DY 48: Statistical Physics far from Thermal Equilibrium

Time: Thursday 9:30–12:15 Location: ZEU 147

DY 48.1 Thu 9:30 ZEU 147

Entropy Production in Open Systems: The Predominant Role of Intraenvironment Correlations — •Krzysztof Ptaszyński[1] and Massimiliano Esposito[2] — [1]Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland — [2]Complex Systems and Statistical Mechanics, Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg, Luxembourg

We show [1] that the entropy production in small open systems coupled to environments made of extended baths is predominantly caused by the displacement of the environment from equilibrium rather than, as often assumed, the mutual information between the system and the environment. The latter contribution is strongly bounded from above by the Araki-Lieb inequality, and therefore is not time-extensive, in contrast to the entropy production itself. Furthermore, we show that in the thermodynamic limit the entropy production is associated mainly with generation of the mutual information between initially uncorrelated environmental degrees of freedom. We confirm our results with exact numerical calculations of the system-environment dynamics.

[1] K. Ptaszyński, M. Esposito, Phys. Rev. Lett. 123, 200603 (2019)

DY 48.2 Thu 9:45 ZEU 147

Tuning Interaction in Long-Range Models Changes Dynamical Scaling During Aging — •Henrik Christiansen[1], Suman Majumder[1], Malte Henkel[2,3], and Wolfhard Janke[1] — [1]Institut für Theoretische Physik, Universität Leipzig, IPF 231101, 04081 Leipzig, Germany — [2]Laboratoire de Physique et Chimie Théoriques (CNRS UMR 7019),Université de Lorraine Nancy, 54506 Vandaeuvre-lès-Nancy Cedex, France — [3]Centro de Física Teórica e Computacional, Universidade de Lisboa, 1749-016 Lisboa, Portugal

Aging in phase-ordering kinetics of the long-ranged $d = 2$ Ising model is studied via Monte Carlo simulations. The dynamical scaling and aging behavior is analyzed. The dynamical scaling of the spin-spin two-time autocorrelation function is best described by sub-aging in the regime of long-range interactions and by simple aging for effective short-range interactions. The sub-aging exponent μ and the nonequilibrium autocorrelation exponent λ depend explicitly on the range parameter σ. Our data support the relation $\lambda = \sigma$ for $\sigma \leq 1$ and $\lambda = 1.25$ for $\sigma > 1$.

DY 48.3 Thu 10:00 ZEU 147

Thermodynamic Uncertainty Relation for the Kardar-Parisi-Zhang Equation — •Oliver Niggemann and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart

Recently, we have proposed a field-theoretic thermodynamic uncertainty relation for a generic field theory [arXiv: 1908.05560]. In this talk, we first formulate a framework which describes quantities like current, entropy production and diffusivity in the case of a generic field theory. We will then apply this general setting to the one-dimensional Kardar-Parisi-Zhang equation, a paradigmatic example of a non-linear field-theoretic Langevin equation. In particular, we will treat the dimensionless Kardar-Parisi-Zhang equation with an effective coupling parameter measuring the strength of the non-linearity. It will be shown that a field-theoretic thermodynamic uncertainty relation holds up to second order in a perturbation expansion with respect to a small effective coupling constant. The calculations show that the field-theoretic variant of the thermodynamic uncertainty relation is not saturated for the case of the Kardar-Parisi-Zhang equation due to an excess term stemming from its non-linearity.

DY 48.4 Thu 10:15 ZEU 147

Domain wall fluctuations between extremal current phases of driven lattice gases — •Marco Bosi, David Locher, and Philipp Maass — Fachbereich Physik, Osnabrück Universität, Germany

Driven lattice gases are systems where fundamental aspects of non-equilibrium physics can be conveniently studied. In addition they have many applications in biology and other fields. In bulk-driven open system coupled to particle reservoir, phase transitions occur, where, the bulk density in stationary states exhibits a singular behaviour upon varying the parameters of the system-reservoir couplings (analogous to first and second transitions known in equilibrium).Self-organized phases can appear with bulk densities equal to values where the bulk current is minimal or maximal[1][2].

In the presence of repulsive nearest-neighbour interactions degenerate maxima in the bulk current-density relation emerge[3], which allow for coexisting maximal current phases[4]. We report on the behaviour of the fluctuations of the domain walls separating those coexisting phases.

[1]J. Krug, *Phys. Rev. Lett.* 67, 1882 (1991).
[2]G. M. Schütz, in *Phase Transitions and Critical Phenomena*, edited by C. Domb and J. Lebowitz (Academic Press, London, 2001), Vol. 19, pp. 1-251.
[3]M. Dierl, M. Einax, and P. Maass, *Phys. Rev.* E 87, 062126 (2013).
[4]P. Maass, M. Dierl, and M. Wolff, in *On Phase Transitions in Biased Diffusion of Interacting Particles* (Springer International, Cham, 2018), Chap. 9, pp. 147-168.

DY 48.5 Thu 10:30 ZEU 147

Diffusion System with Lorentz Force — •Iman Abdoli[1], Hidde Derk Vuijk[1], Holger Merlitz[1], Jens-Uwe Sommer[1,2], Joseph Michael Brader[3], and Abhinav Sharma[1,2] — [1]Leibniz-Institut für Polymerforschung Dresden, Institut Theorie der Polymere, 01069 Dresden, Deutschland — [2]Technische Universität Dresden, Institut für Theoretische Physik, 01069 Dresden, Deutschland — [3]Department de Physique, Université de Fribourg, CH-1700 Fribourg, Suisse

In the presence of Lorentz force arising from an external magnetic field the Fokker-Planck equation picks up a tensorial coefficient, which reflects the anisotropy of the particle's motion. Lorentz force gives rise to diffusive or irrotational fluxes and Brownian vortexes or solenoidal fluxes along and perpendicular to the density gradients, respectively. We first study the systems in which these Brownian vortexes can be ignored in the time evolution of the density. We then investigate how these vortexes influence the probability density function (or PDF) of the particle's positions in the nonequilibrium stationary state of a diffusion system under stochastic resetting with Lorentz force. Next, we show, analytically and computationally, that the solenoidal fluxes persist in the stationary state of a diffusive system with two different temperatures.

15 min. break.

DY 48.6 Thu 11:00 ZEU 147

Acceleration of non-equilibrium relaxations from long-range initial conditions — •Malte Henkel — MPIPKS, Noethnitzer Strasse 38, D - 01187 Dresden, Germany

Physical ageing is a widespread phenomenon which arises typically after a complex many-body system is quenched from some initial state to a more ordered state, where characteristically several equivalent equilibrium states compete in the control of the long-time evolution. Here we study those ageing processes which may arise in systems which undergo *biased* transport, in a preferred direction. Specific examples, notably the exact solution of the one-dimensional biased Glauber-Ising chain, show that the dynamical exponent z, defined through the relevant cluster size $L(t) \sim t^{1/z}$ at large times t, can depend on the chosen initial conditions. In particular, we shall show that sufficiently long-range initial correlations can lead to a cross-over from effectively diffusive transport, where $z = 2$, to ballistic transport with $z = 1$. This leads to a considerable acceleration of the dynamics, whose possible applications will be explored.

M. Henkel, S. Stoimenov, J. Stat. Mech. 084009 (2019) [arxiv:1810.09855].

DY 48.7 Thu 11:15 ZEU 147

Ageing and non-markovian effects in the exactly solved quantum $O(n)$-model — •Sascha Wald[1], Alessio Chiocchetta[2], Malte Henkel[3], and Andrea Gambassi[4] — [1]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Straße 38, 01187, Dresden, Germany — [2]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — [3]Laboratoire de Physique et Chimie Théoriques (CNRS UMR 7019), Université de Lorraine Nancy, B.P. 70239, 54506 Vandoeuvre lès Nancy, France — [4]SISSA - International School for Advanced Studies and INFN, via Bonomea 265, I-34136 Trieste, Italy

The effects of quantum noise on the non-equilibrium dynamics of many-body quantum systems, after a quantum quench, are analysed.

Quantum noise, as opposed to the classical white noise, is inherently non-Markovian and the resulting dynamics is affected by memory effects, which lead to changes compared to Markovian white noises. In order to systematically analyse these effects, we study the quantum $O(n)$-model at large n, in contact with a bath at zero temperature. Starting from the quantum Langevin equation, the dynamical equations are explicitly solved. The universal properties of the dynamics, as given by the quantum noise and after a quantum quench, are analysed by studying the two-time correlation and response functions. Quantum coarsening and quantum ageing in these observables are highlighted and compared with their classical counterparts. In particular, the validity of the fluctuation-dissipation theorem after a quantum quench is studied in detail.

DY 48.8 Thu 11:30 ZEU 147

A quantum heat engine based on dynamical material design — •Gerhard Tulzer[1], Levan Chotorlishvili[2], Martin Hoffmann[1], Robert Zillich[1], Jamal Berakdar[2], and Arthur Ernst[1] — [1]Institute for Theoretical Physics, Johannes Kepler University, Linz, Austria — [2]Institute of Physics, Marthin Luther University Halle-Wittenberg, Halle (Saale), Germany

We investigate the practical usability of a magneto-electric working substance (Cr_2O_3) for a quantum Otto cycle. The new approach here is the exploitation of a new type of driving during the adiabatic work strokes, where non-linear phonon processes controlled by high-intensity terahertz optical pulses are employed to induce structural changes in the magnetic ordering of the system, being described as a spin chain with spin-3/2. The isochoric heating and cooling strokes are based on the coupling to a phonon thermostat. This type of system appears to be very promising due to its swiftness, but still needs a thorough investigation due to the nonlinearity in its dynamics and the much richer energy spectrum compared to toy models.

After confirming that we actually obtain a thermodynamic cycle we investigate the practical feasibility using the Lindblad master equation. Two quantities of interest in this regard are the efficiency as well as the output power and their relation to the experimental control parameters. We then consider the effects of different thermostat settings, and also investigate relaxation times and work stroke duration in order to find the optimal timing for high efficiency and output power.

DY 48.9 Thu 11:45 ZEU 147

Analytical solutions for non-Markovian Brownian systems far from thermal equilibrium — •Timo Dörries, Sarah A.M. Loos, and Sabine H.L. Klapp — Institut für Theoretische Physik, Hardenbergstr. 36, TU Berlin, 10623 Berlin, Germany

Markovian Langevin equations are an established tool to describe stochastic motion. However, in many real-world systems, memory effects play a crucial role and e.g. complex environments can yield to stochastic motion characterized by different timescales. Analytical solutions are in general difficult to obtain here. We propose (linear) toy models where we non-reciprocally couple auxiliary variables to a Brownian particle, each auxiliary variable corresponding to one characteristic timescale. Projecting out the auxiliary variables, we obtain a non-Markovian Langevin equation with memory and colored noise.

By deriving closed expressions for up to three auxiliary variables, we can systematically study the connection between the coupling topology and the resulting autocorrelation functions. Further, by studying the connection between topology and thermodynamical properties, we demonstrate that models with non-reciprocal coupling automatically have a net heat production, i.e. describe nonequilibrium systems [1,2].

Finally, we show that a minimal model with two auxiliary variables yields correlation functions similar to those describing hydrodynamic backflow in an optical trap [3].

[1] S.A.M. Loos et al., arXiv:1910.08372 (submitted)
[2] S.A.M. Loos and H.L. Klapp, Scientific Reports 9, 2491 (2019)
[3] Franosch et al., Nature **478**, 85-88 (2011)

DY 48.10 Thu 12:00 ZEU 147

Dynamics of active hard cross-shaped particles in two-dimensional lattice system — •Rakesh Chatterjee[1], Nimrod Segall[1], Carl Merrigan[1], Kabir Ramola[2], Bulbul Chakraborty[3], and Yair Shokef[1] — [1]Tel Aviv University, Israel — [2]Tata Institute of Fundamental Research Hyderabad, India — [3]Brandeis University, Waltham, USA

We analyse the dynamics of an active tracer particle embedded in a thermal lattice gas. All particles are subject to exclusion up to third nearest neighbours on a square lattice, which leads to slow dynamics at high densities. With no rotational diffusion of the tracer, we derive an analytical expression for the resulting drift velocity of the tracer in terms of non-equilibrium density correlations involving the tracer particle and its neighbours. For the case where the tracer undergoes rotational diffusion, we relate its diffusion coefficient to the thermal diffusion coefficient and drift velocity. We also study dynamics where the rotation of the tracer is limited by the presence of neighbouring particles.

Next we explore phase separation and kinetic arrest when all particles are active and have infinite persistence time of their active orientation. The passive limit of the model quenches into the two-phase coexistence region represent an ageing passive glass. Adding small persistent active bias to the particle dynamics creates states that resemble the passive glass at lower densities. For large active bias, the dense, immobile clusters proliferate until a spanning network bridges the system leading to percolation of an arrested phase.