DY 43 Einstein Symposium Brownian Motion, Diffusion and Beyond (SYBM) – Contributed Talks I

Zeit: Dienstag 14:30–18:00 Raum: TU H2032

DY 43.1 Di 14:30 TU H2032

Ornstein-Uhlenbeck Process in Physics and Finance — •Ralf Remer and Reinhard Mahnke — Institute of Physics, Rostock University, D–18051 Rostock, Germany

We regard the Ornstein-Uhlenbeck process in Physics starting with the historic paper by Uhlenbeck and Ornstein [1] and its solution by Chandrasekhar [2]. We also demonstrate another way for solving the system of equations and visualize the solution.

Then we apply the Ornstein-Uhlenbeck process to the field of Finance by using appropriate transformations. We compare the received system of equations with empirical high frequency data of German stock market by calculating the probability density distributions of price changes for short time lags.

[1] G. E. Uhlenbeck and L. S. Ornstein 1930 On the theory of the Brownian motion *Physical Review* **36** 823–841
[2] S. Chandrasekhar 1943 Stochastic Problems in Physics and Astronomy *Reviews of Modern Physics* **15** 1–89

DY 43.2 Di 14:45 TU H2032

Brownian motion: Some puzzles 100 Years after Einstein and Smoluchowski — •Peter Hänggi — Institut für Physik, Universität Augsburg, Universitästrasse 1

The description of Brownian motion is well understood 100 years after Einstein and Smoluchowski. The stochastic process that describes Brownian motion in thermal equilibrium is a Gaussian. In classical statistical mechanics it is known as the Wiener process that can be derived from microscopic description in terms of a harmonic bath with a continuous spectrum for the bath-oscillator frequencies. The issue is more complex on a quantum level where the Brownian noise becomes operator-valued. Some open problems on the issue of Brownian motion remain nevertheless. These are: (1) the relaxation of an open quantum system in contact with a thermal heat bath that is prepared at initial time with some *arbitrary correlation* is still poorly understood (role of entanglement between bath and system under time evolution). Almost all literature treats the case of a Feynman-Vernon preparation where the system and the bath are not correlated at initial time. (2) The role of Brownian motion in systems exhibiting *aging* is not clear. (3) Another open problem is the problem of *relativistic Brownian motion*. For the latter area there exist practically no publications. In my talk I will review the state of the art and point out an Ansatz for solving the issues raised with points (1) and (2). For point (3), I will present a partial solution [1]. Moreover, I point out why the relativistic issue in its full generality will remain unsolved.

[1]J. Dunkel and P. Hänggi, *Theory of relativistic Brownian motion: The (1+1)-dimensional case*, Phys. Rev. E **70**, XXXXXX (2004), in press.

DY 43.3 Di 15:00 TU H2032

On the quantum description of Einstein's Brownian motion — •Bassano Vacchini[1] and Francesco Petruccione[2] — [1]Universita degli Studi di Milano, Italy — [2]University of KwaZulu-Natal, South Africa

A fully quantum treatment of Einstein's Brownian motion is given, showing the role played by the two original requirements of translational invariance and connection between dynamics of the Brownian particle and atomic nature of the medium. The former leads to a clearcut relationship with Holevo's result on translation-covariant quantum-dynamical semigroups, the latter to a formulation of the fluctuation-dissipation theorem in terms of the dynamic structure factor, a two-point correlation function introduced in seminal work by van Hove, directly related to density fluctuations in the medium and therefore to its atomistic, discrete nature. A microphysical expression for the generally temperature dependent friction coefficient is given. A comparison with the Caldeira Leggett model is drawn.

F. Petruccione and B. Vacchini, quant-ph/0411089; B. Vacchini, Phys. Rev. Lett. 84, p. 1374 (2000); J. Math. Phys. 42, p. 4291 (2001); Phys. Rev. E 66, 027107 (2002)

DY 43.4 Di 15:15 TU H2032

Intracellular Transport: A Levy Flight Process with a Log-Normal Velocity Distribution — •Erich Sackmann and Doris Heinrich — E22, Biophysik, Technische Universität München, Garching, Germany

The micro-viscoelastic behavior and intracellular transport in Dictyostelia cells has been evaluated by analysing the active and passive motion of magnetic and non-magnetic force probes, exploring a large region within the cell cytoplasm. A detailed analysis of the bead velocities showed that the motion can be described by Levy like quasi random walks, which can be represented by a log-normal distributions with velocities ranging from 0,25 -15 microns/s. The log-normal distribution is determined by the superposition of several distinct, statistically independent motions comprising the flagella like motion of the microtubules, the active motion of the bead along microtubules driven by kinesin and dynein motor molecules, the internal hydrodynamic flow, and the locomotion of the cell. The active forces measured in Dictyostelia cells (embedded in agarose) vary between 9 and 30 pN while larger forces (up to 100 pN) were found in free Dictyostelia. The large forces are attributed to actin-myosin mycromuscles. The cytoplasm behaves as a viscoplastic body. The force induced intracellular bead transport is described as a diffusive walk of a particle in a quasi-periodic potential and the mobility is determined by the fracture of intracellular networks. The direction is given by the constraints imposed by the microtubules and the intracellular compartment and the mobility has to be considered as a tensor.

DY 43.5 Di 15:30 TU H2032

Topological Superdiffusion — •Dirk Brockmann and Theo Geisel — MPI für Strömungsforschung, Göttingen

Superdiffusive phenomena abound in physical, biological, economical and ecological systems. Generally these processes, also known as Lévy flights, exhibit power laws in their spatial dispersal kernels. In a number of physical systems these scale free properties have been associated with anomalous thermal properties and corresponding fractional Fokker-Planck equations were established as the canonical way to describe these phenomena. In this talk I will reveal that the description of superdiffusive phenomena is a subtle issue. In particular I will show that paradigmatic systems exist which cannot be accounted for in the canonical way, which exhibit topological Lévy-type dispersal and which are thermally inconspicuous. The description of these processes requires a novel type of fractional Fokker-Planck equation with surprising and often counterintuitive properties. Systems exhibiting topological superdiffusion are numerous, ranging from random walks on folded polymer chains, human dispersal in inhomogeneous environments, and the spread of epidemics in a globalized world.

DY 43.6 Di 15:45 TU H2032

On the proper boundary conditions for the anomalous subdiffusion–reaction processes — •Igor Goychuk and Peter Hänggi — Institut für Physik, Universität Augsburg, Germany

Diffusion can be of substantial importance for many processes in nature, e.g. for biochemical reactions occurring in the living cells. Due to the molecular crowding in the cytoplasm of the biological cells as well as in their membranes (which normally is the case) the molecular diffusion may become anomalously slow. The fractional diffusion equation presents a convenient mathematical tool to describe non-Markovian subdiffusion processes. Its application to the subdiffusion-reaction kinetics requires that the corresponding boundary conditions must be derived properly from the underlying physical consideration. There are two different kinds of the radiation boundary condition for the fractional diffusion equation at use. We justify the correctness and the physical relevance of one of them by invoking (i) the continuous time random walk picture of subdiffusional encounters, (ii) the probability conservation law and (iii) the standard assumption on the Markovian character of the chemical transformations at the encounter events. This justifies the correct use of the fractional Riemann-Liouville derivative for the diffusion part of the (sub)diffusion-reaction equations only. This implies also the failure of the known scaling recipe (in the Laplace-transformed time picture) to obtain the correct solution of a subdiffusion problem involving a pseudo-first order chemical reaction from its normal diffusion counterpart.

DY 43.7 Di 16:00 TU H2032

Anomalous Levy diffusion in an optical lattice and ergodicity breaking — •Eric Lutz — Abteilung Quantenphysik, Universitaet Ulm, D-89069 Ulm

We investigate anomalous transport in an optical lattice from the point of view of statistical mechanics and establish an explicit correspondence between ergodicity breaking and the divergence of the moments of the power-law tail distributions describing the behavior of the system, both in momentum space and in time.

DY 43.8 Di 16:15 TU H2032

Disordered iterated maps: Spectral properties, escape rates and anomalous transport — •Günter Radons and Andreas Fichtner — Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

We investigate the transport properties of simple iterated maps with quenched disorder. The dynamics of these systems is mapped to random walks in random environments with next-nearest neighbour transitions, constituting generalisations of the well-known Sinai model. The non-equilibrium properties are studied numerically by a direct observation of the transport behaviour, by investigating the density of states of the propagator, and by considering the system-size dependence of the escape rate. Characteristic exponents associated with each of these quantities are determined and their dependence on the system parameters is evaluated. We find anomalously slow behaviour which in general deviates from the Sinai case and therefore generalises the latter.

DY 43.9 Di 16:30 TU H2032

Recurrence and Photon Statistics in Fluorescence Fluctuation Spectroscopy — •Christian Hübner[1], Johannes Hohlbein[1,2], and Gert Zumofen[3] — [1]Universität Halle, Fachbereich Physik, Hoher Weg 8, 06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg2, 06120 Halle — [3]Eidgenössische Technische Hochschule Zürich, Physikalische Chemie, 8093 Zürich

We report on fluorescence fluctuations of nanoparticles diffusing through a laser focus. Subject to an intensity threshold the fluorescence signal is transformed into time traces of on- and off-periods. The distribution functions of the experimental on- and off-times follow power laws $t^{-\alpha}$ over several orders of magnitude with exponents $\alpha \simeq 1.5-2$. At long times the distribution functions cross over to exponential decays. For the interpretation of the experimental data a diffusion-reaction equation is proposed which covers both, the diffusion controlled recurrence and the photon statistics as the relevant processes.

DY 43.10 Di 16:45 TU H2032

Fluorescence correlation spectroscopy: Probing Brownian motion of molecules in solution — •Jörg Enderlein[1], Thomas Dertinger[1], and Ingo Gregor[2] — [1]IBI-1, Forschungszentrum Jülich, D-52425 Jülich — [2]IBI-2, Forschungszentrum Jülich, D-52425 Jülich

In the last three decades, advances in optical microscopy and photoelectric detectors had made it possible to routinely monitor the Brownian motion of molecules in and out of femtoliter detection volumes in solution. The resulting spectroscopic technqiue, fluorescence correlation spectroscopy (FCS), has found wide applications in biophysics, chemical analysis, and physical chemistry. The presentation focuses on recent advances of FCS concerning precise measurement of diffusion coefficient with multi-focal excitation and detection, as well as the combination of FCS with fluorescence lifetime spectroscopy for monitoring fast inter- and intramolecular processes such as conformational changes and molecular interactions.

DY 43.11 Di 17:00 TU H2032

Diffusion of single fluorescent dyes in nanometersized channels and cage structures — •Johanna Kirstein[1], Christian Hellriegel[1], Christophe Jung[1], Christoph Bräuchle[1], Nikolay Petkov[1], Barbara Fieres[1], Thomas Bein[1], and Ross Brown[2] — [1]LMU, Dept. Chemie und Biochemie, CeNS, Butenandtstr. 11, D-81377 München — [2]U.P.P.A., umr 5624 du CNRS, IFR, rue Jules Ferry, F-64075 Pau Cedex

We investigate the diffusion of individual molecules incorporated into mesoporous hosts. Using wide-field imaging and single particle tracking we collect trajectories of single fluorescent dye molecules (TDI) with high temporal (70 frames/s) and spatial (< 20 nm) resolution. In the present study thin films of spincoated mesoporous silica are used as hosts. Two different pore architectures were obtained by liquid crystal templating: a hexagonal (pore diameter 6 nm) and a cubic phase (9 nm). Our method provides a direct microscopic view of the diffusion process of single molecules, revealing not only differences in the mean diffusivity, but structural heterogeneities on a nanometer scale. Two populations of mobile molecules could be distinguished in the hexagonal samples. In the cubic phase a broad distribution of diffusion coefficients was observed. Strong deviations from Brownian motion occured: in some cases the shape of the trajectories reflects pore structure and topology of the host system. Simulations of the diffusional behavior based on the structural data of the host-guest systems are done for comparison.

DY 43.12 Di 17:15 TU H2032

Brownian motion of a single levitated mixed phase aerosol particle: Probing the dynamics of coupled Brownian motion employing dynamic light scattering — •Ulrich K. Krieger — Institute for Atmospheric and Climate Science (IACETH), ETH Zurich, 8093 Zurich, Switzerland

Within a liquid atmospheric aerosol particle a solid phase may coexist with the liquid over a wide range of ambient conditions. Aerosol particles often contain water insoluble components such as mineral dust or soot. Or, depending on composition, temperature, and relative humidity, a solid phase may form in an aqueous multicomponent salt particle, leaving a substantial fraction of the total particle mass in the liquid phase.

We apply dynamic light scattering spectroscopy (DLS) to probe the dynamics of single mixed phase particles levitated in a quasi-electrostatic trap under standard gas pressure. The Brownian motion of these particles is complicated because it is a coupled motion of the host droplet suspended in the gas phase and the movement of the inclusion via the viscous drag in the liquid phase. However, the analysis may allow obtaining information not only on the sizes of the host droplet and the inclusion but also on the viscosity of the liquid phase.

We will present experimental data and outline a route for interpreting the dynamic light scattering in the framework of coupled Brownian motion.

DY 43.13 Di 17:30 TU H2032

Studying Diffusion in Monolayers at the Air/Water Interface by Single-Particle-Tracking — •Carsten Selle[1], Florian Rückerl[1], Martin B. Forstner[2], Douglas S Martin[3], and Josef A. Käs[1] — [1]Universität Leipzig, Inst. Exp. Physik I, PWM, Linnestr. 5, 04103 Leipzig — [2]UC Berkeley — [3]Brandeis University

The diffusion properties of single biological membrane components were investigated by a Single-Particle-Tracking (SPT) technique employing monolayers at the air/water interface combined with Monte Carlo simulations. Studies of lipid diffusion with long observation times revealed that (camera) noise can lead to the assumption of subdiffusion. Protein diffusion was mimicked by the motion of surface charged fluorescent polystyrene latexes in inhomogeneous monolayers. Associated with liquid-condensed (LC) lipid domains, dimensionally reduced diffusion was found. We assume that dipole-dipole interactions of beads with LC domains give rise to an underlying attractive potential. This view point is supported by Monte-Carlo simulations. Furthermore, the simulations demonstrated that model protein diffusion might be affected by the domain size and the potential depth. It is conceivable that living cells could make use of a similar mechanism to enhance kinetics of bimolecular enzyme reactions in the membrane.

DY 43.14 Di 17:45 TU H2032

multiple ion diffusion in disordered environments — •Joachim Sohns and Michael Schulz — Universität Ulm, Abteilung theoretische Physik, Albert-Einstein-Allee 11 89069 Ulm

The goal of this study is to give an analytical model to describe the mixed alkali effect. As a first step we discuss the behaviour of two different ions in a stochastic environment A random energy model is used which leads to a multi-particle fokker-planck equation with random potentials. As a model for the two different alkali ions we use two different potentials. We assume cross correlations between the potentials and interaction between the particles by coulomb forces. We use perturbation theory up to second order to find an approximation for the distribution of the particles. We discuss the influence of finite dimensions on our model.