Symposium

Neural Quantum States for Time Evolution
Challenges and Opportunities

Forschungszentrum Jülich

18^{th} to 20^{th} of November 2024

Contents

Overview

Welcome to the symposium "Neural Quantum States for Time Evolution – Challenges and Opportunities" at the University of Regensburg. Below you can find an overview of the symposium schedule, please note that the symposium does not take place in the same room Tuesday as it does on Monday and Wednesday.

Time	**Monday**	**Tuesday**	**Wednesday**
Room		PHY 7.3.14	DE._2.121*
08:45		Jannes Nys	Jonas Rigo
09:30		Zakari Denis	Juan Carrasquilla
10:15		Coffee break	Coffee break
11:00		Markus Heyl	Discussion
11:45		Gianluca Lagnese	
12:30		Lunch at Mensa	
Room	DE._2.121*	H37	
13:00	Registration		
13:45	Welcome	Group picture	
14:00	Matija Medvidović	Annabelle Bohrdt	
14:45	Martin Gärttner	Johannes Zeiher	
15:30	Coffee break	Coffee break	
16:15	Marín Bukov	Poster session	
17:00	Filippo Vicentini		
18:00	Coffee break		
19:30		Dinner at *Wanderlust*	

At the start of the event (Monday 13:00) we ask all participants (who join on Monday) to register at the room DE. 2.121* to receive their name tag, pen and notepad.

On Tuesday lunch is scheduled at the University Mensa, after which the group photo will be taken. All locations are on campus and orientation is easy with the *ur-walking* web-page. The webpage is linked via the QR code to the right. **All location names in this document are clickable links that will guide you from the central Mensa building to the respective event location.**

The symposium dinner takes place on Tuesday at 19:30 at the restaurant *Wanderlust* in Regensburg city center. The restaurant's location is linked via the QR code on the right.

The organizers are thankful to the *Young Excellent Scientist program* at Forschungszentrum Jülich for the funds that allowed this symposium. Special thanks go to the University of Regensburg for providing the venues for this event.

Enjoy the symposium,
The Organizers

Jonas Rigo
Nataliia Voievoda
Markus Schmitt

Schedule

Monday 18th

Time	Speaker / Session	Room
13:45	Welcome	DE._2.121*
14:00	Matija Medvidović	DE._2.121*
14:45	Martin Gärttner	DE._2.121*
15:30	Coffee	
16:15	Marín Bukov	DE._2.121*
17:00	Filippo Vicentini	DE._2.121*
18:00	Coffee	

Variational dynamics of continuous-variable quantum rotor models

18 Nov 14:00

Matija Medvidović

ETH Zürich

Time-dependent variational Monte Carlo (t-VMC) has emerged as a powerful method of simulating real-time dynamics of correlated quantum systems in the recent years. With wider adoption of variational states based on neural networks, these methods have started to reach experimentally relevant time scales. However, despite rapid progress and growing interest, the t-VMC method is still relatively difficult to control and implement in high-parameter regimes of interest. After introducing the method, in this talk I will outline open problems in the field on a specific example of

the quantum rotor model where the method has been successfully applied to a problem with continuous degrees of freedom.

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18 Nov
14:45

Solving quantum and classical dissipative dynamics with artificial neural networks

Martin Gärttner

Friedrich-Schiller-University Jena

We develop a variational approach to simulating the dynamics of open quantum and classical many-body systems using artificial neural networks. The parameters of a compressed representation of a probability distribution are adapted dynamically according to the Lindblad master equation or Fokker Planck equation, respectively, by employing a time-dependent variational principle. We illustrate our approach by solving the dissipative quantum Heisenberg model in one and two dimensions for up to 40 spins and by applying it to the simulation of confinement dynamics in the presence of dissipation. Also, we use normalizing flows to variationally solve diffusive classical dynamics in high dimensions.

Reinforcement learning for quantum error correction

18 Nov
16:15:00

Marín Bukov

Max Planck Institute for the Physics of Complex Systems

Reinforcement learning has proven a successful tool for developing quantum technologies; among applications such as quantum control, gate implementation, circuit synthesis, etc., quantum error correction stands out as a particularly promising new direction. In this talk, we will first give a brief introduction to RL and quantum error correction, and then discuss state of the art results of using RL as a decoder for coherent error channels. Time permitting, we will discuss preliminary results on RL-enhanced decoders for incoherent quantum error correction, where state-of-the-art decoders such as Minimal Weight Perfect Matching, are known to perform suboptimally.

Diving beyond t-VMC with state compression and tailored integration schemes

18 Nov
17:00

Filippo Vicentini

École Polytechnique

TBA

Tuesday 19th

Time	Speaker / Session	Room
08:45	Jannes Nys	PHY 7.3.14
09:30	Zakari Denis	PHY 7.3.14
10:15	Coffee	
11:00	Markus Heyl	PHY 7.3.14
11:45	Gianluca Lagnese	PHY 7.3.14
13:45	Lunch	Mensa
14:00	Annabelle Bohrdt	H37
14:45	Johannes Zeiher	H37
15:30	Coffee	
16:15	Poster session	H37
17:00	–	H37
19:30	Dinner	Wanderlust

19 Nov
08:45

Fermions in Motion: A New Approach to Quantum Dynamics

Jannes Nys
ETH Zürich

Describing the real-time evolution of many-electron quantum systems is crucial for understanding the dynamical properties of condensed matter, molecular systems in quantum chemistry, and the behaviors of complex materials. However, the real-time evolution of non-equilibrium quantum electronic systems poses a significant challenge for theoretical and computational approaches. This work introduces a variational approach for fermionic time-dependent wave functions, surpassing mean-field approximations by capturing many-body correlations. Our methodology introduces a parameterization of the time-evolving quantum state, enabling an accurate approximation of its evolution. We utilize the time-dependent variational Monte Carlo technique to efficiently

compute optimal time-dependent parameters. Additionally, we introduce a new time-evolution method based on Taylor-root expansions of the propagator, enhancing the accuracy and efficiency of our simulations. The results showcase the ability of our variational approach to accurately capture the time evolution of quantum states, providing insight into the quantum dynamics of interacting electronic systems, beyond the capabilities of mean-field.

Real-time quantum dynamics of thermal states with neural thermofields

19 Nov
09:30

Zakari Denis

École Polytechnique Fédérale de Lausanne

Solving the time-dependent quantum many-body Schrödinger equation is a challenging task, especially for states at a finite temperature, where the environment affects the dynamics. Most existing approximating methods are designed to represent static thermal density matrices, 1D systems, and/or zero-temperature states. In this work, we propose a method to study the real-time dynamics of thermal states in two dimensions, based on thermofield dynamics, variational Monte Carlo, and neural-network quantum states. To this aim, we introduce two novel tools: (i) a procedure to accurately simulate the cooling down of arbitrary quantum variational states from infinite temperature, and (ii) a generic thermal (autoregressive) recurrent neural-network (ARNNO) Ansatz that allows for direct sampling from the density matrix using thermofield basis rotations. We apply our technique to the transverse-field Ising model subject to an additional longitudinal field and demonstrate that the time-dependent observables, including correlation operators, can be accurately

reproduced for a 4×4 spin lattice. We provide predictions of the real-time dynamics on a 6×6 lattice that lies outside the reach of exact simulations.

Dynamics of quantum matter with classical networks and neural quantum states

19 Nov
11:00

Markus Heyl

Universität Augsburg

Neural quantum states have emerged as a novel promising numerical method to solve the quantum many-body problem both in and out of equilibrium. In this talk I will discuss recent developments and challenges. I will also highlight potential ways to solve for some of these challenges.

Positive Operator Valued Measures Neural Networks for simulation of light-matter coupled systems.

19 Nov
11:45

Gianluca Lagnese

Institute Jozef Stefan

Recent advances in quantum simulation are focused on combining matter and light to engineer new types of interactions, typically characterized by long-range effects, requiring the devel- opment of advanced numerical simulation techniques. For instance, ordered arrays of atoms placed at distances smaller than the wavelength of light display photo-mediated long-range dipole-dipole interactions and a peculiar correlated emission. The main features observed when starting from a highly excited initial state are a superradiant

burst at short times, followed by a non-trivial "subradiant" critical regime with a slow power-law relaxation [2]. By integrating out the photonic degrees of freedom, the dynamics are effectively described by a Lindblad equation with long-range interactions and dissipation. To simulate these dynamics, we employ a recently proposed numerical approach [1] that combines a positive operator-valued measure (POVM) de- scription of the density matrix — approximated by a neural network — with a time-dependent variational principle (TDVP) to project the evolution of the state onto the neural network manifold. We explore upscaling to larger system sizes as a complementary tool to standard tensor network techniques, especially for long-range interactions and two-dimensional setups. From a more physical perspective, by applying a time-dependent Generalized Gibbs Ensemble Ansatz, we uncover the role of (approximate) integrability at long times, which leads to the observed polynomial decay. [1] M. Reh, M. Schmitt, and M. Gättner, Phys. Rev. Lett. 127, 230501 (2021). [2] L. Henriet, J. S. Douglas, D. E. Chang, and A. Albrecht Phys. Rev. A 99, 023802 (2019).

Solving the (time-dependent) Schrödinger equation

19 Nov
14:00

Annabelle Bohrdt
Universität Regensburg

Simulating the time evolution of interacting quantum systems is in general a very hard problem. Quantum simulation experiments, such as cold atoms in optical lattices, are naturally well suited to study closed system dynamics. A bottleneck for these setups are slow data taking rates, which

enable experimentalists typically only to get a limited number of projective measurements at a limited number of time steps. In this talk, I will (i) demonstrate how limited, noisy, experimental data can be useful in a hybrid approach for ground state searches using neural quantum states (NQS); and (ii) introduce a new NQS based method to simulate the time evolution of interacting quantum many-body systems.

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19 Nov
14:45am

Quantum-gas microscopy of Hubbard systems

Johannes Zeiher

Max-Planck-Institute of Quantum Optics

Neutral atoms trapped in optical lattices are a versatile platform to study many-body physics in and out of equilibrium. Quantum gas microscopes provide an excellent toolbox to prepare, control and detect such systems at the level of individual atoms. First, I will present our recent work on realizing long-range interacting Ising and Hubbard models for Rubidium atoms in optical lattices. Using off-resonant coupling from ground to Rydberg states, we induce tunable interactions via the excitation light. We probe interactions in different experiments on frozen spin systems and the itinerant regime, where they stabilize initial out-of-equilibrium states. In particular, we also observe the buildup of density-density correlations when probing a one-dimensional extended Hubbard system near equilibrium. Second, I will introduce a new strontium setup that combines large-scale optical lattices with local control achieved through tweezer arrays. I will present our efforts on loading, cooling, and imaging individual strontium atoms in optical tweezers and lattices,

where we obtain high-fidelity and low-loss imaging performance using repulsive Sisyphus-cooling. Combining optical tweezer arrays with lattices opens new perspectives to scale tweezer-based quantum simulators to larger system sizes and offers an alternative preparation route of assembled Hubbard systems in optical lattices with the prospect of combining analog and digital quantum simulation capabilities.

Wednesday 20th

Time	Speaker / Session	Room
08:45	Jonas Rigo	DE._2.121*
09:30	Juan Carrasquilla (online)	DE._2.121*
10:15	Coffee	
11:00	Discussion	DE._2.121*

Neural quantum states for (non-) equilibrium dynamics

20 Nov
08:45

Jonas Rigo

Forschungszentrum Jülich

Neural quantum states (NQS) offer a promising framework for compressing complex many-body wave functions, including those with challenging volume-law entanglement. Despite their potential, practical limitations remain unclear, largely due to the technical challenges associated with their optimization. In this talk, I empirically investigate how the parameter scaling of NQS evolves with time in representing

the time-dependent wave function for critical quench dynamics. My findings show that, with carefully tailored architectures and optimization strategies, NQS achieve a parameter cost comparable to the gold-standard tensor network methods. We extend this approach to ground state searches of quantum impurity models and their equilibrium dynamics, demonstrating that NQS successfully capture these ground states. This capability shows their potential as a novel DMFT solver.

Neural network simulation of a spin glass dynamics transition

20 Nov
09:30
online

Juan Carrasquilla
ETH Zürich

I will explain a recent experiment about the simulation of nonequilibrium dynamics of a magnetic spin system quenched through a quantum glass phase transition and our attempt at using neural networks to simulate the dynamics seen in the experiment.

Contributed abstract

The contributed abstracts for Tuesday's poster session are listed here.

Neural Quantum States and Peaked Molecular Wave Functions: Curse or Blessing?

Aleksei Malyshev
ETH Zürich

The field of neural quantum states has recently experienced a tremendous progress, making them a competitive tool of computational quantum many-body physics. However, their largest achievements to date mostly concern interacting spin systems, while their utility for quantum chemistry remains yet to be demonstrated. Two main complications are the peaked structure of the molecular wave functions, which impedes sampling, and large number of terms in second quantised Hamiltonians, which hinders scaling to larger molecule sizes. In this paper we address these issues jointly and argue that the peaked structure might actually be key to drastically more efficient calculations. Specifically, we introduce a novel algorithm for autoregressive sampling without replacement and a procedure to calculate a computationally cheaper surrogate for the local energy. We complement them with a custom modification of the stochastic reconfiguration optimisation technique and a highly optimised GPU implementation. As a result, our calculations require substantially less resources and exhibit more than order of magnitude speedup compared to the previous works. On a single GPU we study molecules comprising up to 118 qubits and outperform the

"golden standard" CCSD(T) benchmark in Hilbert spaces of $\sim 10^15$ Slater determinants, which is orders of magnitude larger than what was previously achieved. We believe that our work underscores the prospect of NQS for challenging quantum chemistry calculations and serves as a favourable ground for the future method development.

Unbiasing time-dependent Variational Monte Carlo by projected quantum evolutio

Alessandro Sinibaldi

École Polytechnique Fédérale de Lausanne

We analyze the accuracy and sample complexity of variational Monte Carlo approaches to simulate the dynamics of many-body quantum systems classically. By systematically studying the relevant stochastic estimators, we are able to: (i) prove that the most used scheme, the time-dependent Variational Monte Carlo (tVMC), is affected by a systematic statistical bias or exponential sample complexity when the wave function contains some (possibly approximate) zeros, an important case for fermionic systems and quantum information protocols; (ii) show that a different scheme based on the solution of an optimization problem at each time step is free from such problems; (iii) improve the sample complexity of this latter approach by several orders of magnitude with respect to previous proofs of concept. Finally, we apply our advancements to study the high-entanglement phase in a protocol of non-Clifford unitary dynamics with local random measurements in 2D, first benchmarking on small spin lattices and then extending to large systems.

The statistical mechanics and machine learning of the Renyi ensemble

Andrew Jreissaty
ETH Zürich

We study the statistical physics of the classical Ising model in the so-called α-Renyi ensemble, a finite-temperature thermal state approximation that minimizes a modified free energy based on the α-Renyi entropy. We begin by characterizing its critical behavior in mean-field theory in different regimes of the Renyi index α. Next, we re-introduce correlations and consider the model in one and two dimensions, presenting an exact analysis of the former and devising an unconventional Monte Carlo approach to the study of the latter. Remarkably, we find that while mean-field predicts a continuous phase transition below a threshold index value of $\alpha \sim 1.303$ and a first-order transition above it, the Monte Carlo results in two dimensions point to a continuous transition at all α. We conclude by performing a variational minimization of the α-Renyi free energy using a recurrent neural network (RNN) ansatz where we find that the RNN performs well in two dimensions when compared to the Monte Carlo simulations. Our work highlights the potential opportunities and limitations associated with the use of the α-Renyi ensemble formalism in probing the thermodynamic equilibrium properties of classical and quantum systems. See `https://arxiv.org/abs/2404.04005` for more info.

Combining time dependent neural quantum state and state reconstruction for quench dynamics

Anka Van de Walle

LMU Münich

Despite very promising results, capturing the dynamics of complex quantum systems with neural-network ansätze has been afflicted by several problems, largely due to, among other challenges, rapid entanglement growth and stochastic noise. Drawing on concepts from time-dependent variational Monte Carlo, we aim to solve the time dependent Schrödinger equation after a quench and enhance the expressive capacity of NQS by implementing a time dependent encoder, as NQS transformers have the advantage that they can implement context in their training. We combine this method with state reconstruction using data from quantum simulator experiments, resulting in a hybrid approach. As a test we apply these methods to time-dependent quench dynamics of the one-dimensional quantum Ising model.

Simulating fractional quantum Hall states using two-dimensional tensor networks

Bart Andrews
ETH Zürich

The simulation of strongly-interacting quantum many-body systems is a long-standing problem in computational physics. Although tensor network methods are highly efficient in one dimension, the development of two-dimensional tensor network methods is still in progress. In this project, we compare the performance of a variety of two-dimensional tensor network algorithms in finding the ground states of particularly challenging fractional quantum Hall states. We show that an imaginary-time stochastic reconfiguration VMC algorithm on top of a PEPS ansatz can, in certain cases, outperform traditional DMRG-based approaches.

Phase Space Dynamics of Continuous-Variable, Open Bosonic Systems with Generative Neural Quantum States

Ege Görgün
iation Friedrich Schiller University Jena

Simulating the dynamics of interacting many-body quantum systems poses a significant challenge due to the exponential complexity scaling with system size. In this work, we derive the quantum master equation for phase space quasi-probability distributions across a diverse set of open bosonic systems, providing an analytical basis for tracking their dynamics. We will then present a neural quantum state (NQS)

ansatz based on an invertible neural network (INN) trained within a time-dependent variational principle (TDVP) framework, offering a versatile approach for modelling the phase space dynamics of a broad class of continuous-variable systems. Leveraging the inherent invertibility of INNs, our model will provide a robust architecture that can serve not only as an efficient Monte Carlo sampler but also enable direct access to probability distributions over time through latent space dynamics.

Measuring the Loschmidt Amplitude for Finite-Energy Properties of the Fermi-Hubbard Model on an Ion-Trap Quantum Computer

Kevin Hémery
Quantinuum

Calculating the equilibrium properties of condensed-matter systems is one of the promising applications of near-term quantum computing. Recently, hybrid quantum-classical time-series algorithms have been proposed to efficiently extract these properties from a measurement of the Loschmidt amplitude, which is defined as the overlap between an initial state and its time evolved state. In this work, we study the operation of this algorithm on a present-day quantum computer. Specifically, we measure the Loschmidt amplitude for the Fermi-Hubbard model on a 16-site ladder geometry (32 orbitals) on the Quantinuum H2-1 trapped-ion device. We assess the effect of noise on the Loschmidt amplitude and implement algorithm-specific error-mitigation techniques. By using a thus-motivated error model, we numerically analyze

the influence of noise on the full operation of the quantum-classical algorithm by measuring expectation values of local observables at finite energies.

[1] K. Hémery et al., Measuring the Loschmidt Amplitude for Finite-Energy Properties of the Fermi-Hubbard Model on an Ion-Trap Quantum Computer, PRX Quantum 5, 030323 (2024) [2] S. Lu, M. C. Bañuls, and J. I. Cirac, Algorithms for quantum simulation at finite energies, PRX Quantum 2, 020321 (2021) [3] A. Schuckert, A. Bohrdt, E. Crane, and M. Knap, Probing finite-temperature observables in quantum simulators of spin systems with short-time dynamics, Phys. Rev. B 107, L140410 (2023)

Predicting Topological Entanglement Entropy in a Rydberg analog simulator

Linda Mauron

Ecole Polytechnique Federale de Lausanne

Predicting the dynamical properties of topological matter is a challenging task, not only in theoretical and experimental settings, but also numerically. This work proposes a variational approach based on a time-dependent correlated Ansatz, focusing on the dynamical preparation of a quantum spin-liquid state on a Rydberg-atom simulator. Within this framework, we are able to faithfully represent the state of the system throughout the entire dynamical preparation protocol. The flexibility of our approach does not only allow one to match the physically correct form of the Rydberg-atom Hamiltonian but also the relevant lattice topology. This is unlike previous numerical studies which were constrained to simplified versions of the problem through the modification

of both the Hamiltonian and the lattice. Our approach further gives access to global quantities such as the topological entanglement entropy (γ), providing insight into the topological properties of the system. This is achieved by the introduction of the time-dependent variational Monte Carlo (t-VMC) technique to the dynamics of topologically ordered phases. Upon employing a Jastrow variational Ansatz with a scalable number of parameters, we are able to efficiently extend our simulations to system sizes matching state-of-the-art experiments and beyond. Our results confirm the topological properties of the state during the dynamical preparation protocol, and additionally deepen our understanding of topological entanglement dynamics. We show that, while the simulated state exhibits local properties resembling those of a resonating-valence-bond (RVB) state, as experimentally observed, it lacks the latter's characteristic topological entanglement entropy signature $\gamma = \ln(2)$, irrespective of the degree of adiabaticity of the protocol.

Neural Projected Quantum Dynamics: a systematic study

Luca Gravina

Ecole Polytechnique Federale de Lausanne

Simulating quantum dynamics is crucial for many areas, including material science, quantum chemistry, and quantum information, but faces challenges due to the exponential growth of the Hilbert space. While tensor network methods, like Matrix Product States (MPS), work well for 1D systems with short-range interactions, they struggle with higher-dimensional systems due to high computational costs and the need for uncontrolled approximations. Neural Quantum States (NQS)

offer a promising alternative by compressing quantum states into a polynomial number of parameters, without restrictions on system geometry. However, neural networks come with optimization challenges, including stochasticity and difficulty in setting error bounds. Two main variational algorithms exist for simulating quantum dynamics: time-dependent Variational Monte Carlo (tVMC) and projected tVMC (p-tVMC). While tVMC is computationally less expensive, it introduces biases and numerical issues, especially for deep neural networks. p-tVMC, although more computationally intensive, decouples the physical dynamics from the optimization process, providing a more structured analysis. In my presentation I will addresses both discretization and optimization challenges in p-tVMC. I will introduce our novel higher-order integration schemes tailored to p-tVMC, and present an adaptive optimization strategy that improves performance and usability. Finally, I will show benchmarks of p-tVMC on a 2D quantum quench problem, demonstrating improvements in accuracy and scalability.

Towards the chaotic melting at low energies in large systems

Mathias Steinhuber
University of Regensburg

Thinking in a classical phase space picture, a many-body ground state should be localized around the minimum of classical mean-field energy landscape with stable integrable features. But here, we investigate many- body ground states on chaotic features, as the phase space picture is actually fragile if we increase the system size and keep the quantum scale (the effective Plank constant $\hbar_{eff}$ fixed. With

the new degrees of freedom, we disturb the energy landscape in the classical limit more and more such that classical chaos is present even for low energies. We show this phenomenon, called 'chaotic melting' [1,2], is indeed happening in the Bose-Hubbard system with disorder. By using neural quantum states we can push quantum calculations for ground states to large systems and find signatures of chaos at the ground state. An intriguing application for these large systems is that the Bose-Hubbard Hamiltonian with disorder is an effective model for transmon arrays which are a prime candidate for quantum computer hardware. Therefore we also gain access to quantum states describing a possible quantum computer with chaotic features.

[1] Simon-Dominik Börner, Christoph Berke, David P. DiVincenzo, Simon Trebst, and Alexander Altland. Classical chaos in quantum computers. Phys. Rev. Research 6, 033128 (2024)
[2] J. Chavez-Carlos, M. A. P. Reynoso, I. Garcıa-Mata, V. S. Batista, F. Perez-Bernal, D. A. Wisniacki, and L. F. Santos. Driving superconducting qubits into chaos. arXiv: 2310.17698 (2024)

Scaling of neural-network quantum states for time evolution

Sheng-Hsuan Lin
Quantinuum

Simulating quantum many-body dynamics on classical computers is a challenging problem due to the exponential growth of the Hilbert space. Artificial neural networks have recently been introduced as a new tool to approximate quantum-many body states. We benchmark the variational power of the restricted Boltzmann machine quantum states and different shallow and deep neural autoregressive quantum states to simulate global quench dynamics of a non-integrable quantum Ising chain. We find that the number of parameters required to represent the quantum state at a given accuracy increases exponentially in time. The growth rate is only slightly affected by the network architecture over a wide range of different design choices: shallow and deep networks, small and large filter sizes, dilated and normal convolutions, with and without shortcut connections.

Towards solving of many-body dynamics in waveguide QED using tensor- and neural-network techniques

Tatiana Vovk
IQOQI Innsbruck

The solution of collective dynamics of an array of emitters near a one-dimensional waveguide is crucial for understanding the performance of relevant experimental platforms. However, beyond the standard Dicke regime such a problem

is hard to solve due to a rapid growth of quantum correlations within the system. In this work we investigate the challenges of tensor-network approaches to solve this problem and propose a way to potentially overcome this obstacle using neural-network methods.

Simulating fractional quantum Hall states using two-dimensional tensor networks

Yantao Wu

RIKEN iTHEMS

The simulation of strongly-interacting quantum many-body systems is a long-standing problem in computational physics. Although tensor network methods are highly efficient in one dimension, the development of two-dimensional tensor network methods is still in progress. In this project, we compare the performance of a variety of two-dimensional tensor network algorithms in finding the ground states of particularly challenging fractional quantum Hall states. We show that an imaginary-time stochastic reconfiguration VMC algorithm on top of a PEPS ansatz can, in certain cases, outperform traditional DMRG-based approaches.
