DY 41: Brownian Motion, Stochastic Processes, Transport II

Time: Friday 10:15–13:15 Location: HÜL 186

DY 41.1 Fri 10:15 HÜL 186

Effective temperatures in hot Brownian motion — •Daniel Rings[1], Dipanjan Chakraborty[1], Markus Selmke[2], Frank Cichos[2], and Klaus Kroy[1] — [1]ITP, University of Leipzig, Germany — [2]EXP1, University of Leipzig, Germany

Recently, we have introduced a theoretical model for the Brownian motion of heated nanoparticles in suspension [1], which successfully passed its first test in photothermal spectroscopy experiments [2].

Now, we wish to shed light on various aspects of the non-equilibrium phenomenon of hot Brownian motion, in particular the implications of the generalized concept of temperature with respect to translational and rotational diffusion, and dynamic effects. Different temperatures must be assigned to different modes of motion in this non-equilibrium system. I shall present results based on both the analytical theory of fluctuating hydrodynamics and molecular dynamics simulations.

[1] D. Rings, R. Schachoff, M. Selmke, F. Cichos, and K. Kroy, Phys. Rev. Lett., 105 (9), 090604 (2010)
[2] R. Radünz, D. Rings, K. Kroy, and F. Cichos, J. Phys. Chem. A 113 (9), 1674-1677 (2009)

DY 41.2 Fri 10:30 HÜL 186

Exact low-density expansion of the dynamics in the Lorentz gas — •Thomas Franosch[1], Felix Höfling[2], Teresa Bauer[3], and Erwin Frey[3] — [1]Institut für Theoretische Physik, FAU Erlangen, Erlangen, Germany — [2]Max-Planck-Institut für Metallforschung, Stuttgart, and Institut für Theoretische und Angewandte Physik, Universität Stuttgart, Stuttgart, Germany — [3]Arnold Sommerfeld Center for Theoretical Physics, LMU München, München, Germany

We provide an analytic solution for the dynamics of a tracer for a dilute planar Lorentz gas [1] employing the many-body T-matrix formalism. In particular, we show that for particles performing Brownian motion in a frozen array of obstacles long-time correlations emerge in the mean-square displacement. Defining the velocity autocorrelation function (VACF) via the second time-derivative of the mean-square displacement, power-law tails govern the long-time dynamics similar to the case of ballistic motion. The physical origin of the persistent memory is due to repeated encounters with the same obstacle which occurs naturally in Brownian dynamics without involving other scattering centers. This observation suggests that in this case the VACF exhibits these anomalies already at first order in the scattering density.

Our result support the idea that quenched disorder provides a generic mechanism for persistent correlations irrespective of the microdynamics of the tracer particle. Our analytic approach is corroborated by computer simulations with a surprisingly large range of validity.

[1] T. Franosch, F. Höfling, T. Bauer, and E. Frey, Chem. Phys. **375** (2010) 540

DY 41.3 Fri 10:45 HÜL 186

Asymmetric Brownian Particles — •Martin Reichelsdorfer and Klaus Mecke — Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudstr. 7, 91058 Erlangen

We study the influence of the shape of Brownian particles on their dynamics. Under nonequilibrium conditions, asymmetric particles are found to be able to conduct directed average motion. A simple generic three-state model is proposed, which already exhibits crucial features and which reveals how the system relaxes to equilibrium from a symmetric nonequilibrium velocity distribution through asymmetric intermediate states. However, the differences in the behaviour of symmetric and asymmetric particles are not restricted to nonequilibrium. For instance, additional time-scales appear in the equilibrium velocity autocorrelation function and the latter may now also oscillate and adopt negative values.

In terms of an application, asymmetric Brownian particles can be used for constructing molecular motors that work even in spatially symmetric environments (e.g., no temperature gradients, no tilted or asymmetric potentials). Inspired by biology, we present a model where nonequilibrium is sustained by periodically stopping the motor at binding sites along a rail.

DY 41.4 Fri 11:00 HÜL 186

Fluctuation relations for anomalous dynamics — Aleksei V. Chechkin[1] and •Rainer Klages[2] — [1]Institute for Theoretical Physics NSC KIPT, Kharkov, Ukraine — [2]Queen Mary University of London, School of Mathematical Sciences, London, UK

We consider work fluctuation relations (FRs) for generic types of dynamics generating anomalous diffusion: Levy flights, long-correlated Gaussian processes and time-fractional kinetics. By combining Langevin and kinetic approaches we calculate the probability distributions of mechanical and thermodynamical work in two paradigmatic nonequilibrium situations, respectively: a particle subject to a constant force and a particle in a harmonic potential dragged by a constant force. We check the transient FR for two models exhibiting superdiffusion, where a fluctuation-dissipation relation does not exist, and for two other models displaying subdiffusion, where there is a fluctuation-dissipation relation. In the two former cases the conventional transient FR is not recovered, whereas in the latter two it holds either exactly or in the long-time limit [1].

[1] A.V.Chechkin, R.Klages, J.Stat.Mech. L03002 (2009)

DY 41.5 Fri 11:15 HÜL 186

Markovian embedding and origin of hyperdiffusion in generalized Brownian motion — Peter Siegle, •Igor Goychuk, and Peter Hänggi — University of Augsburg

The Fractional Langevin Equation (FLE) describes a non-Markovian Generalized Brownian Motion with long time persistence (superdiffusion), or anti-persistence (subdiffusion) of both velocity-velocity correlations, and position increments. It presents a case of the Generalized Langevin Equation (GLE) with a singular power law memory kernel. We propose and numerically realize a numerically efficient and reliable Markovian embedding of this superdiffusive GLE [1], which accurately approximates the FLE over many, about r=N lg b -2, time decades, where N denotes the number of exponentials used to approximate the power law kernel, and b>1 is a scaling parameter for the hierarchy of relaxation constants leading to this power law. Besides its relation to the FLE, our approach presents an independent and very flexible route to model anomalous diffusion. In particular, it contains as a special case the minimal three-dimensional embedding of ballistic superdiffusion [2]. Studying such a superdiffusion in tilted washboard potentials, we demonstrate the phenomenon of transient hyperdiffusion which emerges due to transient kinetic heating effects.

[1] P. Siegle, I. Goychuk, P. Hänggi, arXiv:1011.2848 [cond-mat.stat-mech] (2010).
[2] P. Siegle, I. Goychuk, P. Hänggi, Phys. Rev. Lett. 105, 100602 (2010).

DY 41.6 Fri 11:30 HÜL 186

Random walks in active media: perturbation spreading in many-body systems — Vasily Zaburdaev[1], •Sergey Denisov[2], and Peter Hanggi[2] — [1]School of Engineering and Applied Science, Harvard University, 29 Oxford Str., Cambridge, MA 02138 USA — [2]Institut fur Physik, Universitat Augsburg, Univeritatsstr. 1, 86135 Augsburg

Propagation of an initially localized perturbation through a many-particle Hamiltonian system can be viewed as a diffusion process,due to the conservation of perturbation energy. Remarkably, conventional diffusion equations are not suitable for the description of this process. We argue that the perturbation spreading can be evaluated by use of a Levy walk formalism, and develop a model that describes the dynamics of a cloud of walkers spreading through an active medium. By using two renowned many-particle systems, that is (i) a hard-point gas and (ii) a Fermi-Pasta-Ulam chain, we demonstrate that the perturbation profiles of both systems coincide with the diffusion profiles of the generalized Levy walk process. Parameters of the model are related to the physical parameters of the corresponding testing systems by simple algebraic expressions. Finally we discuss possible practical applications of our findings.

15 min. break.

DY 41.7 Fri 12:00 HÜL 186

Gas-induced metal-insulator transition in nanoporous crystalline multilayered metal oxide systems — •Julia Dräger[1,2], Stefanie Russ[2], Claus-Dieter Kohl[3], and Armin Bunde[1] — [1]Inst. f. Theoret. Physik III, Justus-Liebig-Universität Giessen, Germany — [2]Inst. f. Theoret. Physik, Freie Universität Berlin, Germany — [3]Inst. f. Angew. Physik, Justus-Liebig-Universität Giessen, Germany

We use a site-bond percolation model to study, both numerically and analytically, the gas-induced metal-insulator transition in thin layers of nanoporous crystalline metal oxides. While below a critical gas concentration Nc the nanoporous structure is insulating due to the absence of a percolating path, which consists of conducting grains (sites) and intergranular contacts (bonds), above Nc the conductance increases rapidly. We find two different scenarios: (i) For systems of high porosity, the transition arises from missing conducting grains, leading to site percolation effects. (ii) For systems of low porosity, the underlying conduction mechanism changes with increasing mean grain-size <D>: For large <D> the transition occurs due to bond- and for small <D> due site percolation effects. While for bond percolation Nc grows linearly with <D>, for site percolation a nonlinear behavior of Nc shows up for very small <D>. Our findings explain the linear dependence of Nc on <D> found in former works, which had not been fully understood before and suggest how the different conduction mechanisms possibly show up in experiments. We furthermore explore how the distribution of grain-sizes influences the shape of the characteristics.

DY 41.8 Fri 12:15 HÜL 186

The entropy production paradox in the space-fractional diffusion equation case — •Janett Prehl[1], Karl Heinz Hoffmann[1], and Chris Essex[2] — [1]Institut für Physik, Technische Universität Chemnitz, D-09107 Chemnitz, Deutschland — [2]Department of Applied Mathematics, The University of Western Ontario, London, Canada N6A 5B7

Contrary to intuition, entropy production rates grow as reversible, wave-like behavior is approached. This paradox was discovered in time-fractional diffusion equations. It was found to persist for extended entropies and for space-fractional diffusion as well. This paper completes the possibilities by showing that the paradox persists for Tsallis and Rényi entropies in the space-fractional case. Complications arising due to the heavy tail solutions of space-fractional diffusion equations are discussed in detail.

[1] J. Prehl, C. Essex, K. H. Hoffmann, *Physica A* (2010) **389**: 215–224

DY 41.9 Fri 12:30 HÜL 186

Subdiffusive transport on the infinite cluster of the Lorentz Model — •Markus Spanner[1], Felix Höfling[2], Gerd Schröder-Turk[1], Klaus Mecke[1], and Thomas Franosch[1] — [1]Theoretische Physik 1, Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen — [2]MPI für Metallforschung, Heisenbergstr. 3, und Institut für Theoretische und Angewandte Physik, Pfaffenwaldring 57, 70569 Stuttgart

The Lorentz model is a model for transport in porous materials, where a point-like tracer moves through an array of quenched spherical obstacles. Extensive simulations of this model were performed recently, and revealed anomalous transport at the void-space percolation transition. These studies considered all-cluster-averaged quantities, yet for deeper insight one would like to resolve the motion on the various clusters.

We conducted simulations of particles confined to the 'infinite' cluster, i.e. the fraction of void space that percolates through the system of obstacles, identified using a Voronoi tessellation. We find that the motion stays subdiffusive $\delta r_\infty^2(t) \sim t^{2/d_\mathrm{w}}$ with a new exponent $d_\mathrm{w} = 4.81$ known as walk dimension in the context of random walks in lattice percolation. Besides measuring the volume of the infinite cluster as a function of the obstacle density for systems of overlapping spheres, a detailed analysis of transport on this infinite cluster was carried out, including the vanishing of the diffusion coefficient near the transition, the non-gaussian parameter, the influence of finite system sizes and an extrapolation of the critical density from the dynamics. In contrast to the all-cluster-averaged dynamics, we observe a gaussian behavior for long times for densities below the localization threshold.

DY 41.10 Fri 12:45 HÜL 186

Modeling non-Gaussian 1/f noise using stochastic differential equations and by sequences of stochastic pulses — •Bronislovas Kaulakys, Miglius Alaburda, and Julius Ruseckas — Institute of Theoretical Physics and Astronomy, Vilnius University, A. Gostauto 12, LT-01108 Vilnius, Lithuania

We present and analyze models of $1/f$ noise, which can be relevant for the understanding of the origin, main properties and parameter dependencies of the flicker noise. Signals represented as sequences of the random pulses [1] and models based on the stochastic differential equation with different relaxation rates [2, 3] are analyzed. The models generate signals with the Gaussian and non-Gaussian power-law distributions and $1/f^\beta$ power spectrum.

[1] J. Ruseckas, B. Kaulakys and M. Alaburda, Lith. J. Phys. **43**, 223 (2003); arXiv:0812.4674.

[2] B. Kaulakys, V. Gontis, and M. Alaburda, Phys. Rev. E **71**, 051105 (2005).

[3] B. Kaulakys, M. Alaburda and J. Ruseckas, AIP Conf. Proc. **922**, 439 (2007); arXiv:1001.2635v1.

DY 41.11 Fri 13:00 HÜL 186

Exact solution of a stochastic birth and death process with delayed death — •Luis F. Lafuerza and Raul Toral — Intitute for Cross-Disciplinary Physics and Complex Systems

Motivated by protein dynamics where degradation can occur with a time delay, we study a stochastic birth and death process with delayed-degradation. This is one of the simplest rocesses in which the interplay between stochasticity and delay can be studied.

In this work we develop a rigorous derivation of the stochastic description of a birth and death process that includes delay and solve it exactly. We find that the exact solution for the probabilities leads to equations for the mean values that do not comply with simple intuitive arguments and that oscillatory behavior does not exist (while it is usually assumed to be present in this type of system). This warns about the derivation of dynamical equations describing the evolution of the concentrations in cases in which delay plays a role.