# DY 45: Brownian Motion and Anomalous Transport - organized by Ralf Metzler (Potsdam)

Time: Wednesday 14:00–16:30 Location: DYc

**Invited Talk** DY 45.1 Wed 14:00 DYc

**Small diffusive systems warm up faster than they cool down** — Alessio Lapolla and •Aljaz Godec — Mathematical bioPhysics Group, Max Planck Institute for Biophysical Chemistry, Göttingen

The celebrated laws of linear irreversible thermodynamics dictate that the relaxation of an extensive thermodynamic observable to its equilibrium value depends linearly on the departure from equilibrium, and is therefore independent of the direction of the departure. However, these linear laws rely on the assumption of "local thermodynamic equilibrium" which is expected to break down when systems become sufficiently small. It turns out that the relaxation of nano-scale systems driven out of equilibrium by a rapid change in temperature depends not only on the distance but also on the direction of the displacement from thermodynamic equilibrium. Contrary to intuition nano-scale systems in fact warm up faster than they cool down. This asymmetry is a general feature of reversible overdamped diffusive systems with smooth single-well potentials and also occurs in multi-well landscapes when quenches disturb predominantly intra-well equilibria. In the talk we will explain the physical origin of this intriguing asymmetry in relaxation to equilibrium.

[1] A. Lapolla, A. Godec, *Phys. Rev. Lett* **125**, 110602 (2020) with focus article in *Physics* **13**, 144 (2020)

DY 45.2 Wed 14:30 DYc

**Cooperatively enhanced reactivity and stabilitaxis of dissociating oligomeric proteins** — •Jaime Agudo-Canalejo[1], Pierre Illien[2], and Ramin Golestanian[1] — [1]Department of Living Matter Physics, Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Sorbonne Universite, CNRS, Laboratoire PHENIX, UMR CNRS 8234, Paris, France

Many functional units in biology, such as enzymes or molecular motors, are composed of several subunits that can reversibly assemble and disassemble. This includes oligomeric proteins composed of several smaller monomers, as well as protein complexes assembled from a few proteins. By studying the generic spatial transport properties of such proteins, we investigate here whether their ability to reversibly associate and dissociate may confer on them a functional advantage with respect to non-dissociating proteins [1]. In uniform environments with position-independent association-dissociation, we find that enhanced diffusion in the monomeric state coupled to reassociation into the functional oligomeric form leads to enhanced reactivity with localized targets. In non-uniform environments with position-dependent association-dissociation, caused by, for example, spatial gradients of an inhibiting chemical, we find that dissociating proteins generically tend to accumulate in regions where they are most stable, a process that we term "stabilitaxis."

[1] Agudo-Canalejo, J., Illien, P., & Golestanian, R. (2020). Proceedings of the National Academy of Sciences, 117(22), 11894-11900.

DY 45.3 Wed 14:50 DYc

**Hot Brownian Motion in the Ballistic Timescale** — •Xiaoya Su[1], Alexander Fischer[1], Frank Cichos[1], and Klaus Kroy[2] — [1]Peter Debye Institute for Soft Matter Physics, University Leipzig, Leipzig, Germany — [2]Institute of Theoretical Physics, University Leipzig, Leipzig, Germany

Brownian motion is the erratic motion of particles in a fluid due to the bombardment of the particle with solvent molecules providing thermal energy and viscous friction. It is fundamental for the dynamics of soft matter and defines the prototype of a fluctuation dissipation relation. While at long timescales the motion is purely stochastic, it is at shorter times influenced by hydrodynamic effects and even ballistic at ultrashort times. Yet, the ballistic motion is still determined by the temperature of the system. Here we explore the transition to the ballistic regime for a hot Brownian particle, i.e. a microparticle which is heated by a laser in an optical trap. In this case the particle temperature is different from the solvent temperature and so far, only theoretical predictions exist for the relevant temperature determining the particle velocity.

We report the first measurements of the thermal non-equilibrium process in a specially designed optical trap which is able to resolve particle displacements of about 20 pm with a time-resolution of 5ns. We show how the mean squared displacement of the particle from the nanoseconds to the seconds timescale changes as a function of the surface temperature of the particle and discuss the model of a frequency dependent effective temperature of hot Brownian motion.

DY 45.4 Wed 15:10 DYc

**Stochastic action for tubes: Connecting path probabilities to measurement** — •Julian Kappler[1], Jannes Gladrow[2], Ulrich F. Keyser[2], and Ronojoy Adhikari[1] — [1]Department of Applied Mathematics and Theoretical Physics, Cambridge University, Cambridge, United Kingdom — [2]Cavendish Laboratory, University of Cambridge

The trajectories of diffusion processes are continuous but nondifferentiable, and each occurs with vanishing probability. This introduces a gap between theory, where path probabilities are used in many contexts, and experiment, where only events with nonzero probability are measurable. We bridge this gap by considering the probability of diffusive trajectories to remain within a tube of small but finite radius around a smooth path. This probability can be measured in experiment, via the rate at which trajectories exit the tube for the first time, thereby establishing a link between path probabilities and physical observables. In my talk I will show how this link can be used to both measure ratios of path probabilities [1], and to extend the theoretical stochastic action from individual paths to tubes [2].

[1] J. Gladrow, U. F. Keyser, R. Adhikari, and J. Kappler. Direct experimental measurement of relative path probabilities and stochastic actions. arXiv:2006.16820

[2] J. Kappler and R. Adhikari. Stochastic action for tubes: Connecting path probabilities to measurement. Physical Review Research, 2(2), June 2020.

DY 45.5 Wed 15:30 DYc

**Diffusion and random search in (in)homogeneous media** — •Trifce Sandev[1,2] and Ralf Metzler[1] — [1]University of Potsdam — [2]Macedonian Academy of Sciences and Arts

Different approaches to diffusion in both homogeneous and heterogeneous media will be discussed. Such processes often become anomalous due to the geometric constraints, random potential effects or variations of the diffusion coefficients. Such problems of heterogeneous diffusion might be closely related to inhomogeneous advection-diffusion processes and geometric Brownian motion used to analyze stock prices in financial markets in the Black-Scholes model. The search strategies of many animals follow similar laws but they often return to their nest or resting place, after some (random) search time. We will give results on the first passage and first hitting times for different random search processes with and without external forces for which we will show that introduction of stochastic resetting in such systems leads to various interesting realizations. The investigation of resetting mechanism in aforementioned systems may also be important for description of experiments of random motion with resetting using optical trap techniques, or economic models of income dynamics.

DY 45.6 Wed 15:50 DYc

**Disentangling the origins of anomalous diffusion in data: the Moses/ Noah and Joseph effects** — •Erez Aghion[1], Philipp G. Meyer[1], Vidushi Adlakha[2], Holger Kantz[1], and Kevin E. Bassler[2] — [1]Max-Planck Institute for the Physics of complex systems, Dresden, Germany — [2]University of Houston, Houston Texas, USA

We study a method for detecting the precise elements that lead to anomalous diffusion, when it is observed in a experimental data, where we do not have exact knowledge about the underlying dynamics.

The reasons for anomalous diffusion are decomposed into three effects: Increment correlations are expressed by the *Joseph effect*, fat-tails of the increment probability density lead to a *Noah effect*, and non-stationarity, to the *Moses effect*. Telling these three effects apart is crucial when one tries to infer the underlying structure of the system, and build a model to describe it.

We present this decomposition method by analysing the example of a widely-applicable model for coupled Levy walk. We infer the properties of the dynamics from data using methods of time-series analysis, and compare our results with theoretical predictions.

DY 45.7 Wed 16:10 DYc

**Dynamics of a point-like colloid in a confined critical fluid** —
•Markus Gross — MPI for Intelligent Systems, Stuttgart

We study analytically and via simulations a point-like colloidal particle (tracer) immersed in a confined critical fluid. Particle and fluid are governed by a system of coupled stochastic PDEs. In addition to a white noise, the particle experiences a random force due to the coupling to the fluctuating fluid density, which is spatially correlated and strongly non-Markovian. By adiabatically eliminating the fluid degrees of freedom, we obtain an effective Langevin equation for the particle, which entails a fluctuation-induced (Casimir) potential, a spatially dependent Markovian noise, and a spatially dependent mobility. The stochastic interpretation of the noise is found to depend on the type of coupling between particle and fluid.

Reference: M. Gross, arXiv:2101.02072