Q 18: Quantum Information: Concepts and Methods III

Time: Tuesday 11:00–12:30 Location: K/HS1

Q 18.1 Tue 11:00 K/HS1

Random Hamiltonians, random circuits and unitary designs — •Emilio Onorati[1], Martin Kliesch[1], Albert Werner[1], Winton Brown[2], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Département de Physique, Université de Sherbrooke

Randomness has proven to be a useful tool for a large variety of tasks in quantum information and physics, e.g. tomography and gate benchmarking, decoupling and thermalization making use of unitary designs, i.e. the application of random unitaries chosen according to the uniform Haar distribution. A known method to realise such unitary designs is provided by suitable random quantum circuits, where two-qubit gates are taken from a given distribution and repeatedly applied to a quantum state.

In this work, we provide a general picture of such designs, and specifically show that a continuous-time process with a local fluctuating Hamiltonian is able to mimic the properties of the Haar measure. In this spirit, we divide the total time in small steps; for each of these we generate a Hamiltonian composed of local terms weighted by gaussian coefficients, then we apply the corresponding unitary evolution.

The principal mathematical tool to the proof involves Markov chain theory. In particular, the continuous-time process defines a random walk over Pauli matrices, which converges to the same stationary distribution of the analogous walk induced by the Haar measure.

Q 18.2 Tue 11:15 K/HS1

Local constants of motion imply transport — Mathis Friesdorf[1], •Marcel Goihl[1], Albert H. Werner[1], Winton Brown[2], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universitaet Berlin, 14195 Berlin, Germany — [2]Computer Science Department, University College London, London WC1E 6BT

Generic interacting many-body systems are usually expected to thermalise following out of equilibrium dynamics: Local expectation values should be captured in terms of thermal ensembles. This behaviour necessarily relies on transport in the system, in the sense that information spreads outside of any finite region. A notable class of models that contradicts this intuition is given by systems exhibiting many-body localisation. Their eigenstates are strongly lacking entanglement, concomitant with an absence of thermalisation. The description of these models often relies on local constants of motion, certain operators that remain local even for infinite times. In this work, we show that counter-intuitively, the existence of such operators, together with a suitable non-degenerate Hamiltonian spectrum, implies that there exist other operators for which the system has to have transport. While upper bounds on transport have long been known, lower bounds have only been obtained for very specific models. Our results constitute an important step towards proving transport in generic systems.

Q 18.3 Tue 11:30 K/HS1

Many-body localisation implies that eigenvectors are matrix-product states — •Mathis Friesdorf[1], Albert H. Werner[1], Winton Brown[2], Volkher B. Scholz[3], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany — [2]Computer Science Department, University College London, London, England — [3]Institute for Theoretical Physics, ETH Zurich, Zurich, Switzerland

The phenomenon of many-body localisation received a lot of attention recently, both for its implications in condensed-matter physics of allowing systems to be an insulator even at non-zero temperature as well as in the context of the foundations of quantum statistical mechanics, providing examples of systems showing the absence of thermalisation following out-of-equilibrium dynamics. In this work, we establish a novel link between dynamical properties - a vanishing group velocity and the absence of transport - with entanglement properties of individual eigenvectors. Using Lieb-Robinson bounds and filter functions, we prove rigorously under simple assumptions on the spectrum that if a system shows strong dynamical localisation, all of its many- body eigenvectors have clustering correlations. In one dimension this implies directly an entanglement area law, hence the eigenvectors can be approximated by matrix-product states. We also show this statement for parts of the spectrum, allowing for the existence of a mobility edge above which transport is possible.

Q 18.4 Tue 11:45 K/HS1

Matrix product operators and states: NP-hardness and undecidability — •Martin Kliesch[1], David Gross[2], and Jens Eisert[1] — [1]Freie Universität Berlin, 14195 Berlin, Germany — [2]Universität Freiburg, 79104 Freiburg, Germany

Tensor network states constitute an important variational set of quantum states for numerical studies of strongly correlated systems in condensed-matter physics, as well as in mathematical physics. This is specifically true for finitely correlated states or matrix-product operators, designed to capture mixed states of one-dimensional quantum systems. It is a well-known open problem to find an efficient algorithm that decides whether a given matrix-product operator actually represents a physical state that in particular has no negative eigenvalues. We address and answer this question by showing that the problem is provably undecidable in the thermodynamic limit and that the bounded version of the problem is NP-hard in the system size. Furthermore, we discuss numerous connections between tensor network methods and (seemingly) different concepts treated before in the literature, such as hidden Markov models and tensor trains.

Q 18.5 Tue 12:00 K/HS1

Orbital optimization in fermionic tensor network states — •Christian Krumnow[1], Örs Legeza[2], Reinhold Schneider[3], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany — [2]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [3]Institute for Mathematics, Technische Universität Berlin, Berlin, Germany

Simulating strongly correlated non-local fermionic models is one of the major task of modern theoretical and computational physics and chemistry. In the presence of strong correlations, calculating ground states using traditional ab-initio methods from quantum chemistry, such as CI and CC, becomes infeasible in certain instances. In these cases tensor-network methods provide a new way forward. The long-range nature of the interaction of such systems, however, renders their straightforward numerical simulation using tensor-network methods difficult and implies new questions concerning the optimal topology and basis used to construct the tensor-network. By combining tensor-networks states (TNS) and suited Gaussian transformations we introduce a scheme which allows to optimise both, the tensor network and its basis using local updates. The TNS allows to approximate even strongly correlated states while the Gaussian transformations encode long range entanglement which cannot be captured by TNS efficiently. The resulting method provides a black box tool which optimises the basis of a general long-range interacting system for approximating the ground state by a TNS as efficient as possible.

Q 18.6 Tue 12:15 K/HS1

Variational matrix product states for the steady state of dissipative quantum systems — •Jian Cui[1,2], J. Ignacio Cirac[3], and Mari Carmen Banuls[3] — [1]Imperial College London, the United Kingdom — [2]Freiburg Institute for Advanced Studies, Freiburg, Germany — [3]Max-Planck-Institut fur Quantenoptik, Garching, Germany

We present a new variational method for finding the steady state of dissipative quantum chains. Based on the matrix product operator (MPO) ansatz, the algorithm allows the investigation of stationary states for master equations of the Lindblad form. Different to time dependent (tDMRG) methods, that follow the evolution until convergence, our scheme does not require an accurate repre- sentation of the state at all intermediate times, and can thus benefit from a faster convergence when the steady state is, as often the case, a MPO with small bond dimension. We illustrate the performance of the method in the case of a low-dimensional version of the Dicke model and the dissipative Ising chain, which describes Rydberg atoms.