TT 48: Poster Session: Many Body Systems, Quantum Critical Phenomena

Time: Wednesday 15:00–19:00 Location: P2/4OG

TT 48.1 Wed 15:00 P2/4OG

Low temperature magnetoresistance and Hall effect measurements of $YbNi_4P_2$ — •William Broad[1], Sven Friedemann[1], Kristin Kliemt[2], and Cornelius Krellner[2] — [1]HH Wills Laboratory, University of Bristol, UK — [2]Physikalisches Institut, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

$YbNi_4P_2$ is a heavy-fermion Kondo-lattice metal with a very low ferromagnetic ordering temperature of 0.17 K. The transition temperature can be suppressed by partial substitution of As on the P site, leading to a quantum critical point (QCP). The rarity of such a QCP makes $YbNi_4P_2$ an important material to study for the understanding of ferromagnetic quantum criticality. Magnetoresistance and Hall effect data on $YbNi_4P_2$ are presented from low temperature dilution refrigeration measurements between 35 mK and 1 K. We have observed several Lifshitz transitions with a new orientation of the magnetic field in the *ab* plane, and discuss the anomalous Hall effect in the ferromagnetic state.

TT 48.2 Wed 15:00 P2/4OG

A.C. susceptibility investigations near quantum critical points on strongly correlated spin systems — •Paul Eibisch, Lars Postulka, Bernd Wolf, Ulrich Tutsch, Yeekin Tsui, Franz Ritter, Cornelius Krellner, and Michael Lang — Physikalisches Institut Goethe-Universität

Quantum phase transitions (QPT), i.e., phase transitions at $T = 0$ driven by the variation of a control parameter such as the magnetic field B, continue to be of high interest in condensed matter research. Above the quantum critical point (QCP) the system shows quantum critical behaviour which manifests itself in scaling behaviour of thermodynamic quantities and divergences in certain ratios of these quantities, the so-called Grüneisen parameters. In addition to signatures in these equilibrium properties, quantum criticality is expected to affect also the dynamic properties via a critical slowing down, i.e., the divergence of the correlation time at the QPT. Here we present a study of the a.c. susceptibility, including both the real- and imaginary-contributions, on the low-dimensional quantum spin systems $CuSO_4$ and Cs_2CuCl_4 both of which show B-induced quantum critical points in the field range $B \leq 10\,\mathrm{T}$. At the critical fields for $T < 1\,\mathrm{K}$ we find clear signals in the imaginary part, χ'' of the a.c. susceptibility, yielding a pronounced maximum at finite temperature. The position of these anomalies in the B-T-phase diagram suggests a quantum critical nature, i.e., changes in the spin dynamics on approaching the QCP.

TT 48.3 Wed 15:00 P2/4OG

Thermodynamic studies of field-induced quantum critical behaviour in the organic spin-dimer system $C_{28}H_{32}N_4O_2$ (BY310) — •Christian Thurn[1], Paul Eibisch[1], Lars Postulka[1], Ulrich Tutsch[1], Bernd Wolf[1], Yulia Borozdina[2,3], Martin Baumgarten[2], and Michael Lang[1] — [1]PI, Goethe Uni, Frankfurt/M., SFB/TR49, Deutschland — [2]MPI für Polymerforschung, Mainz, SFB/TR49, Deutschland — [3]MPI für biologische Kybernetik, Tübingen, Deutschland

Systems of interacting spin dimers provide suitable model systems for studying critical phenomena under well-controlled conditions. Prominent examples include the Bose-Einstein-condensation of triplons in 3D systems [1] or the Berezinskii-Kosterlitz-Thoules scenario in a 2D system [2]. Within this class of materials, spin-dimer systems based on organic radicals stand out due to the high degree of tunability with regard to both the interaction strength as well as the dimensionality. In this work we focus on the tolane-bridged imino-nitroxide radical $C_{28}H_{32}N_4O_2$ (BY310) [3]. In BY310 we find quantum-critical points at around 1.8 T and 4.3 T delimiting a B-induced ordered phase for $T \leq 0.5\,\mathrm{K}$. We present results of thermal expansion α as well as magnetostriction λ measurements in the field range up to 5.5 T and for temperatures from 1.7 K down to 50 mK. The results are compared with results of the specific heat, the magnetocaloric effect and the ac-susceptibility.

[1] Giamarchi *et al.*, Nat. Phys. **4**, No 2, 198-204 (2008)
[2] Tutsch *et al.*, Nat. Commun. **5**, 5169 (2014)
[3] Borozdina *et al.*, J. Mater .Chem **5**, 9053-9065 (2017)

TT 48.4 Wed 15:00 P2/4OG

Quantitative analysis of the energy constant's effect on the performance of directed loop quantum Monte Carlo Algorithm — •Dong-Xu Liu and Xue-Feng Zhang — Department of Physics, Chongqing University, Chongqing, 401331, China

The efficiency and performance of the stochastic series expansion (SSE) with directed loop quantum Monte Carlo algorithm is not only related to the specific Hamiltonian, but also the implementation of the algorithm. As one tunable parameter of SSE, the shifted constant of the energy is demonstrated to affect the autocorrelation time and also the performance of the algorithm. In order to quantitatively analyze the effect of the energy constant, we defined the cost-function as $\tau_{int} \times T_{\mathrm{CPU}}$, where τ_{int} is auto-correction time and T_{CPU} is the CPU time costed by loop-updating process. The CPU time T_{CPU} has a good linear relationship with energy constant, because it will linearly increase the length of imaginary time. However, we discovered that auto-correction time shows a power-law decay and exponential decay behaviour with energy constant increased in one-dimensional spin-$\frac{1}{2}$ XY model and Heisenberg model, respectively. Then, we turn to analyze the effect of energy constant on the average length of loops. We demonstrated the average loop length is linearly related to the energy constant, however not proportional to the total energy. Finally, we discussed how to improve performance and also the accuracy of the correlation function by adjusting the energy constant.

TT 48.5 Wed 15:00 P2/4OG

Hierarchy of energy scales in an antiferromagnetic quantum critical metal: a Monte Carlo study — •Carsten Bauer[1], Yoni Schattner[2], Simon Trebst[1], and Erez Berg[3] — [1]University of Cologne, Germany — [2]Stanford University, USA — [3]The Weizmann Institute of Science, Israel

While quantum critical phenomena in insulators are fairly well understood, their metallic counterparts pose a substantial theoretical challenge since the order parameter fluctuations can interact with gapless excitations on a Fermi surface. When driving a metal through a phase transition, this interplay can lead to a damping of the critical modes and can give rise to unconventional superconductivity, and "strange metal" behavior. It might therefore serve as a microscopic model for some of the rich physics of high-T_c materials.

Fortunately, certain classes of metallic quantum critical points can be analyzed by determinant quantum Monte Carlo as one can circumvent the notorious "sign problem" and retain polynomial efficiency. I will show numerically exact studies of two dimensional metals at the verge of an antiferromagnetic transition indicating Landau-damping of the order parameter fluctuations and a breakdown of Fermi liquid theory. I will further discuss the case of an (almost) locally nested Fermi surface, where T_c is strongly suppressed. Lastly, I will demonstrate that a machine learning technique dubbed "quantum loop topography" can be utilized to probe transport and identify the superconductivity transition in such a many-particle system.

TT 48.6 Wed 15:00 P2/4OG

Transport and Localization Phenomena in One-Dimensional Open Quantum Systems Simulated with Matrix Product States — •Manuel Katzer, Willy Knorr, Regina Finsterhoelzl, and Alexander Carmele — Institut fuer Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universitaet Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The discovery of disorder induced localization in the presence of interactions opened up a new field of research. We investigate the yet open question of phase transitions in transport and the conditions for the existence of many-body localization in different one dimensional open quantum systems in the presence of driving by an external bath. Here, we compare the model of a Heisenberg spin chain [1], where isotropic nearest-neighbor coupling shows negative differential conductivity and a transition from diffusive to subdiffusive transport with a chain of harmonic oscillators [2]. When these bosonic oscillators interact with a Kerr nonlinearity, higher-order excitations are suppressed and thus state-filling effects start to dominate. For large nonlinearities, this eventually results in a transport behaviour quite similar to the spin chain. In order to simulate larger chain lengths, the systems are simulated in a MPS approach [3] or via QMC in order to investigate the role of finite size effects and to get closer to a possible regime for many

body localization effects.
[1] Droenner and Carmele, Phys. Rev. B **96**, 184421 (2017)
[2] Huber and Rabl, Phys. Rev. A **100**, 012129 (2019)
[3] Prosen, Phys. Rev. Lett. **106**, 217206 (2011)

TT 48.7 Wed 15:00 P2/4OG

Entanglement, spectra and Floquet engineering of topological many-body localized systems — •Kevin S.C. Decker[1], Dante Kennes[2,3], Jens Eisert[4], and Christoph Karrasch[1] — [1]Technische Universität Braunschweig, Institut für Mathematische Physik, Mendelssohnstraße 3, 38106 Braunschweig, Germany — [2]Institut für Theorie der Statistischen Physik, RWTH Aachen University and JARA-Fundamentals of Future Information Technology, 52056 Aachen, Germany — [3]Max Planck Institute for the Structure and Dynamics of Matter, Center for Free Electron Laser Science, 22761 Hamburg, Germany — [4]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

Many-body localized systems in which interactions and disorder come together defy the expectations of quantum statistical mechanics: They do not thermalize when undergoing non-equilibrium dynamics. In this work, we numerically address how topological features interplay with many-body localized phases as well as the nature of the transition between a topological and a trivial state within the latter. We also show how second-order Floquet engineering can be employed to realize systems in which many-body localization coexists with topological properties in a driven system. This allows one to implement and dynamically control a symmetry protected topologically ordered qubit even at high energies, overcoming the road block that the respective states cannot be prepared as ground states of nearest-neighbor Hamiltonians.

TT 48.8 Wed 15:00 P2/4OG

Interacting bosons in an optical cavity: fluctuation effects — •Alla Bezvershenko, Florian Lange, and Achim Rosch — University of Cologne, Germany

We consider a chain of interacting bosonic atoms coupled to the field of an optical cavity with imperfect mirrors. In such a non-equilibrium open quantum system, temperature in the usual sense is not defined. In the conventional, theoretical mean-field approach, only the mean-field contribution of the coupling between the cavity field and the bosonic degrees of freedom is considered. We argue, however, that fluctuations beyond mean field theory are essential to obtain the effective temperature and, therefore, also the correct value of the mean-field for the atomic subsystem. Our approach is valid in a regime where the thermalization rates of the atomic system are larger than the rates of energy transfer between atoms and light.

TT 48.9 Wed 15:00 P2/4OG

Combining dynamical quantum typicality and numerical linked cluster expansions — •Jonas Richter and Robin Steinigeweg — University of Osnabrück, Germany

We demonstrate that numerical linked cluster expansions (NLCE) yield a powerful approach to calculate time-dependent correlation functions for quantum many-body systems in one dimension. As a paradigmatic example, we study the dynamics of the spin current in the spin-1/2 XXZ chain for different values of anisotropy, as well as in the presence of an integrability-breaking next-nearest neighbor interaction. For short to intermediate time scales, we unveil that NLCE yields a convergence towards the thermodynamic limit already for small cluster sizes, which is much faster than in direct calculations of the autocorrelation function for systems with open or periodic boundary conditions. Most importantly, we show that the range of accessible cluster sizes in NLCE can be extended by evaluating the contributions of larger clusters by means of a pure-state approach based on the concept of dynamical quantum typicality (DQT). Even for moderate computational effort, this combination of DQT and NLCE provides a competitive alternative to existing state-of-the-art techniques, which may be applied in higher dimensions as well.

[1] J. Richter and R. Steinigeweg, Phys. Rev. B 99, 094419 (2019).

TT 48.10 Wed 15:00 P2/4OG

Non-equilibrium dynamics of photo-induced triplons — •Hossam Tohamy and Maria Daghofer — University Stuttgart, Institute for Functional Matter and Quantum Technologies, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We study the non-equilibrium dynamics of photo-induced triplons in periodically driven Mott insulators. Strong spin-orbit coupling in these systems favors a ($J = 0$) singlet ground state while magnetic superexchange favors ($J = 1$) triplet excited states. Triplons are excitations from singlet to triplet states.

We numerically simulate a pump-probe experiment for a 1D spin-orbital Hubbard model using the Lanczos exact diagonalization method. For certain laser pulse excitation frequencies and interaction parameters in the spin-orbital Hubbard model, we find that induced triplet states show antiferromagnetic (AFM) correlations. Both the strength of the triplet moment and the modulation of the AFM pattern depend on the laser excitation frequency, pulse width, and amplitude.

TT 48.11 Wed 15:00 P2/4OG

Irreversible real-time dynamics of quantum, classical and quantum-classical spin systems — •Leon Mixa and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

Macroscopic irreversibility of the time evolution of interacting many-body systems is a necessary condition for thermalisation. For classical systems, the corresponding loss of information on the initial state is due to non-linear dynamics with exponential sensitivity to small perturbations resulting in chaotic behaviour. A closed quantum system, on the other hand, is described by linear unitary dynamics. Recent ideas for quantum irreversibility conceptually build on the eigenstate-thermalisation-hypothesis and on specific measures such as out-of-time order correlators or observable echos, see e.g. [1].

Here, we consider a one-dimensional nonintegrable quantum-spin model, i.e., the Kondo necklace model with anisotropic (XY) local "Kondo" coupling to local quantum spins, and, in a first step, confirm the results of Ref. [1]. We then study the corresponding model with quantum spins replaced by classical spins and find thermalisation driven by classically chaotic motion. Our main goal is to classify the intermediate situation, namely the quantum-classical hybrid model where only the local spins are treated classically. We systematically study observable echos, Lyapunov exponents and other measures.
[1] M. Schmitt and S. Kehrein, Phys. Rev. B 98, 180301(R) (2018)

TT 48.12 Wed 15:00 P2/4OG

Fast Nonequilibrium Green Functions simulations with GW selfenergies — •Christopher Makait, Niclas Schlünzen, Jan-Philip Joost, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, CAU Kiel, Germany

The Nonequilibrium Green Functions (NEGF)[1] method is a powerful tool to compute time-dependent expectation values of single-particle observables in correlated quantum many-body systems. Its unfavorable N_t^3-scaling with propagation time N_t could be reduced to N_t^2 by introduction of the Generalized Kadanoff–Baym Ansatz (GKBA)[2]. Recently, an exact time-local (N_t^1) reformulation of the GKBA, the G1–G2 scheme [3,4], has been found for various self energies, which makes this method viable for long time simulations.
In a general basis the G1–G2 scheme has a computationally expensive scaling with basis size (N_b^5–N_b^6). For the uniform electron gas (UEG) however, we found an advantageous $N_b^3 N_t^1$ scaling for both second-order and GW selfenergies, which makes this scheme particularly interesting for this system. Here, we present first results of the application of the G1–G2 scheme to the UEG.
[1] L. P. Kadanoff, G. Baym, *Quantum Statistical Mechanics* (Benjamin, New York, 1962)
[2] P. Lipavský, V. Špička, B. Velický, *Phys. Rev. B*34, 6933 (1986)
[3] N. Schlünzen, Jan-Philip Joost, Michael Bonitz, *submitted*, arXiv:1909.11489 [cond-mat.str-el]
[4] M. Bonitz, *Quantum Kinetic Theory* (Springer, 2016)