TT 17: Quantum Manybody Systems (joint session QI/TT)

Time: Monday 15:00–18:30 Location: BEY/0245

Invited Talk TT 17.1 Mon 15:00 BEY/0245

Reducing Noise, Complexity, and Optimization Barriers in Quantum Simulations of Strongly Correlated Systems — •Werner Dobrautz — Center for Advanced Systems Understanding (CASUS), Görlitz, Germany — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI) Dresden/Leipzig, Dresden, Germany — Technical University Dresden, Dresden, Germany

Near-term quantum hardware poses severe constraints for quantum chemistry and quantum many-body simulations due to noise, limited coherence, and challenging optimization landscapes. We present a unifying set of algorithmic strategies to address these bottlenecks, combining transcorrelated Hamiltonians, spin-adapted representations, and advanced variational optimization techniques. By embedding electronic correlations directly into the Hamiltonian, transcorrelated methods yield compact, noise-resilient quantum circuits and improved convergence for both molecular systems and lattice models. Spin-adapted formulations further reduce Hilbert space complexity and enable efficient simulations of correlated spin systems. To enhance robustness and trainability, we introduce multireference error mitigation strategies and qBang, a momentum-aware variational optimization scheme that effectively navigates flat and ill-conditioned energy landscapes. Together, these approaches establish a scalable and hardware-aware framework for accurate quantum simulations of strongly correlated systems on current and near-term quantum devices.

TT 17.2 Mon 15:30 BEY/0245

Hybrid superconducting devices — •Anamaria Ghihor[1], Yejin Lee[1], Haolin Jin[1], Markus König[1], Andreas Leithe-Jasper[1], Roemer Hinlopen[1,2], Carsten Putzke[2], Philip Moll[2], Uri Vool[1], and Eteri Svanidze[1] — [1]MPI CPfS - Nothnitzer Str. 40, Dresden, Germany — [2]MPI MPSD - Luruper Chaussee 149, Hamburg, Germany

Superconducting resonators are highly tunable, low-loss coherent macroscopic devices, making them ideal for quantum technology and sensing applications. Recently, these resonators have been paired with van der Waals (vdW) materials to explore their microwave losses, dielectric properties and kinetic inductance. However, creating a hybrid device that only integrates a superconducting resonator with a vdW flake limits the range of materials that can be used. To overcome this limitation, we fabricate a lamella using a focused ion beam (FIB), effectively replicating the flake. This approach offers the added benefit of precise dimensional control, something that is difficult to achieve with exfoliated flakes. The lamella can then be attached in situ to the resonator using a micro-manipulator. In this talk we will show preliminary hybrid devices with lamella developed from conventional and unconventional superconductors.This approach greatly expands the range of materials that can be explored and enables detailed studies of their superfluid density.

TT 17.3 Mon 15:45 BEY/0245

Hybrid Monte Carlo enhanced by exact diagonalization: simulating interacting Hubbard systems — •Martina Gisti[1], Finn Temmen[2], Thomas Luu[1], David Luitz[2], and Johann Ostmeyer[3] — [1]Institute of Physics, University of Bonn, Nußallee 12, 53115 Bonn — [2]Forschungszentrum Jülich GmbH Wilhelm-Johnen-Straße 52428 Jülich — [3]Helmholtz Institute for Radiation and Nuclear Physics, University of Bonn

We present a hybrid simulation framework that integrates the hybrid Monte Carlo method with exact diagonalization techniques to study Hubbard chains coupled through many-body interactions. Within a path integral formulation, thermal expectation values are expressed and evaluated exactly along the chains. We study the impact of the hybrid method on persistent challenges in the application of stochastic simulations, such as the sign problem and ergodicity violations. The approach mitigates the sign problem that hampers conventional simulations, providing a feasible path for studying strongly correlated quantum systems beyond one dimension.

TT 17.4 Mon 16:00 BEY/0245

Topological properties of coupled superconducting chains in the presence of interactions — •Frederick Del Pozo — aboratoire Kastler Brossel, Sorbonne Universite, CNRS, ENS-PSL Research University, Coll'ege de France; 4 Place Jussieu, 75005 Paris, France

We investigate the topological and critical properties of coupled and interacting superconducting wires.

As a prototype of superconductors with topological order, the Kitaev chain model is a perfect testing ground for novel theoretical and numerical tools, including the density-matrix-renormalization-group (DMRG) algorithm and bi-partite entanglement entropy.

In the following talk we report on the results of several recent works, which have lead to a deeper understanding of the topological and critical properties of coupled and interacting Kitaev chains, also in the presence of real-space disorder. We reveal that the usual topological invariant, defined in the absence of interactions, remains a sensible marker for the topology when two wires are brought into close proximity of each other where interaction effects and inter-wire hopping processes become relevant. We also reveal the appearance of a many-body entangled ground state, and interaction reinforced critical region in the wires' phase diagram.

Our results highlight the rich physics present in quasi one-dimensional quantum systems, and motivates the further research into properties relevant for applications in superconducting qubits and topological quantum computation protocols.

TT 17.5 Mon 16:15 BEY/0245

Quantum Assisted Ghost Gutzwiller Ansatz — •PV Sriluckshmy, Francois Jamet, and Fedor Simkovic — IQM Quantum Computers, Georg-Brauchle-Ring 23-25, 80992 Munich, Germany

The ghost Gutzwiller ansatz (gGut) technique was shown to achieve accuracy comparable to dynamical mean-field theory at a much lower computational cost. However, gGut is limited by the bottleneck of computing the density matrix. We develop a hybrid quantum-classical gGut technique that computes ground state properties of embedding Hamiltonians on a quantum computer using the quantum-selected configuration interaction (QSCI) algorithm. We find that the ground states of interest become sufficiently sparse as the number of ghost orbitals increases. We investigate QSCI's performance using local unitary cluster Jastrow (LUCJ) ansatz with circuit cutting on IQM's quantum hardware for up to 24 qubits. Our converged gGut calculations correctly capture the metal-to-insulator phase transition in the Fermi-Hubbard model. This was achieved using quantum samples to build a basis with as little as 1% of the total CI states.

30min. break

TT 17.6 Mon 17:00 BEY/0245

Measurement-Based Quantum Computation in Symmetry-Enriched Topological Phases — •Paul Herringer[1,2,3], Vir B. Bulchandani[4,5], Younes Javanmard[1], David T. Stephen[6,7], and Robert Raussendorf[1,3] — [1]Leibniz Universität Hannover, Hannover, Germany — [2]University of British Columbia, Vancouver, Canada — [3]Stewart Blusson Quantum Matter Institute, Vancouver, Canada — [4]Rice University, Houston, USA — [5]National University of Singapore, Singapore — [6]University of Colorado Boulder, Boulder, USA — [7]California Institute of Technology, Pasadena, USA

We present the first examples of topological phases of matter with uniform power for measurement-based quantum computation. This is possible thanks to a new framework for analyzing the computational properties of phases of matter that is more general than previous constructions, which were limited to short-range entangled phases in one dimension. We show that ground states of the toric code in an anisotropic magnetic field yield a natural, albeit non-computationally-universal, application of our framework. We then present a new model with topological order whose ground states are universal resources for MBQC. Both topological models are enriched by subsystem symmetries, and these symmetries protect their computational power. Our framework greatly expands the range of physical models that can be analyzed from the computational perspective.

TT 17.7 Mon 17:15 BEY/0245

Many-body localization in the Sherrington-Kirkpatrick model — •Gergo Dénes[1], Balázs Hetényi[1], Márton Kormos[1], Angelo Valli[1], Pascu Moca[1,2], and Gergely Zaránd[1] — [1]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary — [2]Department of Physics, University of Oradea, Str. Universitatii nr. 1 Oradea, 410087, Romania

The Sherrington-Kirkpatrick (SK) model has been extensively studied for more than 50 years [1]. In the context of optimization problems, it represents one of the most difficult paradigmatic optimization problems, the MAXCUT problem. Its quantum extension, the transverse field SK model (TFSK model) is therefore a paradigmatic model for the Quantum Adiabatic Optimization Approach (QAOA).

We performed extensive finite-size numerical simulations of the TFSK model at different transverse field strengths to extract various many-body localization (MBL) indicators, such as inverse participation ratio, Shannon entropy, and level spacing ratio. Our numerical and analytical analysis suggest the presence of an MBL transition as a function of the transverse field at certain energy densities, different from the spin-glass transition, and in contrast to the findings of Ref. [2]. In the MBL phase, states do not seem to be exponentially localized, rather, our data suggest the presence of power-law MBL.

[1] M. Mezard, G. Parisi, M. A. Virasoro Spin Glass Theory and Beyond, ISBN: 978-9971-5-0116-7 (1986).

[2] S. Mukherjee, S. Nag, A. Garg, Phys. Rev. B 97, 144202 (2018).

TT 17.8 Mon 17:30 BEY/0245

Typical entanglement entropy of anyon chains — Yale Yauk[1,2], •Alexander Hahn[1,3,2], and Lucas Hackl[4,5] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, D-85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, D-80799 Munich, Germany — [3]Technical University of Munich, TUM School of Natural Sciences, Physics Department, D-85748 Garching, Germany — [4]School of Mathematics and Statistics, The University of Melbourne, Parkville, VIC 3010, Australia — [5]School of Physics, The University of Melbourne, Parkville, VIC 3010, Australia

Random-state entanglement serves as a key probe of quantum chaos, thermalization, and information scrambling, but its behavior in topologically ordered systems remains unclear. Here we study the statistical properties of bipartite entanglement in one-dimensional anyon chains, where the Hilbert space is constrained by the fusion rules. In such systems, the conventional trace must be replaced by the quantum trace, requiring a consistent redefinition of density matrices and entanglement measures that incorporates topological data. We compute the average bipartite entanglement entropy and its variance for both open and periodic boundary conditions. The resulting average anyonic entanglement entropy reproduces the Page curve exactly, revealing that topological constraints modify the normalization but not the universal form of typical entanglement. Despite topological charge conservation, the average entanglement shows no symmetry-related correction of the kind that appears in systems with Lie group symmetries.

TT 17.9 Mon 17:45 BEY/0245

Thermal Entanglement and Out-of-Equilibrium Thermodynamics in 1D Bosonic Systems — •Julia Mathe, Nicky Kai Hong Li, Pharnam Bakhshinezhad, and Giuseppe Vitagliano — TU Wien, Atominstitut, Stadionallee 2, 1020 Vienna, Austria

We investigate entanglement in- and out-of equilibirum in harmonic chains, with direct relevance to low-energy descriptions of paradigmatic models, like 1D Bose-Einstein condensates. Working in a regime where all states are Gaussian, we employ the logarithmic negativity and the covariance matrix criterion (CMC) as known entanglement quantifiers. For thermal states, we extensively characterize entanglement and its scaling behaviour, including in the massless (critical) limit. We extract the optimal entanglement witness coming from the CMC and uncover a simple mode-resolved structure underlying the entanglement-to-separability transition. At finite temperature, the optimal witnesses are diagonal in the normal-mode basis, allowing to characterize entanglement from a few normal mode uncertainties, which are physically related to static susceptibilities. We then investigate out-of-equilibrium dynamics arising from a time-dependent coupling and analyze entanglement growth, suppression, and transport. Based on this, we construct a full Gaussian framework for studying entanglement in thermodynamic cycles. Our results give a unified and physically intuitive picture of how entanglement emerges and evolves in 1D Gaussian many-body systems and show that thermal separability and entanglement are mainly governed by the low-energy (infrared) sector that also underlies the continuum field-theory description.

TT 17.10 Mon 18:00 BEY/0245

Symmetry-preserving warm starts for variational ground state preparation — •Ivana Miháliková — Matej Bel University, Národná ulica 12, Banská Bystrica, 97401, Slovakia — Institute of Physics, Slovak Academy of Sciences, Bratislava 84511, Slovakia

Enforcing physical symmetries can dramatically simplify ground-state preparation in the variational quantum eigensolver (VQE). This work considers a 12-spin all-to-all neutrino-inspired model and a 4×3 Heisenberg lattice. In both systems, simple product states are projected onto symmetry subspaces with fixed total spin J and J_z (and, for the Heisenberg lattice, translation and mirror symmetries), then refined using swap-based entangling layers that generate only symmetry-compatible correlations. The resulting warm starts lie well within previously established worst-case upper bounds on the energy error normalized by system size and interaction-graph degree, showing that symmetry-aware initialization can substantially outperform generic guarantees. For the Heisenberg lattice, the symmetry-preserving construction reduces the relevant search space from 4096 basis states to just 9 symmetry-compatible states and increases the effective spectral gap from about 7 to about 28 energy units. Within a VQE setting this yields a smoother optimization landscape and faster convergence with shallow circuits. In practice, the neutrino-inspired model reaches $\sim 98.8\%$ fidelity within the $J = 0$ subspace, and the Heisenberg lattice exceeds 98.0% fidelity once translation and mirror symmetries are enforced.

TT 17.11 Mon 18:15 BEY/0245

An emerging generator of rotations for a 1- or many-particle Hofstadter problem on a lattice pierced by magnetic field — •Arabi Seshappan[1,2], Tangi Morvan[2], Alberto Nardin[2], and Leonardo Mazza[2] — [1]Department of Physics, University of California, Merced, CA 95343, USA — [2]Université Paris-Saclay, CNRS, LPTMS, 91405, Orsay, France

Topological quantum computation is an exciting direction for development of fault-tolerant qubits—a quintessential example being manipulation of excitations in fractional quantum Hall (FQH) systems. As recent cold-atom and photonic experiments have realized few-particle FQH states in small lattices, and theoretical results have shown spectra of specific lattice sizes to exhibit exactly flat-bands in momentum space, we have theoretically studied similar FQH lattices for 1- and many-particle bosonic cases. Our construction is that of a two-dimensional (2D) square lattice, with nearest-neighbor hopping, pierced by a perpendicular, uniform magnetic field. We vary the magnetic field such that, for lattice edge length L, the flux per plaquette ranges between $\alpha = 1/L$ and $\alpha = 1/4$, and analyze the resultant spectra. We have found that, for low energy levels, measurements of density are an excellent proxy for defining a gauge-invariant generator of rotations (GIGR) and can make order in the spectra. This removes any need for assumption of circular droplet invariance, and provides a useful characterization technique for cold-atom experiments.