Book of abstracts

Poster session of the ASC school 2024
"Modeling strongly correlated electrons: Numerics, analytics, and quantum simulations"

September 16

1. **Low-depth simulations of fermionic systems on realistic quantum hardware**

   Manuel Algaba (IQM Quantum Computers & Autonomous University of Madrid)

   We introduce a general strategy for mapping fermionic systems to quantum hardware with realistic qubit connectivity which results in low-depth quantum circuits as counted by the number of native two-qubit gates. We achieve this by leveraging novel operator decomposition and circuit compression techniques paired with specifically chosen fermion-to-qubit mappings that allow for a high degree of gate cancellations and parallelism. Our mappings retain the flexibility to simultaneously optimise for qubit counts or qubit operator weights and can be applied to the investigation of arbitrary fermionic lattice geometries. We showcase our approach by investigating the Fermi-Hubbard model as well as more complex multi-orbital models and report unprecedentedly low circuit depths per Trotter layer.

2. **Subgap pumping of antiferromagnetic Mott insulators: photoexcitation mechanisms and applications**

   Radu Andrei (ETH Zürich)

   Recent technological advances have enabled increasingly stronger ultrafast driving of correlated insulators at frequencies below their charge excitation gap. Experimental access to new pump-probe regimes challenges the conventional understanding of such materials' nonequilibrium behavior under subgap driving, and motivates further theoretical study of the carrier photoexcitation mechanisms. Here, we employ a time-dependent Gaussian approach to study the behavior of a 2D repulsive Hubbard model at half filling, under driving by strong ac electric fields. We show that dynamical suppression of the Mott gap gives rise to a rich landscape of photoexcitation regimes, and discuss observables accessible in solid-state as well as cold-atom experiments.

3. **Quantum optimisation for graph coloring problem using Rydberg qudit arrays**

   Toonyawat Angkhanawin (Durham University)

   Rydberg atoms have shown remarkably high potential as a candidate for a quantum simulator and quantum computing platform. One of the very famous application that could highly benefit from Rydberg atoms is quantum optimization. In this work, we design new architectures for quantum optimization using one-dimensional arrays of Rydberg-atom qudits where each atom is coherently coupled to multi Rydberg states, giving rise to different species of long-range van de Waals interactions. Each interaction contributes to different penalized terms in Hamiltonian cost function which plays very crucial roles in the optimization processes. In this work, we are focusing on solving the so-called graph coloring problem (GCP), which is known as NP-hard in computer science. It has been found that solutions of GCPs could be encoded in ground states of this interacting Rydberg-qutrit Hamiltonian, and such solutions can be delivered by quantum optimization developed in this work, which are implemented via quantum annealing algorithms based on adiabatic quantum computation.

4. **Ring-exchange physics in a chain of three-level ions**

   Sourav Biswas (Donostia International Physics Center (DIPC))

   We delve into the physics of ring exchange in the context of a Bose-ladder-like system modeled by a chain of three-level ions. We study the system using exact diagonalization (ED) and DMRG techniques. The system shows signatures of an exotic phase known as the "Bose liquid."We discuss experimental

motivation and show how engineering system parameters can develop the sought-after Bose liquid phase.

5. **Towards Certified Finite Energy Quantum Simulation of the 2D Fermi-Hubbard Model**

   Alberto Cavallar (Max Planck Institute for Quantum Optics)

   Instead of experimentally sweeping over the phase diagram of the 2D Fermi-Hubbard Model to study the reach physics of strongly correlated electrons, we provide an alterantive method by using a filtering algorithm extracting microcanonical expectation values of observables by means of Loschmidt echos for an easy-to-prepare initial state. A procedure to extract these numbers from a quantum simulator is analyzed in various details, while taking the constraints and tunability of the Fermionic Quantum Processor (FermiQP) into account.

6. **Neural quantum states for a two-leg Bose-Hubbard ladder under a magnetic field**

   Kadir Çeven (Georg-August-Universität Göttingen)

   This work explores novel quantum phases in a two-leg Bose-Hubbard ladder, achieved using neural quantum states. The remarkable potential of quantum gas systems for analog quantum simulation of strongly correlated quantum matter is well-known; however, it is equally evident that new theoretical bases are urgently required to comprehend their intricacies fully. While simple one-dimensional models have served as valuable test cases, ladder models naturally emerge as the next step, enabling studying higher dimensional effects, including gauge fields. [Çeven et al., PRA 106, 063320 (2022)] investigates the application of neural quantum states to a two-leg Bose-Hubbard ladder in the presence of strong synthetic magnetic fields. This paper showcased the reliability of variational neural networks, such as restricted Boltzmann machines and feedforward neural networks, in accurately predicting the phase diagram exhibiting superfluid-Mott insulator phase transition under strong interaction. Moreover, the neural networks successfully identified other intriguing many-body phases in the weakly interacting regime. These exciting findings firmly designate a two-leg Bose-Hubbard ladder with magnetic flux as an ideal testbed for advancing the field of neural quantum states.

7. **Finite temperature induced interacting symmetry protected topological phases**

   Nitya Cuzzuol (Politecnico di Torino)

   The symmetry-protected topological (SPT) phases in strongly interacting quantum systems have been deeply understood at low temperature. Here, relevant properties can be extracted by looking at entanglement, string order parameters, and energy gaps. Exactly the presence of these gaps supports a finite temperature stability of this phases whose properties are still not completely clear. In models like the XXZ spin-1 and the interacting spin-1/2 SSH, the SPT phases are connected to an ordered phase, through the closing of the bulk gap while the spin gap remains finite. To study the finite temperature regime of these models we applied an MPS based purification procedure on an infinite temperature state ansatz. Due to the different behaviors of the spin and bulk gaps, intriguing phenomena can appear by decreasing the temperature. Even for coupling corresponding to the zero temperature ordered phase the system enters a new SPT phase. This is indicated by the differing behaviors of both local and nonlocal order parameters, as well as edge magnetization, in a temperature range linked to the gap differences. Our results show that when the temperature scale exceeds the bulk gap, the local order parameter decays, but the z-string order parameter remains long-range. Additionally, changes in edge magnetization and the x-string order parameter decay occur, leading to the disappearance of the ordered phase, replaced by a new phase stabilized by the spin gap. Our results thus prove temperature as a new and powerful resource to generate SPT phases.

8. **Spectral properties of ultracold Fermi gases**

   Eugen Dizer (Institut für Theoretische Physik Heidelberg)

   In this poster, we discuss a method to calculate non-perturbative spectral functions of ultracold Fermi gases directly in real frequencies, without the need for numerical reconstruction methods. The spectral functions provide access to transport and excitation properties of the ultracold gas, and can be used to obtain various physical observables which are measured in experiments. Our approach offers a wide range of applications, including the ab initio calculation of transport and spectral properties in the superfluid phase of the BCS-BEC crossover.

9. **Understanding higher order correlation functions in superfluid to mott insulator transition with a Metastable He BEC in optical Lattice.**

Anish Dutta (Indian Institute of Science Education and Research Kolkata)

Here, In ANU we have home-built BEC apparatus, capable of generating BEC in a short time. We are trying to use BEC made up of metastable Helium atoms to understand superfluid-mott insulator transition. Correlation functions, are important indicators of quantum phenomena. In ANU we will attempt to find the behavior of second and higher order correlation functions across the superfluid-mott insulator transition. Metastable Helium, thanks to its large internal energy enables the high resolution detection. Using electronic detection systems, we can accurately reconstruct the 3d profile of the atomic cloud, which means we can calculate the correlation functions easily.

10. **Fate of topological states in a two-band fermionic chain in presence of Hubbard interaction**

Roberta Favata (Università degli Studi di Trieste)

Topological insulators are an emerging class of intriguing materials with unique electronic properties. The topological features of a system are commonly established at the non-interacting level and the fate of topological states in presence of strong interactions is a relevant and vivid topic of research in the condensed matter field. We explore the ground-state properties of a two-band fermionic chain supporting a symmetry-protected topological insulating phase, in the presence of Hubbard interaction. Starting from the non-interacting ground state, we define a two-orbital Jastrow-Slater wavefunction that provides a proper variational description of the topological phase diagram. The topological properties in the presence of interaction are detected by the many-body marker introduced by Resta and Sorella (Phys. Rev. Lett. 82, 370 (1999)). We also find that the topologically non-trivial behaviour of the system persists in the large U limit, where the spin-1 Haldane chain, characterized by string order, emerges as an effective spin Hamiltonian.

11. **A clock-magic quantum-gas microscope for ultracold strontium**

Carlos Gas Ferrer (ICFO)

Quantum-gas microscopes represent an outstanding tool for quantum simulations in optical lattices. Adding strontium to these systems opens access to a vast field of research topics. One of such topics is exotic magnetic phases in the SU(N) symmetric Fermi-Hubbard model with up to N=10 spin states. Furthermore, the available narrow transitions provide a useful tool to probe the prepared quantum many-body systems. Here, we present a quantum-gas microscope for bosonic and fermionic isotopes of strontium. In our experiment, we load ultracold strontium into a two-dimensional optical lattice potential operating at the magic wavelength 813nm of the clock transition. We probe these Hubbard systems with single-site resolution through a microscope objective exploiting attractive Sisyphus cooling with strontium's narrow-linewidth transition at 689nm. So far, we have demonstrated single atom detection of the fermionic 87Sr in the lattice, paving the way to study SU(N) Fermi-Hubbard physics where we are planning to implement spin resolved detection.

12. **Reweighted Time-Evolving Block Decimation for Improved Quantum Dynamics Simulations**

Sayak Guha Roy (Rice University)

We introduce a simple yet significant improvement to the time-evolving block decimation (TEBD) tensor network algorithm for simulating the time dynamics of strongly correlated one-dimensional (1D) mixed quantum states. The efficiency of 1D tensor network methods stems from using a product of matrices to express either: the coefficients of a wavefunction, yielding a matrix product state (MPS) or the expectation values of a density matrix, yielding a matrix product density operator (MPDO). To avoid exponential computational costs, TEBD truncates the matrix dimension while simulating the time evolution. However, when truncating a MPDO, TEBD does not favor the likely more important low-weight expectation values, such as $\langle c_i^\dagger c_j \rangle$, over the exponentially many high-weight expectation values, such as $\langle c_{i_1}^\dagger c_{i_2}^\dagger \cdots c_{i_n} \rangle$ of weight n, despite the critical importance of the significantly smaller number of low-weight expectation values. Motivated by this shortcoming, we propose a reweighted TEBD (rTEBD) algorithm that deprioritizes high-weight expectation values by a factor of γ^{-n} during the truncation. This simple modification, which only requires reweighting certain matrices by a factor of

γ in the MPDO, makes rTEBD significantly more accurate than the TEBD time-dependent simulation of an MPS or MPDO. Furthermore, by prioritizing low-weight expectation values, rTEBD preserves conserved quantities to high precision.

13. **Scale-invariant phase transition of disordered bosons in one dimension**

Tanul Gupta (University of Strasbourg)

The disorder-induced quantum phase transition between superfluid and non-superfluid states of bosonic particles in one dimension is generally expected to be of the Berezinskii-Kosterlitz-Thouless (BKT) type. Here, we show that hard-core lattice bosons with integrable power-law hopping decaying with distance as $1/r\alpha$ - corresponding in spin language to a XY model with power-law couplings - undergo a non-BKT continuous phase transition instead. We use exact quantum Monte-Carlo methods to determine the phase diagram for different values of the exponent α, focusing on the regime $\alpha > 2$. We find that the scaling of the superfluid stiffness with the system size is scale-invariant at the transition point for any $\alpha \leq 3$ - a behavior incompatible with the BKT scenario and typical of continuous phase transitions in higher dimension. By scaling analysis near the transition point, we find that our data are consistent with a correlation length exponent satisfying the Harris bound $\nu \geq 2$ and demonstrate a new universal behavior of disordered bosons in one dimension. For $\alpha > 3$ our data are consistent with a BKT scenario where the liquid is pinned by infinitesimal disorder.

14. **Kinetic magnetism and hole pairing in the doped bosonic t-J model**

Timothy Harris (LMU Munich)

Developing a precise theoretical description of the interplay between spin and charge degrees of freedom in doped Mott insulators is a central challenge at the heart of strongly correlated many-body physics, with implications for our understanding of high-temperature superconductivity and other exotic quantum phases. Here, we outline a new research direction that we are currently pursuing: exploring the strong coupling limit of doped bosonic quantum magnets, specifically the bosonic t-J model [1]. We present recent numerical results from large-scale density-matrix renormalization group (DMRG) calculations investigating the phase diagram of the two-dimensional (2D) antiferromagnetic (AFM) bosonic t-J model at finite doping [2]. In the case of only a few holes—the simplest instance in which the underlying bosonic statistics play a role—our results indicate a strong tendency for holes to form stripe or pair-density wave-like structures with predominantly AFM character, similar to those observed in high-Tc cuprate materials. As doping increases beyond a critical value, we observe clear signatures of an interaction-dependent crossover to itinerant ferromagnetism. These findings not only provide insight into the behavior of doped bosonic systems but also offer a new perspective on the exotic phases that arise in strongly correlated materials. Our results can be realized in state-of-the-art quantum simulation platforms, such as ultracold atoms trapped in optical lattices or tweezer arrays, paving the way for future studies to probe the exotic phases of doped bosonic quantum magnets in microscopic detail. [1] L. Homeier et al., PRL 132, 230401 (2024). [2] T. J. Harris et al., in preparation (2024).

15. **Cold atomic excitons**

Florian Hirsch (Universität Heidelberg)

In various solid state systems, the excitation of an electron from a completely filled valence band into an empty conduction band leads to a small binding energy between the electron-hole pair, called exciton. In the past years, cold atom systems have emerged as versatile platforms for simulating two-dimensional structures, such as hexagonal boron nitride (hBN) and transition metal dichalcogenides (TMDs). Recent experiments have for example managed to map the full band structure of a cold atom system in a honeycomb lattice. With all necessary experimental methods available and successfully utilized, we now investigate the existence of a different effect inspired from the solid state systems: excitons under short range interaction. We predict the existence of a similar atom-hole pair (atomic exciton) in a system of single-component fermionic atoms with nearest neighbour interactions. Our 2D lattice similar to hBN has a hexagonal structure with two different lattice site types, leading to a native two-band structure with nonzero bandgap. We use variational methods to find the energy spectrum of zero-momentum excitons in the single particle band operator basis, which form around the K/K'-point. We show that excitonic effects can be found over a large range of system parameters, which also includes currently accessible regions of band gap, tunnelling rate and nearest neighbour interaction strength. Furthermore,

we use Fermis Golden Rule to propose an already existing experimental procedure consisting of a perturbation operator followed by time-of-flight spectroscopy to probe the predicted states.

16. **Contextual Subspace Auxiliary-Field Quantum Monte Carlo: Improved bias with reduced quantum resources**

    Matthew Kiser (TUM / Volkswagen)

    Using trial wavefunctions prepared on quantum devices to reduce the bias of auxiliary-field quantum Monte Carlo (QC-AFQMC) has established itself as a promising hybrid approach to the simulation of strongly correlated many body systems. Here, we further reduce the required quantum resources by decomposing the trial wavefunction into classical and quantum parts, respectively treated by classical and quantum devices, within the contextual subspace projection formalism. Importantly, we show that our algorithm is compatible with the recently developed matchgate shadow protocol for efficient overlap calculation in QC-AFQMC. Investigating the nitrogen dimer and the reductive decomposition of ethylene carbonate in lithium-based batteries, we observe that our method outperforms a number of established algorithm for ground state energy computations, whilst reaching chemical accuracy with less than half of the original number of qubits.

17. **Density Matrix Renormalization Group for Non-Hermitian Transcorrelated Hamiltonians**

    Ke Liao (LMU)

    Transcorrelation incorporates known physics, such as, but not limited to, the Kato cusp condition, in the similarity-transformation on the Hamiltonian. It has been shown to improve both the efficiency and accuracy of various non-variational methods for strongly correlated electron systems, such as the 2D Hubbard model, the 3D uniform electron gas, as well as molecules and solids. However, the transcorrelated Hamiltonian is non-Hermitian and has up to 3-body interactions. By using the stationary condition, a small modification to the original DMRG algorithm makes it possible to treat non-Hermitian transcorrelated Hamiltonians. The resulting algorithm achieves much faster basis set convergence rate and needs lower bond dimensions to converge to the exact solution. Numerical examples on the strongly correlated ground state of the N2 molecule along its dissociation path will be presented. A preliminary example on the 1st excited state of the H2O molecule will also be shown.

18. **Vertex Representation of Hyperbolic Tensor Networks**

    Matej Moško (Institute of Physics, Slovak Academy of Sciences)

    We propose a vertex representation of the tensor network (TN) that we model on a set of hyperbolic lattices, including the square lattice (arXiv:2406.03426). The response to multi-state spin systems on the hyperbolic TN is analyzed for their entire parameter space. We test the numerical accuracy of vertex TNs in the phase transitions of the first, second, and infinite order at the point of maximal entanglement entropy. The hyperbolic structure of TNs induces non-critical properties in the bulk. We confirm the equivalence between the vertex and the weight (IRF) representation of TN apart from the entanglement entropy. This discrepancy is investigated. Thus developed vertex-type TN can be applied to study low-energy quantum states on negatively curved surfaces.

19. **Entanglement enhancement induced by noise in inhomogeneously monitored systems**

    Cristiano Muzzi (SISSA)

    In this work, we study the entanglement enhancement induced by noise, a counterintuitive phenomenon occurring in inhomogeneously monitored quantum systems. We consider a free fermions model composed of two coupled chains – a system chain and an ancilla chain, each subject to its own noise – and explore the dynamics of entanglement within the system chain under different noise intensities. Our results demonstrate that, contrary to the detrimental effects typically associated with noise, certain regimes of noise on the ancilla can significantly enhance entanglement within the system. Numerical simulations demonstrate the robustness of entanglement enhancement across various system sizes and noise parameters. This enhancement is found to be highly dependent on the hopping strength in the ancilla, suggesting that the interplay between unitary dynamics and noise can be tuned to optimize entanglement.

20. **Improved scaling of QC-AFQMC using matchgate shadows**

Francesco Nappi (LMU Munich and IQM Germany GmbH)

Quantum Computing Auxillary Fields Quantum Monte Carlo (QC-AFQMC) is a hybrid quantum-classical approach designed to tackle strongly correlated many-electron systems. The main idea behind this method is to guide classical AFQMC calculations with trial states prepared on quantum devices. This approach, however, initially suffered from an exponentially scaling overhead in the computational time as a function of system size due to the inefficient computation of overlaps between the quantum trial state and classical Slater-determinant Monte Carlo walkers. This computational bottleneck was later reduced to a polynomial scaling by the introduction of a classical shadow protocol based on matchgate circuits described by fermionic Gaussian unitaries. This has shifted the burden of the computational cost onto the classical side, which was shown to scale as $O(N^9)$, where N is the number of qubits. In this work, we show how to further improve the classical scaling to $O(N^4)$. We then implement our improved QC-AFQMC method on real quantum devices for molecular systems defined on up to 12 qubits and empirically analyse the impact of multi-shot shadows — a scheme where the same matchgate circuit is measured many times — on the variance of overlap calculations in order to further accelerate QC-AFQMC.

21. **Spin-polarized point crossings in 2D altermagnets**

Kirill Parshukov (Max Planck Institute for Solid State Research, Stuttgart)

We study the symmetry requirements for topologically protected spin-polarized Weyl points in 2D altermagnets. The topology is characterized by a quantized -Berry phase and the degeneracy is protected by spin-space group symmetries. Gapped phases with finite Chern and/or spin Chern numbers emerge under different symmetry-breaking mass terms. We investigate the surface and transport properties of these gapped phases using representative electronic tight-binding model. In particular, we calculate the electronic Hall currents and discuss implications for experiments.

22. **Probing magnetism in moiré heterostructures with quantum twisting microscopes**

Fabian Pichler (Technische Universität München (TUM))

Spin-ordered states close to metal-insulator transitions are poorly understood theoretically and challenging to probe in experiments. Here, we propose that the quantum twisting microscope, which provides direct access to the energy-momentum resolved spectrum of single-particle and collective excitations, can be used as a novel tool to distinguish between different types of magnetic order. To this end, we calculate the single-particle spectral function and the dynamical spin-structure factor for both a ferromagnetic and antiferromagnetic generalized Wigner crystal formed in fractionally filled moiré superlattices of transition metal dichalcogenide heterostructures. We demonstrate that magnetic order can be clearly identified in these response functions. Furthermore, we explore signatures of quantum phase transitions in the quantum twisting microscope response. We focus on the specific case of triangular moiré lattices at half filling, which have been proposed to host a topological phase transition between a chiral spin liquid and a 120 degree ordered state. Our work demonstrates the potential for quantum twisting microscopes to characterize quantum magnetism in moiré heterostructures.

23. **Real-frequency quantum field theory applied to the single-impurity Anderson model**

Nepomuk Ritz (LMU Munich)

A major challenge in the field of correlated electrons is the computation of dynamical correlation functions. For comparisons with experiment, one is interested in their real-frequency dependence. This is difficult to compute because imaginary-frequency data from the Matsubara formalism require analytic continuation, a numerically ill-posed problem. Here, we apply quantum field theory to the single-impurity Anderson model using the Keldysh instead of the Matsubara formalism with direct access to the self-energy and dynamical susceptibilities on the real-frequency axis. We present results from the functional renormalization group (fRG) at the one-loop level and from solving the self-consistent parquet equations in the parquet approximation. In contrast with previous Keldysh fRG works, we employ a parametrization of the four-point vertex which captures its full dependence on three real-frequency arguments. We compare our results to benchmark data obtained with the numerical renormalization group and to second-order perturbation theory. We find that capturing the full frequency dependence of the four-point vertex significantly improves the fRG results compared with previous implementations, and that solving the parquet equations yields the best agreement with the numerical renormalizati-

on group benchmark data but is only feasible up to moderate interaction strengths. Our methodical advances pave the way for treating more complicated models in the future.

24. **Variational Simulation of 2D Lattice Fermions with Neural Quantum States**

    Imelda Romero (EPFL)

    Neural networks have shown to be a powerful tool to represent ground state of quantum many-body systems, including for fermionic systems. In this work, we introduce a framework for embedding lattice symmetries in Neural Slater-Backflow-Jastrow wavefunction ansatzes, and demonstrate how our model allows us to target the ground state and low-lying excited states. To capture the Hamiltonian symmetries, we introduce group-equivariant backflow transformations. We study the low-energy excitation spectrum of the t-V model on a square lattice away from half-filling, and find that our symmetry-aware backflow significantly improves the ground-state energies, and yields accurate low-lying excited states for up to 10×10 lattices.

25. **(Almost) Everything is a Dicke model**

    Andreas Schellenberger (Friedrich-Alexander-Universität Erlangen-Nürnberg)

    We investigate interacting quantum spin systems in a single-mode cavity with a Dicke coupling, as a paradigmatic example of correlated light-matter systems. Coming from the limit of weak light-matter couplings and large system sizes, we map the relevant low-energy sector of these models in the non-superradiant phases onto the exactly solvable Dicke model [1]. The results are discussed and verified at the example of the Dicke-Ising model using exact diagonalisation and series expansions [2]. [1] A. Schellenberger, K. P. Schmidt, SciPost Phys. Core 7, 038, 2024, [2] L. Lenke et al., Phys. Rev. A, 108, 2023

26. **Dynamical Instabilities of Ultracold Fermions in an Optical Cavity**

    Luka Skolc (ETHZ)

    Recent observations of in vivo dynamics of ultracold fermions in an optical cavity subject to a quench of the light-matter coupling across the super-radiance transition have shed light on the instabilities that underlie the dynamics of self-organization in long-ranged interacting quantum many-body systems. Motivated by these experiments, we uncover the exponentially growing polaritonic mode associated with the instability towards self-organization. Beyond computing the rate at which density wave order and the photon population grow, we quantify the fluctuations of the pre-quench state which seed the instability. We show that our results fit existing experiments on free fermions. Furthermore, we make predictions for quench experiments involving strongly interacting fermi gases coupled to an optical cavity. Our results suggest that the non-local nature of the photon-mediated interactions between fermions produces a novel context in which the dynamics of self-organization are qualitatively different than the ordering dynamics of short-ranged interacting quantum many-body systems.

27. **Efficient quantum algorithm to simulate open systems through a single environmental qubit**

    Michele Vischi (University of Trieste)

    We present an efficient algorithm for simulating open quantum systems dynamics described by the Lindblad master equation on quantum computers, addressing key challenges in the field. In contrast to existing approaches, our method achieves two significant advancements. First, we employ a repetition of unitary gates on a set of n system qubits and, remarkably, only a single ancillary bath qubit representing the environment. It follows that, for the typical case of m-locality of the Lindblad operators, we reach an exponential improvement of the number of ancilla in terms of m and up to a polynomial improvement in ancilla overhead for large n with respect to other approaches. Although stochasticity is introduced, requiring multiple circuit realizations, the sampling overhead is independent of the system size. Secondly, we show that, under fixed accuracy conditions, our algorithm enables a remarkable reduction in the number of trotter steps compared to previous literature, substantially decreasing circuit depth. These advancements hold particular significance for near-term quantum computers, where minimizing both width and depth is critical due to inherent noise in their dynamics.

28. **Transformer Wave Function for the Shastry-Sutherland Model: emergence of a Spin-Liquid Phase**

Luciano Loris Viteritti (University of Trieste)

Quantum magnetism in two-dimensional systems represents a lively branch of modern condensed-matter physics. In the presence of competing super-exchange couplings, magnetic order is frustrated and can be suppressed down to zero temperature, leading to exotic ground states. The Shastry-Sutherland model, describing S=1/2 degrees of freedom interacting in a two-dimensional lattice, portrays a simple example of highly-frustrated magnetism, capturing the low-temperature behavior of SrCu2(BO3)2 with its intriguing properties. Here, we investigate this problem by using a Vision Transformer to define an extremely accurate variational wave function. From a technical side, a pivotal achievement relies on using a deep neural network with real-valued parameters, parametrized with a Transformer, to map physical spin configurations into a high-dimensional feature space. Within this abstract space, the determination of the ground-state properties is simplified, requiring only a single output layer with complex-valued parameters. From the physical side, we supply strong evidence for the stabilization of a spin-liquid between the plaquette and antiferromagnetic phases. Our findings underscore the potential of Neural-Network Quantum States as a valuable tool for probing uncharted phases of matter, opening opportunities to establish the properties of many-body systems.

29. **A logical qubit-design with geometrically tunable error-resistibility**

Reja Helene Wilke (LMU Munich)

Breaking the error-threshold would mark a milestone in establishing quantum advantage for a wide range of relevant problems. One possible route is to encode information redundantly in a logical qubit by combining several noisy qubits, providing an increased robustness against external perturbations. We propose a setup for a logical qubit built from superconducting qubits (SCQs) coupled to a microwave cavity-mode. Our design is based on a recently discovered geometric stabilizing mechanism in the Bose-Hubbard wheel (BHW), which manifests as energetically well-separated clusters of many-body eigenstates. We investigate the impact of experimentally relevant perturbations between SCQs and the cavity on the spectral properties of the BHW. We show that even in the presence of typical fabrication uncertainties, the occurrence and separation of clustered many-body eigenstates is extremely robust. Introducing an additional, frequency-detuned SCQ coupled to the cavity yields duplicates of these clusters, that can be split up by an on-site potential. We show that this allows to (i) redundantly encode two logical qubit states that can be switched and read out efficiently and (ii) can be separated from the remaining many-body spectrum via geometric stabilization. We demonstrate at the example of an X-gate that the proposed logical qubit reaches single qubit-gate fidelities < 0.999 in experimentally feasible temperature regimes $\sim 10 - 20mK$.