DY 4: Anomalous Diffusion

Time: Monday 9:30–11:15 Location: ZEU 146

DY 4.1 Mon 9:30 ZEU 146

Lévy walks, random time averaged diffusivities and a no-go theorem for ergodicity and an Einstein Relation — •Daniela Froemberg — Max Planck Institute for the Physics of Complex Systems, Dresden

We investigate a Lévy walk alternating between two states characterized by velocities of opposite sign. The sojourn times in either state are drawn according to power law probability distribution functions (pdf). Two different regimes are considered: The first case where the sojourn time pdf lacks its mean, corresponds to a ballistic regime. In the second case the mean of the sojourn time pdf exists while the second moment does not, which results in enhanced diffusion. The correlation functions and the discrepancies between time averaged and ensemble averaged mean squared displacements are investigated. The ballistic case exhibits weak ergodicity breaking and the fluctuations of the shifted time averaged mean squared displacements are universal. In the enhanced diffusion regime, the fluctuations of the time averaged mean squared displacements vanish at large times, yet very slowly. Moreover, we consider an external bias and present a no-go theorem for the generalized Einstein relation and ergodicity in the sense of equal time and ensemble averages.

DY 4.2 Mon 9:45 ZEU 146

Predicting and triggering anomalous Movements in Molecular Diffusion — •Sarah Hallerberg[1] and Astrid S. de Wijn[2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Department of Physics, Stockholm University, 106 91 Stockholm, Sweden

Diffusion can be strongly affected by the appearance of ballistic trajectories (jumps) as well as subdiffusive sticking trajectories (sticks). Using statistical inference techniques, we investigate the appearance of jumps and sticks in molecular-dynamics simulations of diffusion in a prototype system, a benzene molecule on a graphite substrate. We find that specific fluctuations in certain, but not all, internal degrees of freedom of the molecule can be linked to the occurrence of either jumps or sticks. Furthermore, we show that by changing the prevalence of these predictors with an outside influence, the diffusion of the molecule can be controlled. The approach presented in this proof of concept study is very generic, and can be applied to larger and more complex molecules. Additionally, the predictor variables can be chosen in a general way so as to be accessible in experiments.

DY 4.3 Mon 10:00 ZEU 146

Functional Representation and Response Behavior of Fractional Fokker-Planck Equations — •Stephan Eule — MPIDS, Göttingen

The functional representation of stochastic processes provides a powerful method to calculate average values of path dependent observables. Here, the functional representation of Continuous Time Random Walks (CTRWs) and Fractional Fokker-Planck Equations is presented. This formulation, which is based on an alternative formulation of CTRWs, is then used to tackle the delicate and open problem of calculating the response of a CTRW to an external time-dependent perturbation. For the fractional Ornstein-Uhlenbeck process, the response function is calculated explicitly. It is proven that the fluctuation-dissipation theorem holds when the process is perturbed away from equilibrium.

DY 4.4 Mon 10:15 ZEU 146

Normal and anomalous fluctuation relations for Gaussian stochastic dynamics — Aleksei V. Chechkin[1], Friedrich Lenz[2], and •Rainer Klages[2] — [1]Inst. f. Theor. Physics, NSC KIPT, Kharkov, Ukraine — [2]Queen Mary U. of London, School of Math. Sci., UK

We study Fluctuation Relations (FRs) for Gaussian stochastic systems exhibiting anomalous diffusion. For this purpose we use a Langevin approach: We first briefly review the concept of transient work FRs for simple Langevin dynamics generating normal diffusion [1]. We then consider two different types of additive, power law correlated Gaussian noise [2]: (1) internal noise with a fluctuation-dissipation relation of the second type (FDR2), and (2) external noise without FDR2. For internal noise we find that FDR2 leads to conventional (normal) forms of transient work FRs. For external noise we obtain various forms of violations of normal FRs, which we call anomalous FRs. We argue that our theory is important for understanding experimental results on fluctuations in systems with long-time correlations, such as glassy dynamics [1].

[1] R.Klages, A.V.Chechkin, P.Dieterich, *Anomalous fluctuation relations*, book chapter in: R.Klages, W.Just, C.Jarzynski (Eds.), *Nonequilibrium Statistical Physics of Small Systems*, Wiley-VCH, Weinheim (2013)

[2] A.V.Chechkin, F.Lenz, R.Klages, J.Stat.Mech. L11001 (2012)

DY 4.5 Mon 10:30 ZEU 146

Relative entropies and anomalous diffusion — •Janett Prehl[1], Frank Boldt[1], Christopher Essex[2], and Karl Heinz Hoffmann[1] — [1]Technische Universität Chemnitz, Institut of Physics, Chemnitz, Germany — [2]University of Western Ontario, Department of Applied Mathematics, London, Canada

The entropy production paradox for anomalous diffusion processes describes a phenomenon where one-parameter families of dynamical equations, falling between the diffusion and wave equations, have entropy production rates (Shannon, Tsallis or Renyi) that increase toward the wave equation limit unexpectedly [1]. Moreover, also surprisingly, the entropy does not order the bridging regime between diffusion and waves at all [1]. In this talk we will present that different to entropies and entropy production rates relative entropies, with an appropriately chosen reference distribution, will order the bridging regime [2]. Thus, they provide a physically sensible way of setting which process is "nearer" to pure diffusion than another, placing pure wave propagation, desirably, "furthest" from pure diffusion. Furthermore, we examine the time behavior of the relative entropies under the evolution dynamics of the underlying one-parameter family of dynamical equations based on space-fractional derivatives [3].

[1] K.H. Hoffmann et al., *J. Non-Equilib. Thermodyn.* **37**, 393 (2012)

[2] J. Prehl et al., *Entropy* **14**, 701 (2012)

[3] J. Prehl et al., *Entropy* **15**, 2989 (2013)

DY 4.6 Mon 10:45 ZEU 146

Normal vs. anomalous transport by molecular motors in living cells — •Igor Goychuk[1], Vasyl Kharchenko[2], and Ralf Metzler[1,3] — [1]Institute for Physics and Astronomy, University of Potsdam, 14476 Potsdam-Golm, Germany — [2]Institute of Applied Physics, NAS Ukraine, 40030 Sumy, Ukraine — [3]Department of Physics, Tampere University of Technology, 33101 Tampere, Finland

Discovery of anomalously slow diffusion of submicron particles in living cells provokes a number of questions, in particular, on active transport of such subdiffusing nanoparticles by molecular motors. Can such transport be normal or it is also anomalously slow? Can the same motors in the same cells realize both normal and anomalous transport and under which conditions? We answer these intriguing questions [1] within a non-Markovian generalization of standard Markovian continuous diffusion model of molecular motors with two conformational states by taking into account slowly decaying memory effects caused by the viscoelasticity of cytosol. Here we follow to and develop further a general approach to anomalous Brownian motors [2] which is based on Generalized Langevin Equation and its Markovian embedding [3]. Supported by DFG, Grant GO 2052/1-2

[1] Goychuk, I., Kharchenko, V., Metzler, R. arXiv:1309.6724 [physics.bio-ph] (2013); [2] Goychuk, I. Chem. Phys. 375, 450 (2010); Goychuk, I., Kharchenko, V. Phys. Rev. E 85, 051131 (2012); Kharchenko, V. and Goychuk, I. New J. Phys., 14, 043042 (2012); Phys. Rev. E 87, 052119 (2013); [3] Goychuk, I. Adv. Chem. Phys. 150, 187 (2012); Phys. Rev. E 80, 046125 (2009).

DY 4.7 Mon 11:00 ZEU 146

Spin diffusion in a ^{129}Xe crystal on mesoscopic length scales — •Alexander Potzuweit, Hagen Allmrodt, Lars Kraft, Anuschka Schaffner, and Heinz Jänsch — Fachbereich Physik, Philipps-Universität Marburg, D-35032 Marburg

Medical applications using hyperpolarized ^{129}Xe have attracted much attention over the past years. To improve production and storage of hyperpolarized xenon further, a deeper understanding of the relaxation and transport processes is necessary. We employ NMR to investigate relaxation and spin diffusion in Xe films on mesoscopic length scales (nm... μm). Inside the NMR-spectrometer the hyperpolarized ^{129}Xe is frozen onto a Cu single crystal. At the xenon/metal interface the xenon will depolarize, so the copper serves as a polarization drain attached to one side of the xenon crystal. Using a simple diffusion model we analyze the experimental results like the spin transport to this drain as a function of time. By diluting the NMR-active isotope ^{129}Xe in the NMR-inactive isotope ^{132}Xe it is even possible to fine tune the diffusion constant or to inhibit spin diffusion altogether.