DY 22: Brownian motion and transport II

Time: Thursday 10:15–13:00 Location: ZEU 118

DY 22.1 Thu 10:15 ZEU 118

Uphill motion in a deterministic relativistic Josephson Vortex Ratchet — •Edward Goldobin[1], Martin Knufinke[1], Kai Buckenmaier[1], Michael Siegel[2], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena, University of Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Institut für Mikro- und Nanoelektronische Systeme, Universität Karlsruhe (KIT), Hertzstr. 16, D-76187 Karlsruhe, Germany

We investigate experimentally a deterministic relativistic Josephson vortex ratchet (JVR), i.e., a fluxon moving in a spatially asymmetric potential along annular long Josephson junction. The fluxon is driven by deterministic ac force with zero time average[1,2,3,4]. The rectification of an applied ac drive to a dc voltage (unidirectional fluxon motion) in such a system was demonstrated earlier in both quasi-static and non-adiabatic regimes[2,4]. Still the ratchet was not loaded. Now, being in the rectification regime, we apply an additional bias current which tilts the potential so that the fluxon moves uphill due to the ratchet effect. At some value I_{stop} of the bias current the fluxon stops. We determine I_{stop} both experimentally and numerically in a quasi-static and in a non-adiabatic regime and show the regions that are most favorable for operation of a JVR.

[1] P. Hänggi *et al.*, Ann. Phys. (Leipzig) **14**, 51 (2004)
[2] G. Carapella *et al.*, Phys. Rev. Lett. **87**, 077002 (2001).
[3] E. Goldobin *et al.*, Phys. Rev. E **63**, 031111 (2001).
[4] M. Beck *et al.*, Phys. Rev. Lett. **95**, 090603 (2005).

DY 22.2 Thu 10:30 ZEU 118

Computer simulation of ratchet transport of colloids on magnetically striped substrates — •Andrea Fortini and Matthias Schmidt — Theoretische Physik II, Universität Bayreuth, Universitätsstraße 30, D-95440 Bayreuth, Germany

We consider a two-dimensional model of paramagnetic colloidal particles on a magnetically patterned substrate. The pattern consists of stripe-like domains with opposite magnetization and wavelengths of the order of several particle diameters. The influence of an external oscillating magnetic field induces directed particle transport via a ratchet mechanism. Using computer simulations we investigate which of the collective transport phenomena observed in experiments with super-paramagnetic particles sedimented on top of a garnet film [P. Tierno et al, Phys. Rev. Lett 100, 148304 (2008)] can be realized with simple model dynamics. In particular the importance of the roles of topology and of curvature of the magnetic domains is addressed.

DY 22.3 Thu 10:45 ZEU 118

Magnetic Ratchet for transportation and separation of magnetic beads — •Alexander Auge, Alexander Weddemann, Frank Wittbracht, and Andreas Hütten — Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Germany

Transport phenomena in spatially periodic magnetic systems far from thermal equilibrium are considered. The emphasis is put on directed transport of magnetic beads in a so called magnetic ratchet (Brownian motor). An asymmetric magnetic potential and Brownian motion of magnetic beads are the basic concepts for a magnetic ratchet. The asymmetric magnetic potential is achieved by combining an external magnetic field with a spatial periodic array of conducting lines. In this work simulations are carried out to test and optimize this asymmetric potential. As simulation model the Smoluchowski equation with additional flux terms for the magnetic and gravitational force is used. Furthermore experiments are carried out to verify the simulation results. Possible applications like transport in microfluidic devices and separation of magnetic beads are discussed.

DY 22.4 Thu 11:00 ZEU 118

Classical and quantum spin pumps — •Fredy Leonardo Dubeibe Marin[1,2,3], Thomas Dittrich[1,2], and Klaus Richter[3] — [1]Universidad Nacional de Colombia, Departamento de Fisica, Bogota D.C., Colombia — [2]CeiBA – Complejidad, Bogota D.C., Colombia — [3]Institut für Theoretische Physik Universität Regensburg, Regensburg, Germany

Chaotic scattering with an internal degree of freedom and the possibility to generate directed transport of angular momentum in such a system is studied in a specific model, a magnetic dipole moving in periodically modulated magnetic field confined to a compact region in space. We show that this system is an irregular scatterer in large parts of its parameter space. If in addition all spatio-temporal symmetries are broken, directed transport of mass as well as angular momentum occurs. The sensitive parameter dependence of the corresponding currents includes frequent sign reversals. Zeros of either current quantity correspond to the exclusive occurrence of the other and thus give rise in particular to angular-momentum separation without mass transport as a classical analogue of spin-polarized currents. For the quantum case, we sketch the theory for spins and indicate how to extend our classical results in this context. Employing Floquet scattering theory we show that the basic mechanism responsible for the separation of spins in the classical case carries over to the quantum level, thus giving rise to a spin pump capable of generating polarized spin currents.

DY 22.5 Thu 11:15 ZEU 118

Ultrasonically driven nano-mechanical single-electron shuttle — •Daniel König, Eva Weig, and Jörg Kotthaus — Center for NanoScience and Fakultät für Physik der Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany

The transport and detection of single electrons with extraordinary precision has been a long sought goal since its potential impact on metrology was recognized in the 80s. The one-by-one electron transfer with a well defined frequency for example may ultimately lead to the realisation of a quantum standard for the electrical current unit ampere - like the ones already implemented for voltage and resistance based on the Josephson and Quantum Hall effect, respectively. One possible approach to this goal is the mechanical transfer of single electrons. In the talk a nano-mechanical electron shuttle is presented which is mechanically excited by ultrasonic waves and placed within a Faraday cage to shield it from undesired electromagnetic fields. By this, electrically undisturbed mechanical electron transport at temperatures as low as 4 Kelvin is demonstrated. The results demonstrate that the nano-mechanical electron shuttles belong to the class of impacting systems, are intrinsically non-linear and display harmonic, subharmonic and chaotic behaviour. For a certain operating regime excellent agreement in the high temperature limit (20K) between the measured data and theoretical calculations is observed. Further more, the results suggest that operation in the Coulomb blockade regime, for which a well defined number of electrons is transferred during each oscillation period, is within reach for reduced sample dimensions and lower temperatures.

15 min. break.

DY 22.6 Thu 11:45 ZEU 118

Branched flow and caustics in random media with magnetic fields — •Jakob Metzger[1,2], Ragnar Fleischmann[1,2], and Theo Geisel[1,2] — [1]Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Department of Physics, University of Göttingen, Germany

Classical particles as well as quantum mechanical waves exhibit complex behaviour when propagating through random media. One of the dominant features of the dynamics in correlated, weak disorder potentials is the branching of the flow. This can be observed in several physical systems, most notably in the electron flow in two-dimensional electron gases [1], and has also been used to describe the formation of freak waves [2].

We present advances in the theoretical understanding and numerical simulation of classical branched flows in magnetic fields. In particular, we study branching statistics and branch density profiles. Our results have direct consequences for experiments which measure transport properties in electronic systems [3].

[1] e.g. M. A. Topinka *et al.*, Nature **410**, 183 (2001), M. P. Jura *et al.*, Nature Physics **3**, 841 (2007)
[2] E. J. Heller, L. Kaplan and A. Dahlen, J. Geophys. Res., **113**, C09023 (2008)
[3] J. J. Metzger, R. Fleischmann and T. Geisel, *in preparation*

DY 22.7 Thu 12:00 ZEU 118

Suppression of size-quantization steps in disordered graphene

nanoribbon — •Florian Libisch, Stefan Rotter, and Joachim Burgdörfer — Inst.f.theoretische Physik, TU Wien, Österreich

We numerically study impurity scattering in graphene nanoribbons as a function of impurity density and ribbon length. For long ribbons (ribbon length up to 3 micrometers) we observe exponential (Anderson) localization of the wave function over eight orders of magnitude. To contrast the role of AB and K-K' scattering, we compare impurities that either break or conserve pseudo-spin. By calculating the scattering wave function on the A and B sublattice, we can directly visualize broken pseudo-spin conservation. Using a Fourier transformation allows us to quantitatively assess, for different impurity types, the amount of AB and K-K' scattering. For perfect ribbons, the conductance features size quantization steps due to the transverse confinement. We find that these steps are strongly suppressed in disordered ribbons for impurities that break the AB-symmetry. In contrast, short-range impurities that conserve pseudo-spin result in K-K' scattering and preserve size quantization steps. Comparison of our results with recent experimental data suggests that broken AB symmetry plays an important role in realistic graphene devices.

DY 22.8 Thu 12:15 ZEU 118

On moments and scalings in random walks — Michael Schmiedeberg, •Vasily Zaburdaev, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

Anomalous diffusion is commonly characterized by an exponent in the power law behavior of the mean square displacement as a function of time. In many cases this exponent does not provide any information about the scaling properties of the probability density function, not mentioning some superdiffusive regimes with a divergent second moment. However, the study of fractional moments can reveal the missing information. For the class of coupled random walks, one of them is the famous Levy walk model, we systematically analyze three methods used to analytically obtain characteristic exponents for the mean square displacement, scaling of the central part and the asymptotic profile of the probability density function. For example, we show that the scaling of the central part of the probability density can be determined using fractional moments $\langle |\mathbf{r}|^q \rangle$ with $q \ll 1$. These methods deliver distinct and complementary information about an underlying stochastic process. We show how our results can be accessed from experimental data.

DY 22.9 Thu 12:30 ZEU 118

$1/f^\beta$ Noise in Systems showing Weak Ergodicity Breaking — •Markus Niemann, Ivan Szendro, and Holger Kantz — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Systems with weakly broken ergodicity are characterized by the property that the temporal average of an observable does not converge towards its mean value (the ensemble average) in the long time limit, although the phase space does not decompose into mutually inaccessible regions. This behavior is commonly found in systems with power law relaxation such that the relaxation time diverges to infinity. Here the weak ergodicity breaking expresses itself in the fact that the limit of the time average is described by a nontrivial probability distribution. Rebenshtok and Barkai introduced a stochastic model describing these features [PRL 99, 210601 (2007); J Stat Phys 133, 565 (2008)] using which they calculated the limit probability distributions of the time average.

By using a recently published method [PRE 78, 051104 (2008)] we determine the spectral properties of this model. We find analytically that the model shows $1/f^\beta$ noise, but similarly to the time average the spectrum does not converge to a fixed value but remains a probability distribution in the limit of the observation time going to infinity. Furthermore, the spectral values for different frequencies are only weakly correlated resulting in pronounced fluctuation around the $1/f^\beta$ behavior. We illustrate these analytical results by numerical simulations.

DY 22.10 Thu 12:45 ZEU 118

Disordered driven lattice gases with boundary reservoirs and Langmuir kinetics — •Philip Greulich[1] and Andreas Schadschneider[2,3] — [1]Fachrichtung Theoretische Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Köln, Germany — [3]Interdisziplinäres Zentrum für komplexe Systeme, Universität Bonn, Bonn, Germany

The asymmetric simple exclusion process with additional Langmuir kinetics, i.e. attachment and detachment in the bulk, is a paradigmatic model for intracellular transport. Here we examine this model in the presence of randomly distributed inhomogeneities ('defects'). Using Monte Carlo simulations, we find a multitude of coexisting high- and low-density domains. The results are generic for one-dimensional driven lattice gases with short-range interactions and can be understood in terms of a local extremal principle for the current profile. This principle is used to determine current profiles and phase diagrams as well as statistical properties of ensembles of defect samples.