TT 40: Dual-Method Approaches to Quantum Many-Body Systems II

To make an impact on possible applications, theoretical approaches for correlated many-body systems must allow for studying more realistic models and lead to more accurate predictions as compared to what is achievable nowadays. This requires, on the one hand, the development of specialized tools which are mathematically and/or algorithmically demanding. On the other hand, an emergent promising approach to make significant progress beyond toy-model understanding of many-body physics is the combined use of two or more complementary methods. The demand for such type of approaches is growing. The two session of contributed talks will provide an overview of recent successes in such dual-(multi-)method approaches involving analytical as well as numerical tools, and will indicate prospects for future directions.

Compilation: Volker Meden, RWTH Aachen; Stefan Wessel, RWTH Aachen

Time: Tuesday 10:00–13:00 Location: H 3010

TT 40.1 Tue 10:00 H 3010

A practical guide to training neural networks of quantum many body systems — •Thomas C. Lang, Jonas B. Rigo, and Andreas M. Läuchli — Institute for Theoretical Physics, University of Innsbruck, Austria

Encoding the representation of the electronic wave function of a minuscule fragment of a crystal is a nearly impossible task. learning promises to cut through the complexity and to allow for efficient encoding of a vastly complex system in a limited number of degrees of freedom by identifying the subtle, yet relevant signatures of phases of matter. We assess the efficiency and practical limits of the representational power of basic neural networks for the many body wave functions of quantum spin systems. We identify the types of wave functions, bases and network topologies, which are favorable and investigate what features the neural networks learn and how to exploit them in scaling up the network. Finally, we comment on the predictive power and entanglement properties of neural networks trained on small portions of the full phase space.

TT 40.2 Tue 10:15 H 3010

A simple tensor network algorithm for 2d steady states — •Roman Orus — Johannes Gutenberg-Universität, Mainz, Germany

Here we present a tensor network algorithm that approximates steady-states of 2d quantum lattice dissipative systems in the thermodynamic limit. The implementation of our method is remarkably simple and efficient. We prove the validity of the approach by computing the steady states of dissipative quantum Ising and XYZ models, relevant to address controversies in dissipative systems of interacting Rydberg atoms, and benchmark our simulations with a variational algorithm based on product and correlated states. Our results support the existence of a first order transition in the dissipative Ising model, while we find no evidence for a bistable region.

TT 40.3 Tue 10:30 H 3010

Non-Abelian Symmetries in Tensor Network Algorithms — •Philipp Schmoll[1,2] and Román Orús[1] — [1]Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

In recent years Tensor Networks (TNs) have emerged as a natural language to describe quantum states of matter by capturing the amount and local structure of entanglement in the system. They provide an efficient framework to study quantum many-body properties with many remarkable applications such as the Density Matrix Renormalization Group (DMRG) for 1d systems proposed by S. White. The Projected Entangled Pair State (PEPS) ansatz has proven to be a versatile tool for 2d systems with topological order, both chiral and non-chiral. However, at the current stage simulations in 2d are strongly limited due to the complexity of the systems. In this respect, a big step needs to be taken to have a versatile implementation of non-abelian symmetries (such as SU(2) or SU(3)) in 2d PEPS algorithms, which will allow to advance significantly in the study of many relevant systems (e.g., frustrated antiferromagnets, chiral topological spin liquids, ...). In this talk I will report on recent advances in this direction at our group in Mainz.

TT 40.4 Tue 10:45 H 3010

Entanglement properties of the Hubbard chain model — •Francesco Parisen Toldin and Fakher F. Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany

We study the entanglement properties for a bipartition of the one-dimensional Hubbard model. By means of a recently-developed Quantum Monte Carlo method which exploits the replica trick [1], we sample the spin correlations of the entanglement Hamiltonian, and compare our results with those for an open chain of the same size of the entanglement cut. We further introduce a dimerization of the hopping constants, which gives rise to a distinctive behavior in the correlations, depending whether the entanglement cut creates a topological or a trivial phase.

[1] F. F. Assaad, T. C. Lang, F. Parisen Toldin, Phys. Rev. B 89, 125121 (2014)

TT 40.5 Tue 11:00 H 3010

Microscopical justification of the eigenstate thermalization hypothesis (ETH) — •Nils O. Abeling and Stefan Kehrein — Institut für Theoretische Physik, Fakultät für Physik, Georg-August-Universität Göttingen

The ETH postulates how isolated quantum many-body systems thermalize. It is essential to the understanding of thermalization and implicates various thermodynamic relations [1]. While there are several numerical verifications of the ETH ([2]), only few analytical arguments have been found so far. They, in particular, are based on semiclassical approaches [3]. Another argument was given by J. Deutsch who showed how a small interaction which is modelled by a random matrix leads to thermalization [4]. Our work adopts this idea and analyzes whether and how a generic quantum system can be treated as a random matrix. To do this we employ the flow equation method that performs continuous unitary transformations to map an initial Hamiltonian to an effective Hamiltonian. The latter takes on a banded form and is compared to a random matrix. By studying the statistical properties of the numerically obtained matrices we are able to use the analytical flow equation approach to close the gap in Deutsch's reasoning. Our results depict the first step towards a microscopic justification of the eigenstate thermalization hypothesis.

[1] L. D'Alessio et al., Adv. in Phys. Vol. 65, Iss. 3 (2016)
[2] M. Rigol, V. Dunjko, and M. Olshanii, Nature 452 (2008)
[3] M. Srednicki, Phys. Rev. E 50 (1994)
[4] J.M. Deutsch, Phys. Rev. A 43 (1991)

TT 40.6 Tue 11:15 H 3010

Quantum dynamics from classical networks — •Markus Schmitt[1,2] and Markus Heyl[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany — [2]Institute for Theoretical Physics, Georg-August-Universität Göttingen, Germany

The efficient representation of quantum many-body states with classical resources is a key challenge in quantum many-body theory. In our work [1] we analytically construct classical networks for the description of the quantum dynamics in transverse-field Ising models that can be solved efficiently using Monte Carlo techniques. With this construction we compute transient dynamics of transverse-field Ising models in one, two, and three dimensions. We include a mapping to equivalent artificial neural networks and explore the utility of the obtained network structures for numerical time-evolution using a time-dependent variational principle.

[1] M. Schmitt and M. Heyl, arXiv:1707.06656

15 min. break.

TT 40.7 Tue 11:45 H 3010

Exact long time evolution of spinless fermion systems from a highly correlated initial state — •Kristof Harms, Lorenzo Cevolani, Stefan Kehrein, and Salvatore Manmana — Institut für Theoretische Physik, Universität Göttingen

Using time-dependent density matrix renormalization group (tDMRG), we analyze the time evolution of density-density correlations in one-dimensional spinless fermion systems after a global quench of the Hamiltonian. In particular, quenches to free fermion systems are considered. In this case, the time evolution can in fact be obtained exactly up to arbitrary times when providing the four-point propagators of the initial state, which are computed via DMRG at high accuracy. Taking this approach, we are able to both study the dynamics directly after the quench, as well as the long-time behavior. We obtain a ballistic lightcone structure and study the region outside in detail. For gapless initial states, we observe temporal oscillation outside the lightcone which we relate to the initial state and the dispersion relation of the quenched Hamiltonian.

Financial support by DFG CRC1073 (project B03) is gratefully acknowledged.

TT 40.8 Tue 12:00 H 3010

Geometry of driven-dissipative phase transitions — •Mikhail Pletyukhov[1], Dmitry Krimer[2], and Maarten Wegewijs[1,3] — [1]Institute for Theory of Statistical Physics, RWTH Aachen University, Germany — [2]Institute for Theoretical Physics, TU Wien, Austria — [3]Peter Grünberg Institute, Forschungszentrum Jülich, Germany

Recent progress in the study of driven dissipative phase transitions in open quantum systems has raised the question how hysteretic phenomena in many-body systems can be appropriately understood on a quantum level, going beyond the common semiclassical mean-field description. In this talk we explain how hysteresis generically arises when accounting for a typical measurement time. We directly tie this to the eigenmodes of a nonunitary Lindblad dynamics of which a metastable state is composed. The metastable state attained on this given measurement timescale depends on the whole experimental procedure (a sequence of all preceding runs). This dependence must be accounted for at every subsequent experimental run. We show that different branches in the parametric dependence of observables then emerge naturally from the linear quantum master equation. Interestingly, these metastable states can be understood in terms of their path-dependent amplitudes in the Liouvillian-eigenmode expansion. Such amplitudes are familiar from pumping problems in quantum transport that can be related to geometric "phases" of the Landsberg type.

TT 40.9 Tue 12:15 H 3010

Driven-dissipative phase transitions of open quantum systems from a Floquet-Liouville perspective — •Viktor Reimer[1], Mikhail Pletyukhov[1], and Vladimir Gritsev[2] — [1]Institute for Theory of Statistical Physics, RWTH Aachen University, Germany — [2]Institute for Theoretical Physics, University of Amsterdam, Netherlands

The study of driven-dissipative open quantum systems prompted the emergence of a plethora of interesting new physics inaccessible to their equilibrium counterparts. Combining Floquet's theorem with the general Liouvillian approach to open quantum systems provides powerful tools to investigate such systems beyond the adiabatic limit.

Here, we present a general method to calculate the quasistationary state of a driven-dissipative system coupled to a transmission line with arbitrary coherent driving strength and modulation frequency of system parameters. Our first application of the method is the two level system with time-dependent parameters and we explore the regime where the breakdown of the adiabaticity condition happens even for a slow time modulation. Secondly, we apply our method to a driven three level Λ-system exhibiting electromagnetically induced transparency (EIT) and observe how the time modulation modifies the latter phenomenon.

Our focus however lies on the third application – the single-mode Kerr nonlinearity model – where driving is considered across the bistability point of the dissipative phase transition. In this talk I discuss the behaviour of observables in the quasistationary time regime and the critical regime of parameters.

TT 40.10 Tue 12:30 H 3010

Finding purifications with minimal entanglement — •Johannes Hauschild[1], Eyal Leviatan[2], Jens H. Bardarson[3], Ehud Altman[4], Michael P. Zaletel[5], and Frank Pollmann[1] — [1]Department of Physics, T42, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [2]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 7610001, Israel — [3]Department of Physics, KTH Royal Institute of Technology, Stockholm SE-10691, Sweden — [4]Department of Physics, University of California, Berkeley, CA 94720 — [5]Department of Physics, Princeton University, Princeton, NJ 08540, USA

Purification is a tool that allows to represent mixed quantum states as pure states on enlarged Hilbert spaces. A purification of a given state is not unique and its entanglement strongly depends on the particular choice made. Moreover, in one-dimensional systems, the amount of entanglement is linked to how efficiently the purified state can be represented using matrix-product states (MPS). We introduce an MPS based method that allows to find the minimally entangled representation by iteratively minimizing the second Rényi entropy [1]. First, we consider the thermofield double purification and show that its entanglement can be strongly reduced especially at low temperatures. Second, we show that a slowdown of the entanglement growth following a quench of an infinite temperature state is possible.

[1] J. Hauschild et al., arXiv:1711.01288

TT 40.11 Tue 12:45 H 3010

A time-dependent variational description latttice gauge theories. — Ignacio Cirac[1], Eugene Demler[2], Tao Shi[1,3], and •Pablo Sala[1,4] — [1]Max Planck Institute for Quantum Optics, Garching, Germany — [2]Harvard University, Cambridge, Massachusetts — [3]Institute of Theoretical Physics, Beijing, China — [4]Technical University of Munich, Germany

Fermionic Gaussian states are completely characterized by their two-point correlation functions. These are collected in the so-called covariance matrix, which then becomes the main object in their description. We derive a time-dependent variational description of (1+1)-dimensional gauge theories using the framework of lattice gauge theories as well as fermionic Gaussian states. We compare our results to previously obtained results via matrix product states for ground-state properties and real-time dynamics. Specifically, we investigate the phase transition between the string and string-breaking phases, and the dynamical properties in the massive Schwinger model and other non-Abelian generalizations.