TT 16: Symposium: Efficient Classical Simulation of Strongly Correlated Quantum Systems

Time: Tuesday 14:00–17:45 Location: H 0104

Invited Talk TT 16.1 Tue 14:00 H 0104

Density matrix renormalization meets quantum information — •Ulrich Schollwöck — Institut für Theoretische Physik C, RWTH Aachen

In this talk I want to give an overview of the reassessment of the well-established density-matrix renormalization group method for the simulation of low-dimensional quantum systems by the use of quantum information concepts: it is in some sense the first of a set of essentially optimally efficient methods to simulate quantum systems on a classical computer. While this allows to get a very simple picture of the essence of this method which in my view is more adequate than renormalization group perspectives, it also allows to devise a plethora of new simulation techniques that have largely extended the scope of this method. I will give an introduction to these new developments and illustrate them by applications in the field of ultracold atoms and more conventional nanosystems. The purpose of this talk is also to set the stage for further talks on the individual new methods in the session in which it is presented.

TT 16.2 Tue 14:45 H 0104

Time-dependent DMRG: Applications to cold atoms in optical lattices — •Corinna Kollath[1], Andreas Laeuchli[2], and Ehud Altman[3] — [1]Ecole Polytechnique Palaiseau, France — [2]IRRMA Lausanne, Switzerland — [3]The Weizmann Institute of Science, Israel

Ultracold atoms constitute a system to investigate non-equilibrium physics in strongly correlated systems. Their good tunability allows to rapidly change the system parameters and observe the subsequent quantum evolution. For example the non-adiabatic dynamics across the superfluid-Mott-insulating phase transition has been realized in ultracold bosonic gases confined to optical lattices. The theoretical description of these time-dependent phenomena is very involved. We apply the recently developed adaptive time-dependent DMRG method to study the response of these strongly correlated quantum systems to different parameter changes.

TT 16.3 Tue 15:15 H 0104

A Renormalisation-Group Algorithm for Eigenvalue Density Functions of Interacting Quantum Systems — •Tobias Osborne — Royal Holloway, University of London

In this talk I'll describe a certifiable algorithm to calculate the eigenvalue density function – the number of eigenvalues within an infinitesimal interval – for an arbitrary 1D interacting quantum spin system. The method provides an arbitrarily accurate numerical representation for the smeared eigenvalue density function, which is the convolution of the eigenvalue density function with a gaussian of prespecified width. In addition, with the algorithm it is possible to investigate the density of states near the ground state. This can be used to numerically determine the size of the ground-state energy gap for the system to within a prespecified confidence interval. The method exploits a finitely correlated state/matrix product state representation of the propagator and applies equally to disordered and critical interacting 1D quantum spin systems.

15 min. break

Invited Talk TT 16.4 Tue 16:00 H 0104

Projected Entangled Pair States: status and prospects — •Frank Verstraete — Universitaet Wien, Austria

We report on the progress made to extend the density matrix renormalization group to higher dimensions, discuss the underlying theory of projected entangled pair states (PEPS) and illustrate its potential on the hand of a few examples.

TT 16.5 Tue 16:30 H 0104

DMRG and quantum impurity models — •Andreas Weichselbaum and Jan von Delft — Ludwig Maximillians Universität, Arnold Sommerfeld Center, Theresienstr. 37, 80333 München

Quantum impurity models are analyzed routinely and reliably at very low energies using the Numerical Renormalization Group (NRG). Its great benefit of energy scale separation, however, comes at the cost of reduced resolution at finite energy. By realizing that the algebraic structure underneath NRG is the same as for the density matrix renormalization group (DMRG), namely matrix product states, several strict NRG contraints such as the rigid discretization scheme can be relaxed due to the variational principle of DMRG. Our recent work in that respect will be discussed.

TT 16.6 Tue 17:00 H 0104

Unitary networks to describe quantum many-body systems — •Jens Eisert[1], Chris Dawson[1], Tobias Osborne[2], and Frank Verstraete[3] — [1]Imperial College London, UK — [2]Royal Holloway, University of London, UK — [3]University of Vienna, Austria

To describe strongly correlated quantum many-body systems is typically hard, as the dimension of the underlying state space grows exponentially with the system size. The number of relevant parameters to simulate many-body systems, yet, is typically smaller. This talk will give an overview over variational sets of states which can faithfully grasp ground state properties of quantum lattice systems, which can be described by polynomially many parameters and for which one can efficiently compute local properties. We will introduce a flow approach to varying over such unitary networks, bringing together ideas of Wegner flow with variational methods. Applications to the simulation of two-dimensional lattice systems are outlined.

TT 16.7 Tue 17:30 H 0104

Optimized ensembles in quantum Monte Carlo simulations — •Stefan Wessel[1], Norbert Stoop[2], Emanuel Gull[2], Simon Trebst[3], and Matthias Troyer[2] — [1]Institute for Theoretical Physics, Stuttgart University, Germany — [2]Theoretical Physics, ETH Zurich, Switzerland — [3]Microsoft Research, Station Q, University of California Santa Barbara, USA

We present an adaptive means for improving the efficiency of Monte Carlo simulations of quantum systems in rough free energy landscapes. Such occur e.g. near strongly first-order (quantum) phase transitions, and due to competing interactions. Our approach is based on an extension of the concept of optimized broad-histogram ensembles for classical simulations to the quantum regime. We present examples of this approach within the context of the stochastic series expansion quantum Monte Carlo approach, and indicate the limits of such extended ensemble methods.