TT 64: Coherent Quantum Dynamics (joint session DY, TT, organized by DY)

Time: Thursday 9:30–13:15 Location: ZEU 160

Invited Talk TT 64.1 Thu 9:30 ZEU 160

Equilibration and ensembles in coherent quantum systems — •Fabian Essler — Oxford University

I consider the relaxation after quantum quenches in isolated quantum systems. In the thermodynamic limit local relaxation towards a stationary state occurs. I first discuss the characterization of the stationary state for generic and integrable systems and how this relates to properties of finite energy density eigenstates. In generic systems the stationary state is locally thermal and has a volume-law entanglement entropy, while there is a considerably richer set of possibilities in integrable models. I then turn to the recently proposed "quantum disentangled liquid", in which thermalized and non-thermalized degrees of freedom are postulated to co-exist. I discuss the possible existence of such states in the half-filled Hubbard model with strong repulsive interactions.

TT 64.2 Thu 10:00 ZEU 160

Thermalization and light cones in a model with weak integrability breaking — Bruno Bertini[1,2], Fabian Essler[1], •Stefan Groha[1], and Neil Robinson[3] — [1]The Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford, OX1 3NP, United Kingdom — [2]SISSA and INFN, Sezione di Trieste, via Bonomea 265, I-34136, Trieste, Italy — [3]Condensed Matter Physics and Materials Science Division, Brookhaven National Laboratory, Upton, New York 11973, USA

We employ equation of motion techniques to study the non-equilibrium dynamics in a lattice model of weakly interacting spinless fermions. Our model provides a simple setting for analyzing the effects of weak integrability breaking perturbations on the time evolution after a quantum quench. For sufficiently weak integrability-breaking interactions we always observe prethermalization plateaux, where local observables relax to non-thermal values at intermediate time scales. At later times a crossover towards thermal behaviour sets in. We determine the associated time scale, which depends on the initial state, the band structure of the non-interacting theory, and the strength of the integrability breaking perturbation. Our method allows us to analyze in some detail the spreading of correlations and in particular the structure of the associated light cones in our model. We find that the interior and exterior of the light cone are separated by an intermediate region, the temporal width of which appears to scale with a universal power-law $t^{1/3}$.

TT 64.3 Thu 10:15 ZEU 160

Non-equilibrium interacting integrable models — •Jacopo De Nardis[1], Jean-Sébastien Caux[2], Enej Ilievski[2], Michael Brockmann[3], and Milosz Panfil[4] — [1]CNRS-Laboratoire de Physique Théorique de l'Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris Cedex, France — [2]Institute for Theoretical Physics, University of Amsterdam, Science Park 904,
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We review the recent progresses in computing the non-equilibrium steady states (often referred as Generalized Gibbs Ensemble states) of interacting integrable models, as the XXZ spin 1/2 chain and the Lieb-Liniger model for interacting bosons on a line. We show how the role of quasi-local charges is fundamental in order to capture the long time limit of the expectation values of simple local observables and how important information regarding the time evolution towards equilibrium can be extracted by such steady states and their thermodynamic quasi-particle excitations. Finally we show how the steady state can be directly computed via experimental observations with cold atoms in a shallow trap or in an optical lattice.

TT 64.4 Thu 10:30 ZEU 160

Quenching a Quantum Critical State by the Order Parameter: Dynamical Quantum Phase Transitions and Quantum Speed Limits — •Markus Heyl — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

Quantum critical states exhibit strong quantum fluctuations and are therefore highly susceptible to perturbations. In this work we study the dynamical stability against a sudden coupling to these strong fluctuations by quenching the order parameter of the underlying transition. We find that such a quench can generate superextensive energy fluctuations. This leads to a dynamical quantum phase transition with nonanalytic real-time behavior in the resulting decay of the initial state. At the corresponding critical time the dynamically-evolved state becomes orthogonal to the initial one yielding an unconventional quantum speed limit. An outlook is given on the implications onto potential restricted thermalization despite of nonintegrability.

TT 64.5 Thu 10:45 ZEU 160

Localization in a disorder-free model after a global quantum quench. — •Adam Smith[1], Johannes Knolle[1], Dmitry Kovrizhin[2], and Roderich Moessner[3] — [1]T.C.M. group, Cavendish Laboratory, JJ Thomson Ave, Cambridge CB3 0HE, United Kingdom — [2]Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, United Kingdom — [3]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

We consider an interacting, translation invariant one dimensional model in which we observe complete localisation in one of two fermionic subsystems. Its effective disorder is generated dynamically and can be rigorously identified through a set of conserved quantities. To corroborate the emergence of localization after a global quantum quench we show persistence of a density wave in the initial state, absence of domain-wall melting, and suppression of light-cone growth of correlations.

TT 64.6 Thu 11:00 ZEU 160

Transport in Out-of-Equilibrium XXZ Chains: Exact Pro les of Charges and Currents — •Bruno Bertini[1], Mario Collura[1,2], Jacopo De Nardis[3], and Maurizio Fagotti[3] — [1]SISSA and INFN, Trieste, Italy — [2]Oxford University, Oxford, United Kingdom — [3]École normale supérieure, Paris, France

We consider the non-equilibrium time evolution of piecewise homogeneous states in the XXZ spin-1/2 chain, a paradigmatic example of an interacting integrable model. The initial state can be thought as the result of joining chains with different global properties. Through dephasing, at late times the state becomes locally equivalent to a stationary state which explicitly depends on position and time. We propose a kinetic theory of elementary excitations and derive a continuity equation which fully characterizes the thermodynamics of the model. We restrict ourselves to the gapless phase and consider cases where the chains are prepared: 1) at different temperatures; 2) in the ground state of two different models; 3) in the "domain wall" state. We find excellent agreement (any discrepancy is within the numerical error) between theoretical predictions and numerical simulations of time evolution based on TEBD algorithms. As a corollary, we unveil an exact expression for the expectation values of the charge currents in a generic stationary state.

15 min. break

TT 64.7 Thu 11:30 ZEU 160

Unconventional quasienergy bands in tilted optical lattices — •Onno Renke Diermann — Institut für Physik, Carl von Ossietzky Universität Oldenburg

The existence of quasienergy bands in periodically driven lattices under the influence of an additional static force has first been predicted by J.Zak ["Finite Translations in Time and Energy", Phys. Rev. Lett **71**, 2624 (1993)]. Among other things, it was suggested that within a single-band approximation such bands may take the form of cosine bands "modulated with the Bessel function of the shaking amplitude". Considering the experimentally accessible example of ultracold atoms in deep shaken cosine lattices, we show by numerical calculations of the full quasienergy spectrum that the single-band approximation is not reliable, and the quasienergy bands in fact are broken by a multitude of multiphoton resonances. This means that particles prepared in such bands tend to heat up on short time scales, and dynamic localization will be hard to observe.

TT 64.8 Thu 11:45 ZEU 160

iDMRG Study of the Kitaev-Heisenberg Model — •Matthias Gohlke, Ruben Verresen, Frank Pollmann, and Roderich Moessner — MPI-PKS, Dresden, Germany

Quantum spin-liquids represent novel phases of matter that host emergent fractionalized excitations. The Kitaev-Heisenberg model is a two-dimensional model system in this context and relevant for recent experiments on putative quantum spin-liquid materials. We revisit the ground state phase diagram of the Kitaev-Heisenberg model using large scale infinite density-matrix renormalization group method of cylinders with up to twelve sites circumference. In particular, the cylindrical geometry allows to capture the gapless points and to extract its universal critical properties. Furthermore, we observe that the gapless excitations remain stable under perturbation with Heisenberg interaction.

TT 64.9 Thu 12:00 ZEU 160

Dynamics of the Kitaev-Heisenberg Model — •Ruben Verresen, Matthias Gohlke, Roderich Moessner, and Frank Pollmann — MPI for Physics of Complex Systems, Dresden, Germany

Quantum spin-liquids represent novel phases of matter that host emergent fractionalized excitations. The Kitaev-Heisenberg model is a two-dimensional model system in this context and relevant for recent experiments on putative quantum spin-liquid materials. We obtain the dynamical spin-structure factor for this model using a matrix-product state based method. This quantity can be compared to neutron scattering measurements and provides characteristic insights into the dynamics of the fractionalized excitations. We find significant broad high energy features beyond spin-wave theory even in the ordered phases when tuned near the spin-liquid regime. We then focus on the zig-zag phase of the Kitaev-Heisenberg model which is relevant for α-$RuCl_3$ and observe that the high energy part reveals features that were first seen in neutron scattering experiments, displaying proximate spin liquid physics. In particular we are led to the interpretation of the observed broad high energy features as the intersection of remnants of very diffuse spin-wave bands.

TT 64.10 Thu 12:15 ZEU 160

Probing density and spin correlations in two-dimensional Hubbard model with ultracold fermions — •Chun Fai Chan[1], Jan Henning Drewes[1], Marcell Gall[1], Nicola Wurz[1], Eugenio Cocchi[1,2], Luke Miller[1,2], Daniel Pertot[1], Ferdinand Brennecke[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Quantum gases of interacting fermionic atoms in optical lattices is a promising candidate to study strongly correlated quantum phases of the Hubbard model such as the Mott-insulator, spin-ordered phases, or in particular d-wave superconductivity. We experimentally realise the two-dimensional Hubbard model by loading a quantum degenerate Fermi gas of 40K atoms into a three-dimensional optical lattice geometry. High-resolution absorption imaging in combination with radiofrequency spectroscopy is applied to spatially resolve the atomic distribution in a single 2D layer. We investigate in local measurements of spatial correlations in both the density and spin sector as a function of filling, temperature and interaction strength. In the density sector, we compare the local density fluctuations and the global thermodynamic quantities, and in the spin sector, we observe the onset of non-local spin correlation, signalling the emergence of the anti-ferromagnetic phase.

TT 64.11 Thu 12:30 ZEU 160

Adiabatic Dynamics of the Excited States for the Lipkin-Meshkov-Glick Model — •Wassilij Kopylov and Tobias Brandes — Technische Universität Berlin, Institut für Theoretische Physik, Berlin, Deutschland

We theoretically investigate the impact of the excited state quantum phase transition (ESQPT) on the adiabatic dynamics for the Lipkin-Meshkov-Glick model. Using a time dependent protocol, we continuously change a model parameter and discuss then the scaling properties of the system especially close to the ESQPT. On top, we show that the mean-field dynamic with the time dependent protocol gives the correct expectation values in the thermodynamic limit even for the excited states.

1) W. H. Zurek, U. Dorner, and P. Zoller, PRL 95, 105701 (2005)
2) H. J Lipkin, N. Meshkov and A. Glick, Nucl. Phys. 62, 188 (1965)
3)T. Caneva, R. Fazio and G. E. Santoro, PRB 78, 104426 (2008)

TT 64.12 Thu 12:45 ZEU 160

Spectral functions of quantum impurity models in the long-time limit of the time-dependent numerical renormalization group approach — •Theo Costi and Hoa Nghiem — Peter Grünberg Institut (PGI-2) and Institute for Advanced Simulation IAS-3), Forschungszentrum Jülich, Jülich, Germany

We develop a new multiple-quench time dependent numerical renormalization group (TDNRG) approach to study the time-evolution of strongly correlated quantum impurities in response to quantum quenches, pulses and periodic driving fields with potential application to a number of fields, including cold atom systems, non-equilibrium transport in nanoscale devices, and the theory of pump-probe spectroscopies of correlated materials within the non-equilibrium dynamical mean field theory. While the single-quench TDNRG suffers from sizeable errors for spectral functions and thermodynamic observables in the long-time limit, we show that our new multiple-quench TDNRG approach systematically reduces these errors to negligible values. Precise results are presented for local observables of the Anderson model, both static (local occupation and double occupancy) and dynamic (spectral function), in the long-time limit. For finite times and periodic driving, we demostrate a significant improvement for the time evolution of the local occupation as compared to our previous approach [1].

[1] H. T. M. Nghiem, T. A. Costi, Phys. Rev. B90, 035129 (2014).

TT 64.13 Thu 13:00 ZEU 160

Energy exchange in driven open quantum systems at strong coupling — •Matteo Carrega[1], Paolo Solinas[2], Maura Sassetti[2,3], and Ulrich Weiss[4] — [1]Nest, Istituto Nanoscienze and Scuola Normale Superiore (CNR-Pisa) — [2]SPIN-CNR — [3]Università di Genova — [4]Universität Stuttgart

The time-dependent energy transfer in a driven quantum system strongly coupled to a heat bath is studied within an influence functional approach. Exact formal expressions for the statistics of energy dissipation into the different channels are derived. The general method is applied to the driven dissipative two-state system. It is shown that the energy flows obey a balance relation, and that, for strong coupling, the interaction may constitute the major dissipative channel. Results in analytic form are presented for the particular value K = 1/2 strong Ohmic dissipation. The energy flows show interesting behaviors including driving-induced coherences and quantum stochastic resonances. It is found that the general characteristics persists for K near 1/2.