Q 18: Quantum Information: Concepts and Methods III

Time: Tuesday 11:00–13:00 Location: e214

Q 18.1 Tue 11:00 e214

Lattice Gauge Tensor Networks — •Simone Montangero — Institute for complex quantum systems & Center for Integrated Quantum Science and Technologies, Ulm university, Albert-Einstein-Allee 11, 89075 Ulm, Germany.

We show that gauge invariant quantum link models, Abelian and non-Abelian, can be exactly described in terms of tensor networks states. Quantum link models represent an ideal bridge between high-energy and cold atom physics, as they can be used in cold atoms in optical lattices to study lattice gauge theories. In this framework, we characterize the equilibrium and out-of-equilibrium physics of Abelian and non Abelian (1+1)D quantum link lattice gauge theories, such as the phase diagrams of U(1) and SU(2) theories and the real-time dynamics of the string breaking and of the Schwinger mechanisms.

Q 18.2 Tue 11:15 e214

Tree Tensor Network algorithms: Simulating quantum many-body models on lattices in one and two dimensions — •Matthias Gerster[1], Matteo Rizzi[2], Pietro Silvi[1], Rosario Fazio[3], and Simone Montangero[1] — [1]Institute for Complex Quantum Systems, Ulm University, D-89069 Ulm, Germany — [2]Johannes Gutenberg-Universität Mainz, Institut für Physik, D-55099 Mainz, Germany — [3]NEST, Scuola Normale Superiore & Istituto Nanoscienze CNR, I-56126 Pisa, Italy

We present a tree tensor network algorithm suitable for numerically determining and characterizing ground states of quantum lattice models in one and two spatial dimensions. Our tensor network method has several attractive features, the most prominent one being the treatment of open and periodic boundary conditions on equal footage. Moreover, the loopless network geometry guarantees the existence of a stable and efficient energy minimization algorithm, and a moderate scaling of the computational cost with the refinement parameter (bond dimension). We also comment on strategies for implementing symmetries in the state architecture, allowing to reduce the computational demands and enabling precise targeting of conserved quantities. We demonstrate the usefulness of our technique by some benchmark results for paradigmatic lattice models like an Ising chain.

Q 18.3 Tue 11:30 e214

A positive tensor network approach for simulating open quantum many-body systems — Albert H. Werner[1], Daniel Jaschke[2], Pietro Silvi[3], •Martin Kliesch[1], Tommaso Calarco[3], Jens Eisert[1], and Simone Montangero[3] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Department of Physics, Colorado School of Mines, Golden, Colorado 80401, USA — [3]Institute for Complex Quantum systems (ICQ), Universität Ulm, 89069 Ulm, Germany

Open many-body quantum systems play an important role in quantum optics and condensed-matter physics, and capture phenomena like transport, interplay between Hamiltonian and incoherent dynamics, and topological order generated by dissipation.

We introduce a versatile and practical method to numerically simulate one-dimensional open quantum many-body dynamics using tensor networks. It is based on representing mixed quantum states in a locally purified form, which guarantees that positivity is preserved at all times. Moreover, the approximation error is controlled with respect to the trace norm. Hence, this scheme overcomes various obstacles of the known numerical open-system evolution schemes.

Q 18.4 Tue 11:45 e214

Tree Tensor Networks at work: a study of 1D disordered Bose-Hubbard model — Matthias Gerster[1], •Matteo Rizzi[2], Ferdinand Tschirsich[1], Pietro Silvi[1], Rosario Fazio[3,4], and Simone Montangero[1,5] — [1]Institute for Complex Quantum Systems, Ulm University, Germany — [2]Johannes Gutenberg-Universität, Mainz, Germany — [3]ICTP, Trieste, Italy — [4]NEST, Scuola Normale Superiore & Istituto Nanoscienze CNR, Pisa, Italy — [5]Center for Integrated Quantum Science and Technology (IQST)

We study the equilibrium properties of the one-dimensional disordered Bose-Hubbard model by means of a gauge-adaptive tree tensor network variational method suitable for systems with periodic boundary conditions. We compute the superfluid stiffness and superfluid correlations close to the superfluid to glass transition line, obtaining accurate locations of the critical points. By studying the statistics of the exponent of the power-law decay of the correlation, we determine the boundary between the superfluid region and the Bose glass phase in the regime of strong disorder and in the weakly interacting region, not explored numerically before. In the former case our simulations are in agreement with previous Monte Carlo calculations.

Q 18.5 Tue 12:00 e214

Entanglement in qudit hypergraph states — •Christina Ritz[1], Frank Steinhoff[2], Nikolai Miklin[1], and Otfried Gühne[1] — [1]Naturwissenschaftlich Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany — [2]Instituto de Física, Universidade Federal de Goiás, 74001-970, Goiânia, Goiás, Brazil

Hypergraph states form a class of multipartite states, where the free parameters are reduced by restrictions on the initial state and the allowed entangling operations. Within this framework the study of multipartite entanglement regarding SLOCC- and LU-equivalence classes has raised interest in the field of hypergraph states for qubits. In this work, we generalize the class of hypergraph states to multipartite systems of arbitrary dimension by means of discrete phase-space constructions. For uniform hypergraphs a complete SLOCC classification is obtained in terms of the greatest common divisor hierarchy. The special case of tripartite systems is analyzed in detail, resulting in a full classification for prime dimension and dimension four. In addition to the local creation of (hyper)edges from existing ones connecting the same or more vertices, a new feature, namely the creation from less vertices, appears for non-prime dimensions.

Q 18.6 Tue 12:15 e214

Extreme violation of local realism in hypergraph states — •Mariami Gachechiladze, Costantino Budroni, and Otfried Gühne — University if Siegen, Siegen, Germany

Hypergraph states form a family of multiparticle quantum states that generalizes the well-known concept of Greenberger-Horne-Zeilinger states, cluster states, and more broadly graph states. We study the nonlocal properties of quantum hypergraph states. We demonstrate that the correlations in hypergraph states can be used to derive various types of nonlocality proofs, including Hardy-type arguments and Bell inequalities for genuine multiparticle nonlocality. Moreover, we show that hypergraph states allow for an exponentially increasing violation of local realism which is robust against loss of particles. Our results suggest that certain classes of hypergraph states are novel resources for quantum metrology and measurement-based quantum computation.

Q 18.7 Tue 12:30 e214

Trace-norm contraction under tensor product channels — •David Reeb[1] and Peter Vrana[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]Budapest University of Technology and Economics

We establish upper bounds on the information storage time in a quantum memory under independent noise in the case where active error correction is allowed. For this, we provide an upper bound on the trace-norm contraction coefficient of a tensor product of quantum channels. Our method yields nontrivial bounds in cases where others fail. Specializing to qubit channels, this solves a conjecture by Ben-Or/Gottesmann/Hassidim concerning the Quantum Refrigerator model of computation (arXiv:1301.1995).

Q 18.8 Tue 12:45 e214

Improving compressed sensing with the diamond norm — •Martin Kliesch[1], Richard Kueng[2], Jens Eisert[1], and David Gross[2] — [1]Freie Universität Berlin — [2]Universität zu Köln

In low-rank matrix recovery, one aims to reconstruct a low-rank matrix from a minimal number of linear measurements. Within the paradigm of compressed sensing, this is made computationally efficient by minimizing the nuclear norm as a convex surrogate for rank.

In this work, we identify an improved regularizer based on the so-called diamond norm, a concept imported from quantum information theory. We show that –for a class of matrices saturating a certain norm inequality– the descent cone of the diamond norm is contained in that of the nuclear norm. This suggests superior reconstruction properties for these matrices. We explicitly characterize this set of matrices, which also contains quantum channels. Moreover, we demonstrate numerically that the diamond norm indeed outperforms the nuclear norm in a number of relevant applications: These include not only the task of quantum process tomography but also signal analysis tasks such as blind matrix deconvolution or the retrieval of certain unitary basis changes.

The diamond norm is defined for matrices that can be interpreted as order-4 tensors and it turns out that the above condition depends crucially on that tensorial structure. In this sense, this work touches on an aspect of the notoriously difficult tensor completion problem.