Pre 2025 TPS miniworkshop

Report of Contributions

Contribution ID: **1** Type: **not specified**

Quantum Spin Nematics in Spin-1/2 Frustrated Ferromagnets: A Highly-Entangled State of Matter

Monday, 13 January 2025 09:40 (40 minutes)

In the absence of conventional magnetic order of spin-dipolar moments, ordering with higher-order moments like spin-quadrupoles may occur. Magnets with spin-1/2 degrees of freedom, however, can only exhibit spin-quadrupoles—or quantum spin-nematic (QSN) states—if two spin-1/2 are combined into an effective spin-1. Such a QSN state generically features a large degree of entanglement with a possible analogy to an RVB-liquid of spin-singlets and -triplets. We revisit the square-lattice frustrated ferromagnets using a combination of modern numerical techniques, i.e. matrix-product states based methods and high-field exact diagonalization. We confirm the existence of the bond-nematic phase sandwiched between the fully-polarized phase at high fields and a long-range magnetically ordered phase at low fields, and characterise its microscopic and entanglement properties. Both methods enable us to subsequently study its dynamical fingerprint—a characteristic Goldstone mode associated with the director of the spin-quadrupole—taking into account the strongly interacting many-body nature.

Presenter: Dr GOHLKE, Matthias (OIST)

Session Classification: Pre TPS 2025

Contribution ID: **2** Type: **not specified**

xfac/TCI.jl: Libraries for tensor cross interpolation

Monday, 13 January 2025 10:30 (40 minutes)

The tensor cross interpolation (TCI) algorithm is a rank-revealing algorithm for decomposing low-rank, high-dimensional tensors into tensor trains/matrix product states (MPS).TCI learns a compact MPS representation of the entire object from a tiny training data set. We will introduce a new open-source implementation of TCI: xfac/TCI.jl [1]. We will briefly introduce improved TCI algorithms and demonstrate the use of the libraries.

[1] Yuriel Núñez Fernández, Marc K. Ritter, Matthieu Jeannin, Jheng-Wei Li, Thomas Kloss, Thibaud Louvet, Satoshi Terasaki, Olivier Parcollet, Jan von Delft, Hiroshi Shinaoka, Xavier Waintal, arXiv:2407.02454v3

Presenter: Prof. SHINAOKA, Hiroshi (Saitama University)

Session Classification: Pre TPS 2025

Contribution ID: **3** Type: **not specified**

SO(5)-symmetric deconfined quantum critical point in the extended JQ-model

Monday, 13 January 2025 11:20 (40 minutes)

Since its original proposal [1], the existence and microscopic realization of deconfined quantum critical (DQC) points with lattice models has been under extensive debate. Field-theoretic arguments for DQC provide a plausible scenario where the quantum phase transition between a Neel phase and a valence-bond solid phase – two most basic phases of matter in quantum magnetism – will generically be critical (and is dubbed DQC), despite the fact that they are both spontaneous symmetry breaking phases with a priori completely unrelated symmetries. The so-called JQ model has always been a prominent candidate for a microscopic model exhibiting DQC, but anomalous finite-size scalings and violations with conformal bootstrap bounds had hindered conclusive resolution.

In this talk, I will present our recent efforts to clarify this situation. By examining various correlation functions in the JQ model, we show that the DQC point actually has an additional relevant field, which implies the need for extra parameter tuning to arrive at the true DQC point [2]. After observing a clearly first-order transition with emergent SO(5) symmetry in a related JQ-type model [3], we recently conducted a large-scale numerical experiment for the JQ model with an additional parameter that extends the phase diagram [4]. Our results are consistent with the existence of an SO(5) symmetric DQC point in the extended JQ model phase diagram, but only in the sign-problematic region for quantum Monte Carlo. Although the true DQC point is not directly observable, we show how the extrapolated critical exponents match very well with recently calculated values from sophisticated conformal field theoretic fuzzy sphere calculations [5].

[1] T. Senthil et al., Science 303, 1490 (2004)
[2] B. Zhao, JT, and A. Sandvik, PRL 125, 257204 (2020)
[3] JT and A. Sandvik, PRR 2, 033459 (2020)
[4] JT, S. Hui, B. Zhao, W. Guo, and A. Sandvik, arXiv:2405.06607 (2024)
[5] Z. Zhou, L. Hu, W. Zhu, Y-C. He, arXiv:2306.16435 (2023)

Presenter: Prof. TAKAHASHI, Jun (University of Tokyo)

Session Classification: Pre TPS 2025

Contribution ID: **8** Type: **not specified**

Entanglement diagnosis of many-body systems: applications to non-unitary conformal field theory and topological quantum field theories

Monday, 13 January 2025 13:20 (40 minutes)

Entanglement measures provide powerful tools for diagnosing quantum many-body phases of matter. In particular, in (1+1)-dimensional systems with conformal symmetry, entanglement entropy exhibits logarithmic scaling, where the coefficient determines the central charge of the underlying conformal field theory (CFT). However, in the absence of the unitary condition, the central charge can be negative, leading to negative entanglement entropy. To address this issue, we propose the generalized entanglement entropy to extract the negative central charges in several examples. In addition, in (2+1)-dimensional systems described by topological quantum field theories (TQFT), the sub-leading term of the entanglement entropy is referred to as the topological entanglement entropy (TEE), which contains information about the topological data of the quasiparticles. In this talk, I would like to discuss the TEE for different bipartitions.

Presenter: Prof. CHANG, Po-Yao (National Tsing Hua University)

Session Classification: Pre TPS 2025

Contribution ID: **9** Type: **not specified**

Constructing a Matrix Product Operator for the time evolution operator

Monday, 13 January 2025 14:10 (40 minutes)

Simulating the real or imaginary time evolution of a quantum state using tensor networks requires constructing a representation of the time evolution operator, which can only be done approximately (except in some trivial cases). As an alternative to the common Trotter-Suzuki decomposition, we construct directly a Matrix Product Operator representation of the exponential function[1], which has some advantages over other methods. In recent work, this extends quite naturally to the case where the Hamiltonian is time-dependent, and reveals an interesting algebraic structure of higher powers of operators in terms of representations of the symmetric group.

[1] https://scipost.org/SciPostPhys.17.5.135

Presenter: Prof. MCCULLOCH, Ian (National Tsing Hua University)

Session Classification: Pre TPS 2025

Contribution ID: **10** Type: **not specified**

Interference-caged quantum many-body scars: the Fock space topological localization and interference zeros

Monday, 13 January 2025 16:00 (40 minutes)

The presence of athermal high-energy eigenstates in quantum many-body systems, known as quantum many-body scars, challenges the Eigenstate Thermalization Hypothesis. This article introduces a formulation of quantum many-body scars (QMBS) by interpreting the many-body Hilbert space as a Fock space graph, with a focus on closed quantum systems with weak ergodicity breaking. In this framework, QMBS emerge as localized eigenstates caged to specific subsets of vertices within the graph. Their anomalous thermal behavior emerges from destructive interference of wavefunction amplitudes at the boundaries of these subgraphs, akin to strictly localized states in flat-band physics. By extending this single-particle picture from conventional lattices to the many-body regime within the Fock space graph, we reveal new insights into the structure of QMBS. However, the intricate structure of the Fock space graph, compared to traditional lattices, complicates the identification of QMBS, as many desirable lattice properties are absent. Despite these challenges, analyzing the local topology of the Fock space graph provides a systematic way to identify QMBS in lattice models across various spatial dimensions. Furthermore, this perspective suggests that any Hamiltonian deformations preserving the local topology, including non-Hermitian dissipation, can be explored. Ultimately, the robustness of QMBS is determined by the underlying local topology, offering insights into their behavior and stability.

Presenter: Mr TAN, Tao-Lin (National Tsing Hua University)

Session Classification: Pre TPS 2025