QSOE13

Participant	Title	Abstract
Vincenzo Alba	Entanglement evolution after a geometric quench in quantum spin chains	We investigate the entanglement evolution in the anisotropic Heisenberg XXZ spin chain after a geometric quench. This consists in a sudden change in the geometry (size) of the system. At the non interacting point (vanishing anisotropy) the evolution of the entanglement entropy is studied analytically using free fermionic techniques. The von Neumann entropy grows logarithmically after the quench, similarly to the case of local quenches, although its time evolution is not described by the known conformal field theory result. We provide an analytic formula which reproduces the behavior of the entropy at short time scales. In the interacting case (non zero anisotropy) the entropy can be accurately obtained using time dependent DMRG. We discuss the consequences of interactions in the entanglement dynamics.
Felix Andraschko	Doublon and holon dynamics in the one-dimensional Bose-Hubbard model	We study the spreading of local impurities inserted into Bose-Hubbard chains in a prepared thermal or product state. By considering different interaction strengths, we draw a connection between the weakly interacting regime, in which the dynamics is compared to the predictions of Luttinger Liquid theory, and the large-U regime, in which the impurities can be well described by a model of free fermionic quasiparticles. Making use of the Lieb-Robinson bound, we are able to perform numerical simulations in the thermodynamic limit, using a light cone renormalization algorithm based on corner transfer matrices.
Enrico Arrigoni	Steady-State Nonequilibrium Dynamical Mean Field Theory: an auxiliary Lindblad Master Equation approach	We present a method to compute electronic steady state properties of strongly correlated quantum systems out of equilibrium within dynamical mean-field theory (DMFT). The DMFT solver is based on the exact solution of an auxiliary system consisting of a small number of bath sites coupled to the interacting impurity and to two Markovian reservoirs. The steady state Green's function of the auxiliary system is solved by exact diagonalisation of the corresponding many-body Lindblad equation. The approach can be regarded as the non-equilibrium extension of the exact-diagonalization based DMFT.
Ádám Bácsi	Quantum quench in Luttinger liquids with finite temperature initial state	We study the non-equilibrium dynamics of Luttinger liquids after a quantum quench, when the initial state is a finite temperature thermal equilibrium state. We start by determining the diagonal elements of the density matrix in the steady state, which do not show thermalization in general. The time evolution of fidelity, which measures the distance between the time evolved and initial states, is evaluated at finite temperatures using various generalizations of the zero temperature overlap. In the long time limit, the overlap between the time evolved and initial system decreases as the temperature rises. Within perturbation theory, the statistics of final total energy and work are numerically evaluated in the case of a sudden quench. We show that at low temperature the final energy distribution function is the convolution of the initial energy distribution and the zero temperature work statistics. In both statistics, temperature effects are more significant in small systems.
Karsten Balzer	Strongly correlated systems out of equilibrium. The dual fermion approach and dynamical mean-field theory with a Hamiltonian-based impurity solver	K. Balzer, Ch. Gramsch, M. Eckstein and M. Kollar Strongly correlated materials out of equilibrium attract more and more attention as they show interesting phase transitions [1,2] and represent novel candidates for high-Tc superconductivity [3]. In this contribution, we present two approaches which are well suited to describe strongly correlated systems far from equilibrium. In the first part, we focus on the method of dual fermions which follows the superperturbation idea [4] and, to zeroth order, is equivalent to cluster perturbation theory [5] which treats local correlations exactly. To higher orders, the method also accesses non-local correlations via vertex corrections which partially resum the linked cluster expansion [6,7]. In the second part, we present an exact mapping of the nonequilibrium dynamical mean-field theory action to a single-impurity Anderson model with time-dependent parameters [8]. Thereby, the time evolution of the parameters follow from Cholesky or eigenvalue decompositions of the Weiss field. In both approaches, the central quantities (Green and vertex functions) are computed using the Krylov method and a commutator-free exponential time-propagation scheme [9]. As applications, we study the time evolution of Hubbard model. Future directions concern the field-induced creation and destruction of charge ordered phases [10]. [1] J. Simon, W.S. Bakr, R. Ma, M.E. Tai, P.M. Preiss and M. Greiner, Nature 472, 307 (2011). [2] Ph. Werner, N. Tsuji and M. Eckstein, Phys. Rev. B 86, 205101 (2012). [3] D. Fausti, R. I. Tobey, N. Dean, S. Kaiser, A. Dienst, M. C. Hoffmann, S. Pyon, T. Takayama, H. Takagi and A. Cavalleri, Science 331, 6014 (2011). [4] C. Jung, A. Lieder, S. Brener, H. Hafermann, B. Baxevanis, A. Chudnovskiy, A.N. Rubtsov, M.I. Katsnelson and A.I. Lichtenstein, Ann. Phys. 524, 49 (2012). [5] M. Balzer and M. Potthoff, Phys. Rev. B 83, 195132 (2011). [6] W. Metzner, Phys. Rev. B 43, 8549 (1991). [7] K. Mikelsons, J.K. Freericks and H.R. Krishnamurthy, Phys. Rev. Lett 109, 260402 (2012). [8] Ch. Gramsch, K. Balzer, M. Eckstein, and M. Kollar, arXiv:1306.6315 (2013). [9] A. Alvermann and H. Fehske, J. Comput. Phys. 230, 5930 (2011). [10] S. Sachdev, K. Sengupta and S.M. Girvin, Phys. Rev. B 66, 075128 (2002).
Wouter Beugeling	Finite-size scaling study of the eigenstate thermalization hypothesis	In the field of nonequilibrium quantum dynamics, the issue of thermalization in isolated systems has been the topic of intense recent interest. The eigenstate thermalization hypothesis (ETH) has been proposed as a mechanism for the thermalization of nonintegrable systems. According to the ETH, the expectation values of typical physical observables in eigenstates vary smoothly as a function of the corresponding eigenenergies. For finite systems, the expectation values typically show fluctuations, the magnitude of which decreases with increasing system size. We present a quantitative study of the system-size dependence of these fluctuations. Our numerical results suggest that in the case where the ETH is satisfied, they should scale as the reciprocal square-root of the dimension of the Hilbert space. We have reproduced the results for three different model systems, and for several observables for each of those. We give heuristic arguments to provide a plausible explanation for the observed behaviour. We show that the minimal system size required for observing the power law depends on the vicinity of integrability, in line with the idea that integrability prevents thermalization.
Lars Bonnes	Driven Quantum Chains Out of Equilibrium: An MPS Study on Engineered Dissipation	Engineered dissipation provides a new route towards the preparation of non-trivial quantum states. The dissipator acts on the bonds of a one-dimensional chain and lifts antisymmetric combinations to the superfluid bath where they can relax to the system by emitting a Bogoliubov quasi-particle, i.e. the bosons are created in a symmetric fashion. This dissipation has the property that the unique dark state of the dissipator is the k=0 condensate. Incompatible Hamiltonian dynamics can lead to dynamical phase transitions as well as the proliferation of a supersolid phase, as it has been pointed out by Diehl et al. Here, we use a superoperator algorithm to study the time evolution of the full quantum master equation for a chain with open boundary conditions. Frustration of the kinetic term of the Hamiltonian as well as a finite Hilbert space cut-off already lead to heating and thus a disordered steady-state with exponential correlations. Furthermore, we benchmark the quantum trajectory approach for open quantum system against the superoperator scheme

for a Bose-Hubbard chain with dephasing.
We find important differences in the entanglement scaling of the trajectory ensemble and the operator entanglement for local and global dissipation that helps us to evaluate the performance of both methods.

Michael Brockmann

ESR spectrum of the spin-1/2 Heisenberg-Ising chain

We analyze the absorption of microwaves by the one-dimensional spin-1/2 Heisenberg-Ising magnet exposed to a static magnetic field. This model is most relevant for the description of the low-energy behavior of quasi one-dimensional anti-ferromagnetic materials, such as LiCuVO$_4$, which is dominated by many-body effects. Due to the anisotropic exchange between electrons the sharp absorption resonance, which would be expected for paramagnetic materials, is shifted and broadened. Due to the integrability of the model short-range correlation functions, and thus the resonance shift and the line width of the absorbed intensity, can be calculated exactly over the whole range of temperatures and for arbitrary magnetic fields.
Additionally, we performed numerical calculations of the full absorption profile which are supported by the exact data as well as exact two-spinon calculations in the massive regime.

Michael Buchhold

Spin and Photon Glasses in Open Quantum Systems

Recent studies of interacting atoms and photons in optical cavities have triggered the interest in open system realizations of the Dicke model of atomic qubits coupled to discrete photon cavity modes. In the framework of a non-equilibrium Keldysh path integral approach tailored to study open quantum systems, we analyze the open multi-mode Dicke model with variable atom-photon couplings and cavity photon loss. In spite of the dissipative nature of this model, we identify a spin glass phase as a possible steady state of the system. The glassy system shows low frequency thermalization and unusual spectral behavior of the atoms as well as a strong competition between relaxational and reversible dynamics close to the glass transition. As a main feature, the physical properties of the spin glass are completely mapped onto the photonic degrees of freedom, which, as we demonstrate, makes spin glass physics directly observable in cavity QED experiments.

Elena Canovi

Transport through two interacting resonant levels connected by a Fermi sea

We study transport at finite bias, i.e. beyond the linear regime, through two interacting resonant levels connected by a Fermi sea, by means of time-dependent density matrix renormalization group. We first consider methodological issues, like the protocol that leads to a current-currying state and the characterization of the steady state. At finite size both the current and the occupations of the interacting levels oscillate as a function of time. We determine the amplitude and period of such oscillations as a function of bias and extension of the Fermi sea. In particular, the occupations on the two dots oscillate with a relative phase which depends on the distance between the impurities and on the Fermi momentum of the Fermi sea, as expected for RKKY interactions. Also the approximant to the steady-state current displays oscillations as a function of the distance between the impurities. Such a behavior can be explained by resonances in the free case. We discuss finally the incidence of interaction on such a behavior.

Florian Cartarius

Structural and dynamical properties of quasi-1D dipolar crystals

We study the ground state of classical dipolar particles in quasi-1D geometries, which can be realized in highly anisotropic traps. Here, the dipolar interaction between the particles can be made repulsive by confining the particles on a plane in presence of an external field perpendicular to it. We study the equilibrium configurations which are obtained for decreasing values of the trap aspect ratio by means of a Basin-Hopping Monte Carlo method and of analytical calculations of the motional spectra, and determine the structural phase diagram.

Alexander Cherny

Theory of superfluidity and drag force in the one-dimensional Bose gas

The one-dimensional Bose gas is an unusual superfluid. In contrast to higher spatial dimensions, the existence of non-classical rotational inertia is not directly linked to the dissipationless motion of infinitesimal impurities. Recently, experimental tests with ultracold atoms have begun and quantitative predictions for the drag force experienced by moving obstacles have become available. This topical review discusses the drag force obtained from linear response theory in relation to Landau¢s criterion of superfluidity. Based upon improved analytical and numerical understanding of the dynamical structure factor, results for different obstacle potentials are obtained, including single impurities, optical lattices and random potentials generated from speckle patterns. The dynamical breakdown of superfluidity in random potentials is discussed in relation to Anderson localization and the predicted superfluid-insulator transition in these systems.

Chung-Hou Chung

Quantum criticality out of equilibrium in the pseudogap Kondo model

We theoretically investigate the non-equilibrium quantum phase transition in a generic setup: the pseudogap Kondo model where a quantum dot couples to two-left (L) and right (R)-voltage-biased fermionic leads with power-law density of states (DOS) with respect to their Fermi levels \mu_L/R, \rho_c,L(R) (\omega) \propto |\omega - \mu_L(R) |^r, and 0 < r < 1 [1]. In equilibrium (zero bias voltage) and for 0 < r < 1/2, with increasing Kondo correlations, in the presence of particle-hole symmetry this model exhibits a quantum phase transition from a unscreened local moment (LM) phase to the Kondo phase. Via a controlled frequency-dependent renormalization group (RG) approach, we compute analytically and numerically the non-equilibrium conductance, conduction electron T-matrix and local spin susceptibility at finite bias voltages near criticality. The current-induced decoherence shows distinct nonequilibrium scaling, leading to new universal non-equilibrium quantum critical behaviors in the above observables. Relevance of our results for the experiments is discussed.

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Mario Collura

Equilibration Of A Tonks-girardeau Gas Following A Trap Release

We study the non-equilibrium dynamics of a Tonks-Girardeau gas released from a parabolic trap to a circle. We present the exact analytic solution of the many body dynamics and prove that, for large times and in a properly defined thermodynamic limit, the reduced density matrix of any finite subsystem converges to a generalized Gibbs ensemble.

Adolfo del Campo

Shortcuts to adiabaticity in many particle systems

This talk is a "tapas selection", reviewing recent advances in the design of shortcuts to adiabaticity in many-body systems.
- Adiabatic invariants, and the inversion of dynamical scaling laws, will be applied to trapped ultracold gases [1-3]. In particular, a proposal will be discussed to drive controlled expansions in which quantum correlations are preserved, essentially realizing a quantum dynamical microscope [2,3].
- Controlling the dynamics through a quantum phase transition implies an additional challenge: to prevent the formation of excitations in spite of the critical slowing down in the neighborhood of the critical point. According to the Kibble-Zurek mechanism, in inhomogeneous systems with a spatially varying critical point, whenever the speed of the spatial front crossing the transition is lower than the sound velocity excitations can be completely suppressed [4,5].
Experimentally, this scenario has recently been demonstrated in ion Coulomb crystals [6].
- An alternative approach in quantum critical systems exploits recent advances in the simulation of coherent k-body interactions and transitionless quantum driving [7]. This method is ideally suited to access the ground state manifold in quantum simulators.
- We shall close introducing a generalized time-energy uncertainty relation which is applicable to both isolated and open quantum systems.
This relation constitutes a fundamental quantum speed limit for any dynamical process [8].

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Maurizio Fagotti

Quantum quenches in the XXZ spin-1/2 chain: stationary state properties

TBA

Uwe R. Fischer

runcated many-body dynamics of interacting

We introduce a scheme to describe the evolution of an interacting system of bosons,
for which the field operator expansion is truncated after a finite number of modes, in a rigorously controlled manner.

	bosons: A variational principle with error monitoring	Using McLachlan's principle of least error, we find a set of equations for the many-body state. As a particular benefit, and in distinction to previously proposed approaches, our approach allows for the dynamical increase of the number of orbitals during the temporal evolution. arXiv:1301.2199 [cond-mat.quant-gas] The additional orbitals, determined by the condition of least error of the truncated evolution relative to the exact one, are obtained from an initial trial state by a method we call steepest constrained descent.
Nick Fläschner	Collective spin dynamics in a high-spin Fermi sea	Collective behavior in interacting many-body systems is the origin of many fascinating phenomena. A striking example is magnetism, which arises from collective effects between many individual spins. For a fundamental understanding of these processes, quantum gas experiments can serve as ideal model systems. Here, we report on the first realization of collective spin-changing dynamics in a Fermi sea. At ultralow temperatures we demonstrate long-lived and large-amplitude spin oscillations, governed by Zeeman and interaction energy. Increasing the temperature we find a strongly enhanced damping of the oscillations, indicating that the stability of the observed macroscopic dynamics is preserved by Pauli blocking. We further map out various binary spin mixtures and characterize the underlying dynamical spin instabilities. Our results allow for a deeper understanding of the interplay between microscopic spin-interaction processes and the resulting macroscopic collective behavior of a fermionic many-body system.
Roberto Emilio Franco Peñaloza	Thermoelectric transport properties through an interacting quantum dot: Atomic Approach for the single impurity Anderson model	tba
Loic Freton	Out-of-equilibrium properties and non-linear effects for interacting quantum impurity systems in their strong coupling regime	We build an exact description of out-of-equilibrium xed points in quantum impurity systems, that is able to treat time-dependent forcing. We then show that exact analytical out-of-equilibrium results can be obtained in interacting quantum impurity systems in their strong coupling regime, provided they are integrable at equilibrium and they only allow for integer charge hopping at low energy. We apply this formalism to the interacting resonant level model.
Martin Ganahl	Quantum Bowling: Particle-hole transmutation in one-dimensional strongly interacting lattice models	We study the scattering of a soliton-like propagating particle with a wall of bound particles, in several strongly interacting one-dimensional lattice models with discrete degrees of freedom. We consider spin-polarized fermions (anisotropic Heisenberg spin chain), the fermionic Hubbard model, and the Bose Hubbard model, using precise numerical time dependent Density Matrix Renormalization Group techniques. We show that in all integrable models studied, there is no reflection. Instead, an incoming particle experiences particle-hole transmutation upon entry and exit of the wall, and travels inside the wall as a hole, analoguous to Klein tunneling, even though the dispersion is highly nonlinear and there is no external potential. {\em Two} particles are added to the wall on the incoming side and removed on the opposite side. For spin-polarized fermions a single transmitted particle thus shifts the wall by two lattice sites, in complete contrast to classical physics. For both Hubbard models, the wall shifts by one doubly occupied single site. In the nonintegrable models studied, the same process occurs in linear superposition with backscattering events. We demonstrate a corresponding fermionic quantum Newton's cradle and a metamaterial with "tachyonic" modes travelling faster than in an empty system. We present a possible atomic scale signal counter for spintronics. Our scenario should be realizable in future cold atom experiments.
Shreyoshi Ghosh	Non-equilibrium dynamics of Kondo cloud following quenches in resonant level model	We study the non-equilibrium dynamics of lattice realizations of the Resonant Level Model. In equilibrium, the conduction electrons form a screening cloud around the impurity site. This impurity screening cloud has been the subject of longstanding fascination, especially in the Kondo model, from which the resonant level model emerges in the Toulouse limit. We present results on the time evolution of the spatial structure of the impurity screening cloud, after quenches of system parameters.
Denis Golež	Ultrafast relaxation dynamics of a hole in anti-ferromagnetic spin background	We study a highly excited hole propagating in the antiferromagnetic background modeled by the \$t\$-\$J\$ Hamiltonian on a square lattice. We show that the relaxation consists of two distinct stages. The initial ultrafast stage with the relaxation time \$\tau\sim (\hbar/t_0)(J/t_0)^{-2/3}\$ (where \$t_0\$ is the hopping integral and \$J\$ is the exchange interaction) is based on generation of string states in the close proximity of the hole. This unusual scaling of \$\tau\$ is obtained by means of comparison of numerical results with a simplified \$t\$-\$J_z\$ model on a Bethe lattice. In the subsequent (much slower) stage local spin excitations are carried away by magnons. The relaxation time on the two--leg ladder system is an order of magnitude longer due to the lack of string excitations. This is further reinforcing the importance of string excitations for the ultrafast relaxation in the two-dimensional system.
Simone A. Hamerla	Relaxation of fermionic quantum systems after an interaction quench	One efficient way to take the system out of equilibrium are quenches, i.e., sudden changes in the intrinsic system parameters. We study fermionic Hubbard models after interaction quenches. In these quenches the interaction between the particles is suddenly turned on so that the build-up of correlations can be observed. As sensitive probe for the dynamics after the quench we calculate the momentum distribution. The method used is a semi-analytic approach based on the Heisenberg equations of motion[1]. In this work we focus on the prethermalization regime, i.e., short and intermediate times after the quench. The method allows us to address Hubbard models in 1D and 2D. Besides, the influence of various dopings on the relaxation can be studied[2]. We find surprising similarities between the 1D and the D= DMFT results for the case of large interactions. For large interactions the physics is governed by strong Rabi oscillations. The dynamics after the quench displays two regimes: the regime of weak interactions and the one with strong interactions where pronounced oscillations are found. The two regimes are separated by a dynamical transition. Furthermore, the 1D results can only partially be understood by bosonization[3]. Indeed we find a power law behavior after the quench but the exponents differ significantly from the value expected from equilibrium bosonization theory. [1] G.S. Uhrig Phys. Rev. A 80, 061602(R)(2009) [2] S.A. Hamerla and G.S. Uhrig Phys. Rev. B 87, 064304 (2013) [3] S.A. Hamerla and G.S. Uhrig arXiv:1207.2006
Sebastian Hild	Single site resolved spin physics	
Ingo Homrighausen	TBA	TBA
Bastian Hundt	Production of Degenerate Ytterbium-Gases for Experiments in Triangular/Honeycomb Optical Lattices	Quantum gases of alkaline-earth-like atoms, like Strontium or Ytterbium (Yb), provide exciting opportunities to study many-body physics in optical lattices, such as the Kondo lattice model, SU(N)-symmetric spin Hamiltonians, and novel means for creating artificial gauge fields. We present a new setup for the investigation of bosonic and fermionic Yb quantum gases in triangular and honeycomb optical lattices. It is the first apparatus to produce quantum gases of an alkaline-earth-like species using a 2D-/3D-MOT scheme. A 2D-MOT captures atoms of Yb and directly loads a 3D-MOT operating on the weak intercombination transition. Subsequently, the atoms are transferred into a crossed optical dipole trap, where they are evaporatively cooled to quantum degeneracy. We routinely produce pure BEC of 200.000 atoms of Yb-174 and degenerate Fermi gases with about 40.000 atoms of Yb-173. Furthermore, we report on our current efforts and first results on high-precision spectroscopy of Yb quantum gases in triangular and honeycomb optical lattices in the optical domain. An ultrastable, high-power laser system has been set up for spectroscopy on the ultranarrow clock transition and we will present first spectroscopic results. It serves as a versatile tool for sensing energy shifts, e.g., induced by atomic interactions, and selective addressing and manipulation of atoms in an optical lattice. This work is supported by the Deutsche Forschungsgemeinschaft within SFB 925 and GrK 1355, the FET-Open Scheme of the European Commission (iSense), and the Marie Curie Initial Training Network QTea.
Tatsuhiko Ikeda	The second law of pure state thermodynamics	The diagonal entropy has recently been proposed to describe the thermodynamic entropy in isolated quantum systems during operations [1]. For thermal ensembles such as canonical ensemble, it coincides with von Neumann's entropy, thus satisfies the properties required as the thermodynamic entropy. Moreover, unlike von Neumann's entropy, it varies every time we operate the system, which is consistent with experimental facts. In this poster, we consider an operation between two equilibrated states in an isolated quantum system. We show the second law of thermodynamics, which states that the diagonal entropy after the operation is greater than the one before it for a large system. We also show that, in a small system, the diagonal entropy after an operation involves a universal

constant, (gamma-1), where gamma is Euler's constant. We also verify the universal quantum correction by numerical calculations. We examine the quench dynamics of hard-core Bosons by exact diagonalization.

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Dante Kennes — **Oscillatory Dynamics and Non-Markovian Memory in Dissipative Quantum Systems**

The nonequilibrium dynamics of a small quantum system coupled to a dissipative environment is studied. We show that (i) the oscillatory dynamics close to a coherent-to-incoherent transition is significantly different from the one of the classical damped harmonic oscillator and that (ii) non-Markovian memory plays a prominent role in the time evolution after a quantum quench.

Marton Kormos — **Interaction quenches in the Lieb-Liniger model**

I present results on interaction quenches in the 1D Bose gas described by the integrable Lieb-Liniger model. After discussing the severe difficulties in defining a Generalized Gibbs Ensemble (GGE) in this system, I compute the predictions of the GGE using an integrable lattice regularisation of the model. I determine local correlation functions for sudden quenches from a non-interacting initial state and arbitrary final interactions, as well as non-local correlation functions for quenches to the fermionised Tonks-Girardeau point characterised by infinite repulsion. The GGE predictions show significant deviations from the predictions of the grand canonical ensemble.

[Based on a corrected and improved version of the preprint arXiv: 1204.3889.]

Carlo Krimphoff — **Modes of propagation in the one and two-dimensional Heisenberg model**

We investigate the time evolution of lines of overturned spins in the one and two-dimensional spin-1/2 Heisenberg model after a local quench of the magnetic field. In one dimension a rich sequence of bound states, which propagate ballistically at different velocities, has already been observed. We investigate here how this picture changes and enriches as we move from decoupled one-dimensional chains towards the two-dimensional plane.
As the spin-1/2 Heisenberg model is the strong coupling limit of the two-species Bose-Hubbard model at unit filling, our results will shed light on the expected dynamics of lines of mobile spin impurities in two-species bosonic atoms confined to a two-dimensional optical lattice.

Further contributors to this work: Masud Haque, Andreas M. Läuchli

Sven Krönke — **Simulating Non-Equilibrium Quantum Dynamics with the Multi-Layer Multi-Configuration Time-Dependent Hartree Method for Bosons**

We develop and apply the multi-layer multi-configuration time-dependent Hartree method for bosons (ML-MCTDHB), which represents a highly flexible tool for investigating the quantum many-body dynamics of ultra-cold bosonic multi-species systems out of equilibrium in arbitrary dimensions. Being an ab initio method for solving the time-dependent Schrödinger equation, ML-MCTDHB takes all correlations into account. The multi-layer feature of ML-MCTDHB allows for tailoring the wave function ansatz to system specific correlations. Both single- and multi-species applications of the ML-MCTDHB method will be presented.

Tim Langen — **Local emergence of thermal correlations in an isolated quantum many-body system**

Tim Langen, Remi Geiger, Maximilian Kuhnert, Bernhard Rauer, Joerg Schmiedmayer -
We experimentally demonstrate how thermal properties in an non-equilibrium quantum many-body system emerge locally, spread in space and time, and finally lead to the globally relaxed state. In our experiment, we quench a one-dimensional (1D) Bose gas by coherently splitting it into two parts. By monitoring the phase coherence between the two parts we observe that the thermal correlations of a prethermalized state emerge locally in their final form and propagate through the system in a light-cone-like evolution. Our results underline the close link between the propagation of correlations and relaxation processes in quantum many-body systems.

Achilleas Lazarides — **Periodic thermodynamics of isolated integrable quantum systems**

We show that the long-time steady-state behaviour of a periodically driven quantum system is well described by the maximum entropy approach first proposed by Jaynes and more recently applied to integrable quantum systems. This result implies that the notion of thermalization survives in this far from equilibrium situation.

Zala Lenari — **Ultrafast charge recombination in photoexcited Mott-Hubbard insulator**

Recent femtosecond pump-probe experiments on Mott-Hubbard insulators reveal charge recombination and thermalization, which is in picosecond range, much faster than in clean band-gap semiconductors although the excitation gaps in Mott-Hubbard insulators are larger. We present a calculation of the recombination rate of the excited holon-doublon pairs, based on the model relevant for undoped cuprates, which shows that such fast processes can be explained even quantitatively with the multi-magnon emission. The precondition is the existence of the Mott-Hubbard bound exciton of the s-type. We find that its decay is exponentially dependent on the Mott-Hubbard gap and on the magnon energy, with a small prefactor which can be traced back to strong correlations and consequently large exciton-magnon coupling. Time evolution of the charge relaxation and recombination, together with optical response will also be considered.

Z. Lenar\vi\v and P. Prelov\vek, arXiv:1211.3236 (2012)
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Tommaso Macri — **TBA**

TBA

Salvatore R. Manmana — **Can non-equilibrium dynamics be used to detect phase transitions?**

TBA

Mariya Medvedyeva — **Sudden quench in Kondo model: decay of correlations**

We consider a sudden quench in the Kondo model: attaching a magnetic impurity to the electron band. We work in the Toulouse limit which describes the strong coupling regime of the Kondo model and investigate the spatio-temporal correlation decay between the impurity spin and the conduction band electron spin. An infinitesimal magnetic field acting on the impurity spin triggers a magnetic response of the conduction band spin. The response is given by the antisymmetric correlation function which is therefore a directly measurable quantity. We confirm that it vanishes outside the light-cone, as expected from causality. On the other hand, a statistically determined quantity --- the symmetric correlation function between the conduction band electron and the impurity spin --- decays toward zero outside the light-cone, exponentially at non-zero temperature and as a power law at zero temperature. We suggest that the non-zero correlation function for the local quench outside the light-cone reveals the initial entanglement in the conduction band.

Michael Möckel — **Comparing new approaches for the real and imaginary time evolution of the Hubbard model**

Recent advances in the experimental realization and theoretical simulation of fermionic many-body systems have motivated new interest in the Hubbard model both under real and imaginary time evolution. The possibility to follow the dynamics of excited states in cold quantum gases loaded on optical lattices [1] allows to observe relaxation behavior of the Hubbard model under the influence of nonadiabatic parameter changes. On the other hand, initiator full configuration interaction quantum Monte Carlo (iFCIQMC) provides a promising new approach to an efficient sampling of the Hilbert space based on a mapping of imaginary time evolution onto a population dynamics in Slater determinant space [2]. Since characteristic features of the Hubbard model like time scale separation and long time transient behavior [3] become visible in both approaches I provide a comparison of related results. [1] I. Bloch, J. Dalibard, W. Zwerger, Rev. Mod. Phys. 80, 885-964 (2008) [2] G. H. Booth, A. Thom, A. Alavi, J. Chem. Phys. 131, 054106 (2009); D. Cleland, G. H. Booth, A. Alavi, J. Chem. Phys. 132, 041103 (2010 [3] M. Moeckel, S. Kehrein, Phys. Rev. Lett. 100, 175702 (2008)

Klaus Morawetz — **Nonlocal quantum kinetic theory**

A consistent kinetic equation of nonlocal and non-instantaneous character is derived which unifies the achievements of transport in dense gases with the quantum transport of dense Fermi systems. The numerical solution is not more expensive than solving the Boltzmann equation. In order to achieve this, large cancellations in the off-shell motion have been used which are buried usually in non-Markovian behaviors. The remaining effects are: (i) off-shell tails of the Wigner distribution, (ii) renormalization of scattering rates and (iii) of the single-particle energy, (iv) collision delay and (v) related non-local corrections to the scattering integral. The balance equations for the density, momentum and energy now include besides known quasiparticle parts additionally two-particle contributions exceeding the Landau theory. Different aplications are worked out: (also possible to present as additional poster)

As a first example, the non-local corrections from experimental scattering data have been implemented into numerical simulations of heavy ion reactions. The experimentally observed higher energy spectrum of nucleons in central collisions can be explained and the non-local corrections are shown to be responsible for the enhanced midrapidity distribution. Near a phase transition the correlations become important and lead to non-Hubblean anomalous expansion.

The collision delay results into the correlated density and consequently the number of quasiparticles is not conserved. In superconductors this leads to a shift of the chemical potential and the compensating electrostatic potential known as

Bernoulli potential. As a second application calculations are shown with strong gradients of the superconducting gap like vortices. An electrostatic dipole is found on the surface which resolves the long-standing disagreement between the theoretical predictions and the experimentally observed Bernoulli potential. A similar dipole appears between CuO$_2$ planes and CuO chains in YBaCuO which explains the charge transfer in the Abrikosov vortex lattice observed by NMR and NQR measurements.

Victor Mukherjee

Speeding up and slowing down the relaxation of a qubit by optimal control

Authors: Victor Mukherjee, Alberto Carlini, Andrea Mari, Tommaso Caneva, Simone Montangero, Tommaso Calarco, Rosario Fazio and Vittorio Giovannetti;

We consider a two-level quantum system prepared in an arbitrary initial state and relaxing to a steady state due to the action of a Markovian dissipative channel. We study how optimal control can be used for speeding up or slowing down the relaxation towards the fixed point of the dynamics. We analytically derive the optimal relaxation times for different quantum channels in the ideal ansatz of unconstrained quantum control (a magnetic field of infinite strength). We also analyze the situation in which the control Hamiltonian is bounded by a finite threshold. As byproducts of our analysis we find that: (i) if the qubit is initially in a thermal state hotter than the environmental bath, quantum control cannot speed up its natural cooling rate; (ii) if the qubit is initially in a thermal state colder than the bath, it can reach the fixed point of the dynamics in finite time if a strong control field is applied; (iii) in the presence of unconstrained quantum control it is possible to keep the evolved state indefinitely and arbitrarily close to special initial states which are far away from the fixed points of the dynamics.

Ref: arXiv:1307.7964

Tanay Nag

Scaling of decoherence factor coupled to one dimensional quantum systems

We study the dynamics of quantum many body system driven across quantum critical points and its connection to the decoherence of a qubit which is coupled to it. We show that the decoherence factor of the qubit satisfies the same scaling relation as that of the defect density in some cases. We illustrate this case using an integrable spin model as the environment to which the qubit is coupled; this study is also extended to the case of one dimensional hard-core boson model under an interesting quenching scheme known as the Rosen-Zener quenching.

Tomas Novotny

Strong quantum memory at resonant Fermi edges revealed by shot noise

Studies of non-equilibrium current fluctuations enable assessing correlations involved in quantum transport through nanoscale conductors. They provide additional information to the mean current on charge statistics and the presence of coherence, dissipation, disorder, or entanglement. Shot noise, being a temporal integral of the current autocorrelation function, reveals dynamical information. In particular, it detects presence of non-Markovian dynamics, i.e., memory, within open systems, which has been subject of many current theoretical studies. We report on low-temperature shot noise measurements of electronic transport through InAs quantum dots in the Fermi-edge singularity regime and show that it exhibits strong memory effects caused by quantum correlations between the dot and fermionic reservoirs. Our work, apart from addressing noise in archetypical strongly correlated system of prime interest, discloses generic quantum dynamical mechanism occurring at interacting resonant Fermi edges.

Martin Nuss

A variational cluster approach to strongly correlated quantum systems out of equilibrium

The theoretical understanding of the non-equilibrium behaviour of strongly correlated quantum many-body systems is a long standing challenge, which has become increasingly relevant with the progress made in the fields of molecular-and nano- electronics, spintronics, spectroscopy or quantum optics and simulation. We report on the development of non-equilibrium cluster perturbation theory, and its variational improvement, the non-equilibrium variational cluster approach for steady-state situations. The non-equilibrium extensions of the wellestablished cluster perturbation theory and the variational cluster approach are based on the Keldysh Green's function method which allows, in this case, accessing single particle dynamic quantities on the whole complex plane. These flexible and versatile techniques can in principle be applied to any fermionic / bosonic lattice Hamiltonian, including multi-band and multi-impurity systems. Within this framework it is possible to work in the thermodynamic limit and therefore exchange particles with a bath and/or dissipate energy. We present results for the steady-state of molecular / nano devices under bias including the effects of electron-electron interactions.

Manuel Obergfell

Broadband ultrafast probing of Electron distribution function in metals

The development of broadband timeresolved spectroscopy of the complex dielectric function gives access to the electron dynamics of many solid state materials. I will give an overview over the experimental technique and proceed with some recent results on the timeresolved electron distribution function in copper. Further I will compare these data with the Two Temperature Model.

Johannes Oberreuter

Entanglement propagation and thermalization in the quantum Kac ring.

When a quantum many body system interacts with the environment, it is believed to get irriversibly entangled and thermalize at least for time scales, which are comparable longer than the lifetime of the universe.The Kac-ring is a simple classical toy model, in which Boltzmann and anti-Boltzmann behaviour can be studied analytically. I present a quantum version of the Kac ring, in which entanglement between a
system and the environment is generated, but which shows recurrence on a time comparable with the size of the system rather than with the size of its Hilbert space.

Giuliano Orso

Phase Diagram of a Driven-Dissipative Bose-Hubbard model

In recent years, quantum fluids of light in nonlinear optical systems have attracted a lot of interest [1].
We present recent theoretical results on strongly correlated photons in arrays of nonlinear cavities, described by a driven-dissipative Bose-Hubbard model. We have determined the mean-eld phase diagram, studied the collective excitations and quantum correlations of the steady-state phases [2]. We have found that modulational instabilities can be triggered by purely imaginary excitation branches, which
have no equivalent in the equilibrium case.

[1] I. Carusotto and C. Ciuti, Rev. Mod. Phys. 85, 299 (2013),
[2] A. Le Boite, G. Orso, C. Ciuti, Phys. Rev. Lett. 110, 233601 (2013)

Arijeet Pal

Many-body localization

TBA

Milosz Panfil

Metastable Criticality and the super Tonks-Girardeau gas

We consider a 1D Bose gas with attractive interactions in a highly excited state containing no bound states. We show that in this so-called super Tonks-Girardeau gas, relaxation processes are suppressed, making the system metastable over long time scales. We compute dynamical correlation functions, revealing the structure of excitations, an enhancement of umklapp correlations and new branches due to intermediate bound states. These features give a clear signature of the super Tonks-Girardeau regime and can be used to experimentally identify it. We demonstrate that, despite its off-equilibrium nature, the system displays critical behavior: correlation functions are characterized by asymptotic power-law decay described by the Luttinger liquid framework.

David Papoular

Dipolar-Induced Resonance for Ultracold Bosons in a Quasi-1D Optical Lattice

We study the role of the dipolar interaction, correctly accounting for the Dipolar-Induced Resonance (DIR) [1], in a quasi-one-dimensional system of ultracold bosons [2]. We first show how the DIR affects the lowest-energy states of two particles in a harmonic trap. Then, we consider a deep optical lattice loaded with ultracold dipolar bosons. We describe this many-body system using an atom-dimer extended Bose-Hubbard model. We analyze the impact of the DIR on the phase diagram at T=0 by exact diagonalization of a small-sized system. In particular, the resonance strongly modifies the range of parameters for which a mass density wave should occur with respect to previous results [3].

[1] M. Marinescu, L. You. Phys. Rev. Lett. 81, 4596 (1998).
[2] F. Deuretzbacher et al. Phys. Rev. A 81, 063616 (2010).
[3] R. V. Pai, R. Pandit. Phys. Rev. B 71, 104508 (2005).

Sebastiano Peotta

Shock waves and population inversion in collisions of ultracold atomic clouds

Ultracold atomic gases represent an ideal toolbox to study quantum effects that are difficult to probe using other systems. Here, we use a time-dependent density matrix renormalization group approach to show that the collision of two interacting bosonic clouds in one dimension gives rise to shock waves with a concomitant local energy distribution typical of population inversion, i.e., an effective negative temperature. A classical hydrodynamic description compares well with the exact quantum dynamics only up to the gradient catastrophe time. Such a highly nonequilibrium local distribution, however, does not prevent the system from recovering its initial state after an oscillation period which is renormalized by the interaction. All these results can be tested experimentally.

Stefan Schütz

Semiclassical theory for laser-driven atoms in optical cavities

We theoretically study the formation of self-organized structures of atoms, whose dipolar transition is driven by a laser and also couples to the optical mode of a high-finesse cavity. Self-organization in the cavity field emerges due to the mechanical forces of the cavity photons on the atoms, whereby the cavity field is sustained by the photons scattered by the atoms from the laser and hence depends on the atomic position. We consider the semiclassical model in [1], which is used when the laser is well above the self-organization threshold, and identify the limits of validity. We then extend the theoretical description to a Fokker-Planck equation which is valid below threshold, when the intracavity photon number is low. In this regime we analyze the dynamics of cavity cooling, and determine the final temperatures and the cooling rates. Additionally, the first and second order correlation functions of the cavity field are investigated as a function of the pump intensity.

[1] P. Domokos et al., J.Phys. B: At. Mol. Opt. Phys. 34 187-198 (2001)
[2] J.K.Asbóth, P. Domokos, H. Ritsch, and A. Vukics, Phys. Rev. A 72, 053417 (2005)

Bruno Sciolla

Anomalous diffusion in the Bose-Hubbard model with dissipation

We study the effect of incoherent photon scattering in cold atoms bosonic lattice systems. Although these systems are well isolated from their environment, the scattering events are one of the main source of dissipation and cause a loss of coherence, leading to qualitatively new out of equilibrium phenomena.
We characterize the dynamics on times larger than the dissipative timescale, using adiabatic elimination. The interplay of strong dissipation and interactions results in a diffusion process in the Fock space, described by a classical Master equation.
We investigate the dynamics of the one dimensional Bose-Hubbard model using Monte-Carlo sampling. For short times there is a sub-diffusive regime, where density fluctuations grow in a non-Gaussian way due to the strong effect of interactions. We also study the late time relaxation to the asymptotic state and find a complex, glass-like behavior, which can be attributed to the role of rare high energy states.

Yulia Shchadilova

Quantum quenches and work distributions in ultra-low-density systems

We present results on quantum quenches in systems with a fixed number of particles in a large region. We show that the typical differences between local and global quenches present in systems with regular thermodynamic limit are lacking in this low-density limit. In particular, we show that in this limit local quenches may not lead to equilibration to the new ground state, and that global quenches can have power-law work distributions ("edge singularities") typically associated with local quenches for finite-density systems. We also show that this regime allows for large edge singularity exponents beyond that allowed by the constraints of the usual thermodynamic limit. This large-exponent singularity has observable consequences in the time evolution, leading to a distinct intermediate power-law regime in time. We demonstrate these results first using local quantum quenches in a low-density Kondo-like system, and additionally through global and local quenches in Bose-Hubbard, Aubry-Andre, and hard-core boson systems in the low-density regime.

Lukas Sieberer

Non-equilibrium Functional Renormalization for Driven Open Many-Body Quantum Systems

We study phase transitions in bosonic driven-dissipative systems with competing dissipative and unitary dynamics, describing a natural long-wavelength model for pumped quantum systems such as exciton-polariton condensates or cold atomic systems with optical Feshbach resonances. In three spatial dimensions, these systems thermalize at low frequencies and exhibit universal critical behavior governed by an interacting Wilson-Fisher fixed point. We identify a new and independent non-equilibrium critical exponent, measuring the fade-out of the microscopic competition of unitary and dissipative dynamics.

The starting point of our analysis is a description of the driven-dissipative dynamics by a Markovian many-body master equation which we map to a Keldysh functional integral partition function. The Keldysh technique provides an excellent framework to put into practice a functional renormalization group approach for the study of criticality in non-equilibrium stationary states.

Pietro Smacchia

Universal aspects of quantum quenches through the statistics of the work

The paradigmatic out-of equilibrium process is a quantum quench, i.e a sudden change in time of a control parameter in the Hamiltonian. But how much does the physics change if vary this parameter in an arbitrary, generic way?
This issue is relevant both for fundamental and practical reasons. First, it is natural to ask what are the features of the dynamics of quantum many-body systems that are independent from the choice of the specific protocol, and possibly also universal in the usual sense of statistical mechanics. Second, such generic protocols are relevant for quantum information and quantum optimization problems.
In this talk I will discuss the characterization of these generic protocols through the statistics of the work. I will consider both local and global protocols in the Ising model and in systems of Bosons with quadratic Hamiltonians. After describing the complete characterization of the statistics of the work in these models, I will show that the low energy part of the work distribution displays an edge singularity that is independent and universal in all the cases considered.

Spyros Sotiriadis

Quantum Quench of the trap frequency in the harmonic Calogero model

We consider a quantum quench of the trap frequency in a system of bosons interacting through an inverse-square potential and confined in a harmonic trap (the harmonic Calogero model). We determine exactly the initial state in terms of the post-quench eigenstates and derive the time evolution of the local boson density and its moments. Since this model possesses an infinite set of integrals of motion (IoM) that allow its exact solution, a generalised Gibbs ensemble (GGE), i.e. a statistical ensemble that takes into account the conservation of all IoM, can be proposed in order to describe the values of local physical observables long after the quench. Even though, due to the presence of the trap, physical observables do not exhibit equilibration but periodic evolution, such a GGE may still describe correctly their time averaged values. We check this analytically for the boson density and find that the GGE conjecture is indeed valid in the thermodynamic limit. (Ref. arXiv:1307.7697)

Shintaro Takayoshi

Many-body Floquet theory of laser-induced phase transition in quantum spin chains

Phase transitions in quantum many body systems induced by strong laser, such as photo-induced Mott transition and photo-induced topological phase transition, are being intensively studied. On the other hand, studies on direct coherent spin manipulation in quantum spin systems are still lacking. In this presentation, we demonstrate that, in antiferromagnetic systems, net magnetization can be induced by the magnetic component of circularly polarized laser [1]. The laser frequency is estimated to be in the THz region.
In particular, we consider the S=1 antiferromagnetic Heisenberg chain with a single ion anisotropy, which has a topologically nontrivial ground state, namely the Haldane state. This model describes the properties of organic materials such as Ni(C$_2$H$_8$N$_2$)$_2$NO$_2$ClO$_4$ (NENP) and Ni(C$_5$H$_$N$_2$)$_2$N$_3$(PF$_6$) (NDMAP). We calculate the dynamics of the Haldane chain by using the infinite time-evolving block decimation (iTEBD) method. Starting from the initial state with no magnetization, we show that the application of rotating field in the xy-plane provokes magnetization along the z-axis. In contrast to previously realized optical spin manipulation [2], this is a quantum coherent effect. To clarify the mechanism, we also make an analysis by the many-body Floquet theory. By calculating the string order parameter, we show that the emergence of magnetization indicates a laser-induced phase transition from the Haldane state.

[1] S. Takayoshi, H. Aoki, and T. Oka, arXiv:1302.4460.
[2] A. Kirilyuk, A. V. Kimel, and Theo Rasing, Rev. Mod. Phys. 82, 2731 (2010).

Wladimir Tschischik

Breathing mode in Bose-Hubbard chain with a harmonic trapping potential.

Bosons in the continuum and bosons in optical lattices are both well-studied systems. We investigate the breathing mode of harmonically trapped bosons in the Bose-Hubbard (lattice) model at low fillings, seeking to connect to known results from Gross-Pitaevskii theory for continuum bosons. In 1D systems where there is no true Bose condensation, comparison with Bose-Hubbard dynamics is a particularly stringent test of the Gross-Pitaevskii description, which assumes a condensate. Using several numerical methods, we demonstrate that there is an intermediate interaction regime, between a "free-boson" limit and a "free-fermion" limit, in which the Bose-Hubbard breathing mode frequency approaches the Gross-Pitaevskii prediction.

Oleksandr Tsyplyatyev

Luttinger parameters of interacting fermions in 1D beyond the low energy limit

Interactions between electrons in one-dimension are fully described at low energies by only a few parameters of the Tomonaga-Luttinger model which is based on linearisation of the spectrum. We consider a model of spinless fermions with a short range interaction via the Bethe-Ansatz technique and show that a Luttinger parameter emerges in an observable beyond the low energy limit. A distinct feature of the spectral function, the edge that marks the lowest possible excitation energy for a given momentum, is parabolic for arbitrary momenta and the prefactor is a function of the Luttinger parameter, K.

Romain Vasseur

Crossover physics in the non-equilibrium dynamics of quenched quantum impurity systems

A general framework is proposed to tackle analytically local quantum quenches in integrable impurity systems, combining a mapping onto a boundary problem with the form factor approach to boundary-condition-changing operators introduced in Phys. Rev. Lett. 80, 4370 (1998). We discuss how to compute exactly two central quantities of interest: the Loschmidt echo and the distribution of the work done during the quantum quench. Our results display an interesting crossover physics characterized by the energy scale T_b of the impurity corresponding to the Kondo temperature. We discuss in detail the non-interacting case as a paradigm and benchmark for more complicated integrable impurity models, and check our results using numerical methods.

Artem Volosniev

Spin-flip in trapped few-fermion systems at fermionization.

Recent advances in cooling and
trapping ultracold atomic gases
in quasi one-dimensional setups give us a versa-
tile setup to test and develop our
understanding of Nature.
Some remarkable results as the Tonks-Girardeau gas
or "quantum Newton's cradle" were already obtained
in the lab. We study strongly-interacting
fermions with two
hyperfine spin states in one dimension.
Specifically we consider fermionic particles

		interacting in an external potential for infinite repulsion between the particles. We describe time evolution after a spin-flip of a single particle in a few-body setup using an analytical approach.
Eli Wilner	Multiple steady-states in nonequilibrium systems with electron-phonon interactions	The existence of more than one steady-state in a many-body quantum system driven out-of-equilibrium has been a matter of debate, both in the context of simple impurity models and in the case of inelastic tunneling channels. In this work, we combine a reduced density matrix formalism with the multilayer multiconfiguration time-dependent Hartree method to address this problem. This allows to obtain a converged numerical solution of the nonequilibrium dynamics. Considering a generic model for quantum transport through a quantum dot with electron-phonon interaction, we prove that a unique steady-state exists regardless of the initial electronic preparation of the quantum dot consistent with the converged numerical results. However, a bistability can be observed for different initial phonon preparations. The effects of the phonon frequency and strength of the electron-phonon couplings on the onequillbrium dynamics and on the emergence of bistability is discussed.