DY 3: Statistical Physics far from Thermal Equilibrium

Time: Monday 10:00–12:30 Location: H18

DY 3.1 Mon 10:00 H18

Relaxation to a parity-time symmetric generalized Gibbs ensemble after a quantum quench in a driven-dissipative Kitaev chain — •Elias Starchl and Lukas Sieberer — Institute for Theoretical Physics, University of Innsbruck, Austria

After a quench, isolated thermalizing quantum many-body systems relax locally to an equilibrium state that is universally determined by conservation laws and the principle of maximum entropy. In contrast, open quantum systems, subjected to Markovian drive and dissipation, typically evolve toward nonequilibrium steady states that are highly model-dependent. However, focusing on a driven-dissipative Kitaev chain, we show that relaxation after a quantum quench can be described by a maximum entropy ensemble, if the Liouvillian governing the dynamics has parity-time (PT) symmetry. We dub this ensemble, which is determined by the biorthogonal eigenmodes of the adjoint Liouvillian, the PT-symmetric generalized Gibbs ensemble (PTGGE). Resembling isolated systems, thermalization becomes manifest in the growth and saturation of entanglement, and the relaxation of local observables. In contrast, the directional pumping of fermion parity represents a phenomenon that is unique to relaxation dynamics in driven-dissipative systems. We expect that our results apply rather generally to integrable, driven-dissipative bosonic and fermionic quantum many-body systems with PT symmetry.

DY 3.2 Mon 10:15 H18

Finite-time dynamical phase transition in non-equilibrium relaxation — •Jan Meibohm[1,2] and Massimiliano Esposito[1] — [1]Complex Systems and Statistical Mechanics, Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]Department of Mathematics, King's College London, London WC2R 2LS, United Kingdom

We uncover a finite-time dynamical phase transition in the thermal relaxation of a mean-field magnetic model. The phase transition manifests itself as a cusp singularity in the probability distribution of the magnetization that forms at a critical time. The transition is due to a sudden switch in the dynamics, characterized by a dynamical order parameter. We derive a dynamical Landau theory for the transition that applies to a range of systems with scalar, parity-invariant order parameters. Close to criticalilty, our theory reveals an exact mapping between the dynamical and equilibrium phase transitions of the magnetic model, and implies critical exponents of mean-field type. We argue that interactions between nearby saddle points, neglected at the mean-field level, may lead to critical, spatiotemporal fluctuations of the order parameter, and thus give rise to novel, dynamical critical phenomena.

DY 3.3 Mon 10:30 H18

Mori-Zwanzig formalism for general relativity: a new approach to the averaging problem* — •Michael te Vrugt[1], Sabine Hossenfelder[2], and Raphael Wittkowski[1] — [1]Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [2]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

Cosmology provides a coarse-grained description of the universe that is valid on very large length scales. However, the Einstein field equations are not valid for coarse-grained quantities since, due to their nonlinearity, they do not commute with an averaging procedure. Thus, it is unclear in which way small-scale inhomogeneities affect large-scale cosmology (backreaction). In this work [1], we address this problem by extending the Mori-Zwanzig projection operator formalism, a highly successful coarse-graining method from statistical mechanics, towards general relativity. This allows to derive a dynamic equation for the Hubble parameter in which backreaction is taken into account through memory and noise terms. Our results are linked to cosmological observations.

[1] M. te Vrugt, S. Hossenfelder, R. Wittkowski, Physical Review Letters 127, 231101 (2021)

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

DY 3.4 Mon 10:45 H18

Synthetic horizons in 1D tight-binding model and thermalisation of the many-body groundstate — •Lotte Mertens[1,2], Ali G. Moghaddam[2,3], Dmitry Chernyavsky[2], Corentin Morice[1], Jeroen van den Brink[2,4], and Jasper van Wezel[1] — [1]Institute for Theoretical Physics and Delta Institute for Theoretical Physics, University of Amsterdam, 1090 GL Amsterdam, The Netherlands — [2]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [3]Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan 45137-66731, Iran — [4]Institute for Theoretical Physics and Wurzburg-Dresden Cluster of Excellence ct.qmat, Technische Universitat Dresden, 01069 Dresden, Germany

Open problems in general relativity have motivated the search for analogue gravitational systems in condensed matter implementations. In one such system, a 1D tight-binding model with position-dependent hopping, the possibility of realizing an analogue gravitational horizon has recently been demonstrated. Here, we introduce the concept of emergent temperature, inspired by Unruh radiation, and show that it arises naturally in tight-binding lattice models featuring a horizon. Despite finding many similarities between the emergent lattice temperature and the gravitational Unruh temperature, we show that the nature of the thermal spectrum in the lattice theory is radically different from that in the continuum limit. Additionally, we provide a detailed analysis of outgoing radiation showing the conditions under which the horizon behaves purely as a thermal source.

DY 3.5 Mon 11:00 H18

Renormalized Fluctuation Expansion for Non-Equilibrium Disordered Networks — •Michael Dick[1,2,3], Alex van Meegen[1,4], and Moritz Helias[1,5] — [1]Institute of Neuroscience and Medicine (INM-6) and Institute for Advanced Simulation (IAS-6) and JARA-BRAIN Institute I, Jülich Research Centre, 52425 Jülich, Germany — [2]Department of Computer Science 3 - Software Engineering, RWTH Aachen University, Aachen, Germany — [3]Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Jülich Research Centre, 52425 Jülich, Germany — [4]Institute of Zoology, University of Cologne, 50674 Cologne, Germany — [5]Department of Physics, Faculty 1, RWTH Aachen University, Aachen, Germany

It is frequently hypothesized that cortical networks display hallmarks of critical dynamics. Such critical dynamics are beyond the validity of a mean-field approximation because it inherently neglects fluctuations. Thus, a renormalized theory is necessary. We consider an archetypal neural network model which displays a magnetic as well as a chaotic transition. Based on the analogue of a quantum effective action, we derive self-consistency equations for the first two renormalized Greens functions. Their self-consistent solution reveals critical slowing down near the transition to the ferromagnetic state and an optimal level of disorder which favors collective behavior. The quantitative theory explains the shape of the single-unit autocorrelation function, featuring multiple temporal scales, and the population autocorrelation function.

15 min. break

DY 3.6 Mon 11:30 H18

Modeling flash sintering conditions with Boltzmann equations — •Magdulin Dwedari, Lothar Brendel, and Dietrich Wolf — University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg

In a flash sintering experiment, a suitable combination of electric field and furnace heating is applied to the sample, which makes it possible to sinter it in a matter of seconds and at significantly lower temperatures compared to conventional sintering. An established hypothesis that explains the key signatures of a flash sintering event, such as a surge in conductivity, is that the electric field causes a rapid generation of Frenkel defects in the sample. With molecular dynamic simulations it has been confirmed that a phonon proliferation at the Brioullin-Zone edge can cause a Frenkel defect concentration 10^{15} times higher than the thermal concentration.
To study the effects of an electric field on the phonon distribution, we model the electron system governed by an electric field and the phonon system coupled to an external heat bath with two coupled Boltzmann equations. The key difference to previous work exciting the electron

system via a laser pulse is that our excitation term models the effects of the electric field and is therefore continuous and imposes a cylindrical symmetry.

DY 3.7 Mon 11:45 H18

Barrier crossing in a viscoelastic bath — •Félix Ginot[1], Juliana Caspers[2], Matthias Krüger[2], and Clemens Bechinger[1] — [1]Fachbereich Physiks Universität Konstanz, 78457 Konstanz, Germany — [2]Georg-August Universität Göttingen, 37073 Göttingen, Germany

The activated, i.e., fluctuation-assisted hopping of a Brownian particle across an energy barrier ΔU is a fundamental process with important applications across science, such as in chemical reactions, protein folding, or drug absorption. Such processes can be rationalized using Kramers theory, which predicts the hopping rate $\nu \propto \exp(-\Delta U/k_B T)$ with $k_B T$ the thermal energy, in agreement with experimental observations. Many systems, however, cannot be described in terms of a single degree of freedom, notably when memory effects need to be taken into account. In this work we experimentally investigate barrier crossing of a Brownian particle in a double-well potential suspended in a viscoelastic solvent which exhibits non-Markovian behavior, i.e., memory. For potential barriers up to several $k_B T$ we find the hopping dynamics to be characterized not by a single but by *two* time scales which can differ by more than two orders of magnitude. While the long time scale increases exponentially with ΔU (as in Kramers theory), the short one is almost unaffected by the barrier height. The latter results from elastic energy fluctuations of the viscoelastic bath due to excitations arising from the particle's hopping motion. Our results, which are in agreement with a simple model where the fluid is described as a Maxwell medium, have immediate consequences for the above examples, e.g., altering the interpretation and prediction of lifetimes.

DY 3.8 Mon 12:00 H18

Scalar Active Mixtures: The Nonreciprocal Cahn-Hilliard Model — •Suropriya Saha[1], Jaime Agudo-Canalejo[1], and Ramin Golestanian[1,2] — [1]Department of Living Matter Physics, Max Planck Institute for Dynamics and Self-Organization — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford

Pair interactions between active particles need not follow Newton's third law. In this work, we propose a continuum model of pattern formation due to nonreciprocal interaction between multiple species of scalar active matter. The classical Cahn-Hilliard model is minimally modified by supplementing the equilibrium Ginzburg-Landau dynamics with particle-number-conserving currents, which cannot be derived from a free energy, reflecting the microscopic departure from action-reaction symmetry. The strength of the asymmetry in the interaction determines whether the steady state exhibits a macroscopic phase separation or a traveling density wave displaying global polar order. The latter structure, which is equivalent to an active self- propelled smectic phase, coarsens via annihilation of defects, whereas the former structure undergoes Ostwald ripening. The emergence of traveling density waves, which is a clear signature of broken time- reversal symmetry in this active system, is a generic feature of any multicomponent mixture with microscopic nonreciprocal interactions.

DY 3.9 Mon 12:15 H18

Quantum thermodynamics of nonadiabatically driven systems: The effect of electron-phonon interaction — •Jakob Bätge[1], Amikam Levy[3], Wenjie Dou[2], and Michael Thoss[1] — [1]Institute of Physics, University of Freiburg, Freiburg,Germany — [2]Department of Physics, School of Science, Westlake University, Hangzhou, China — [3]Department of Chemistry, Bar-Ilan University, Ramat-Gan, Israel

The development and optimization of quantum devices have increased the interest in dynamics and thermodynamics of systems on the scale of single atoms and molecules. In this contribution, we investigate the nonequilibrium quantum dynamics of a driven nanosystem with two different approaches. By comparing results from the numerically exact hierarchical equations of motion method [1] and a Markovian quantum master equation [2], we analyze non-Markovian effects in the system dynamics. Furthermore, we discuss nonadiabatic effects in thermodynamic quantities induced by electronic-vibrational coupling.

[1] J. Bätge *et al.*, Phys. Rev. B **103**, 235413 (2021)
[2] R. Dann *et al.*, Phys. Rev. A **98**, 052129 (2018)