test the consistency of our results against the well-known subdiffusive scaling of the equilibrium transport.

[1] F. Höfling and T. Franosch, Rep. Prog. Phys. **76**, 046602 (2013).
[2] F. Höfling, T. Franosch, and E. Frey, PRL **96**, 165901 (2006).
[3] M. Spanner et al., PRL **116**, 060601 (2016).
[4] G. Marcelli and F. Höfling, in preparation.