BP 61: Anomalous Diffusion in Complex Environments (Focus Session)

Joint session with DY, organized by Reza Shaebani and Ludger Santen, Saarland University, for BP.

Time: Thursday 11:30–13:00 Location: H45

BP 61.1 Thu 11:30 H45

Apparent Super-Diffusion Induced by Trail-Mediated Self-Interaction of Microorganisms — •Till Kranz, Anatolij Gelimson, and Ramin Golestanian — Rudolf-Peierls Centre for Theoretical Physics, University of Oxford

Many microorganisms, namely surface bound bacteria [1] and amoeboid slime moulds [2], leave trails of sticky substances. We will present a simple model of a self-propelled microorganism whose propulsion force depends on the concentration of trail material [3]. The trail-mediated self-interactions of a single microorganism and its own trail profoundly alter the dynamics. Above a critical interaction strength with the trail a discontinuous localisation transition emerges. Close to the transition, the orientational dynamics becomes super-diffusive and, in fact, super-ballistic, on a diverging timescale. Interestingly, no such super-diffusive regime appears for the translational dynamics. We will discuss the implications for real biological systems and the interplay of their finite timescales with the emergent diverging timescale.

[1] K. Zhao *et al.*, Nature **497**, 388 (2013)
[2] B. Rodiek and M. J. B. Hauser, EPJ ST **224**, 1199 (2015)
[3] W. T. Kranz, A. Gelimson, and R. Golestanian, arXiv:1504.06814

BP 61.2 Thu 11:45 H45

Transport of active Brownian particles in complex environments — •Maria Zeitz and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin, Germany

From the perspective of physics, biological microswimmers such as bacteria can be viewed as active particles. Since bacteria often inhabit porous or crowded environments, we examine the dynamics and transport of active particles in a complex environment. We focus on active Brownian particles (APB), which provide a simple model for microswimmers. ABPs have an intrinsic speed and perform rotational as well as translational diffusion.

We study the transport of ABPs moving in a two-dimensional environment of randomly placed and fixed obstacles of a given area fraction ϕ_o. For increasing ϕ_o we observe a transition from diffusive transport to trapping on long time scales, which happens close to the percolation threshold of the void space $1 - \phi_0 \approx 0.67$. The behavior on long time scales is universal and depends only on the obstacle density and not on the intrinsic dynamics of the particle. However, on time scales much shorter than the rotational diffusion time, we find ballistic transport and on intermediate timescales we find subdiffusive transport. The crossover times between the three regimes depend not only on ϕ_o but also on the details of particle propulsion, e.g. Peclét number.

In a second step we study how obstacles can serve as nucleation seeds for clustering in collective motion of ABPs and therefore promote clogging.

BP 61.3 Thu 12:00 H45

Impact of detachment frequency on transport dynamics of cytoskeletal motor proteins — •Anne E Hafner, M Reza Shaebani, Ludger Santen, and Heiko Rieger — Department of Theoretical Physics, Saarland University, Saarbrücken, Germany

Cytoskeletal motor proteins are involved in key intracellular transport processes which are vital for maintaining appropriate cellular function. The motors exhibit distinct states of motility: active motion along filaments, and inactive state in which the motor detaches from the filament and remains effectively stationary by performing passive diffusion in the vicinity of the detachment point due to cytoplasmic crowding until it attaches again to the cytoskeleton. The rates of transitions between motion and pause states are considerably affected by changes in environmental conditions which influences the efficiency of cargo delivery to specific targets. By considering the motion of molecular motor on a single filament as well as a dynamic filamentous network, we present an analytical model for the dynamics of self-propelled particles which undergo frequent pause phases, and validate the theoretical predictions by performing extensive Monte Carlo simulations. The transition rates between the two states drastically change the dynamics: multiple transitions between different types of anomalous diffusive dynamics may occur and the crossover time to the asymptotic diffusive or ballistic motion varies by several orders of magnitude. We map out the phase diagrams in the space of transition rates, and address the role of initial conditions of motion on the resulting dynamics.

BP 61.4 Thu 12:15 H45

The Power Spectrum of Ionic Nanopore Currents: The Role of Ion Correlations — •mira zorkot, Ramin Golestanian, and Douwe Jan Bonthuis — Rudolf Peierls Centre for Theoretical Physics, Oxford University, Oxford, OX13NP, United Kingdom

Measuring the ionic current passing through a nanometer-scale membrane pore has emerged over the past decades as a versatile technique to study molecular transport. These measurements su*er from high noise levels that typically exhibit a power law dependence on the frequency. A thorough theoretical understanding of the power spectrum is essential for the optimisation of experimental setups and for the use of measurement noise as a novel probe of the nanopores microscopic properties.

We calculate the power spectrum of electric-*field-driven ion transport through nanopores using both linearized mean-fi*eld theory and Langevin dynamics simulations. With only one *tting parameter, the linearized mean-*field theory accurately captures the dependence of the simulated power spectrum on the pore radius and the applied electric *field. Remarkably, the linearized mean-*field theory predicts a plateau in the power spectrum at low frequency f, which is con*rmed by the simulations at low ion concentration. At high ion concentration, however, the power spectrum follows a power law that is reminiscent of the 1/f dependence found experimentally at low frequency. Based on simulations with and without ion-ion interactions, we attribute the low-frequency power law dependdence to ion-ion correlations.

BP 61.5 Thu 12:30 H45

Fluctuation relations for anomalous dynamics generated by time fractional Fokker-Planck equations — Peter Dieterich[1], •Rainer Klages[2,3], and Aleksei V. Chechkin[2,4,5] — [1]Institut fuer Physiologie, Technische Universitaet Dresden — [2]Max Planck Institute for the Physics of Complex Systems, Dresden — [3]Queen Mary University of London, School of Mathematical Sciences — [4]Institute for Theoretical Physics NSC KIPT, Kharkov, Ukraine — [5]Institute of Physics and Astronomy, University of Potsdam

Anomalous dynamics characterized by non-Gaussian probability distributions (PDFs) and/or temporal long-range correlations can cause subtle modifications of conventional fluctuation relations (FRs). As prototypes we study three variants of a generic time-fractional Fokker-Planck equation with constant force. Type A generates superdiffusion, type B subdiffusion and type C both super- and subdiffusion depending on parameter variation. Furthermore type C obeys a fluctuation-dissipation relation whereas A and B do not.We calculate analytically the position PDFs for all three cases and explore numerically their strongly non-Gaussian shapes. While for type C we obtain the conventional transient work FR, type A and type B both yield deviations by featuring a coefficient that depends on time and by a nonlinear dependence on the work.We discuss possible applications of these types of dynamics and FRs to experiments.

P. Dieterich et al., New J. Phys. **17**, 075004 (2015)

BP 61.6 Thu 12:45 H45

Induced anomalous diffusion nearby cell membranes — •Abdallah Daddi-Moussa-Ider, Achim Guckenberger, and Stephan Gekle — Biofluid Simulation and Modeling, University of Bayreuth, 95440 Bayreuth, Germany

The approach of a small particle to the cell membrane represents the crucial step before active internalization and is governed by thermal diffusion. Using a fully analytical theory, we show that the membrane induces a long-lived subdiffusive behavior on the nearby particle, during which the residence time is increased by up to 50 % for a typical scenario. The corresponding scaling exponent is found to be as low as 0.87 in the perpendicular direction, and as low as 0.92 in the parallel direction. Such behavior is qualitatively different from the normal diffusion near a hard wall or in a bulk fluid. A good agreement is found for the frequency dependent mobility between the analytical predictions and the numerical simulations that we performed using a boundary integral method.