TT 90: Low-Dimensional Systems: Topological Order 1 (jointly with DS, HL, MA, O)

Time: Thursday 11:30–13:00 Location: H 3010

TT 90.1 Thu 11:30 H 3010

Towards a complete characterization of 2d topological order using tensor networks and multipartite entanglement — •Roman Orus — Johannes-Gutenberg Universität, Mainz, Deutschland

Topological order in a 2d quantum matter can be determined by the topological contribution to the entanglement Renyi entropies. However, when close to a quantum phase transition, its calculation becomes cumbersome. In this talk I will show how topological phase transitions in 2d systems can be much better assessed by multipartite entanglement, as measured by the topological geometric entanglement of blocks. Specifically, I will present an efficient tensor network algorithm based on Projected Entangled Pair States (PEPS) to compute this quantity for a torus partitioned into cylinders, and then use this method to find sharp evidence of topological phase transitions in 2d systems with a string-tension perturbation. When compared to tensor network methods for Renyi entropies, this approach produces almost perfect accuracies close to criticality and, on top, is orders of magnitude faster. Moreover, I will show how the method also allows the identification of Minimally Entangled States (MES), thus providing a very efficient and accurate way of extracting the full topological information of a 2d quantum lattice model from the multipartite entanglement structure of its ground states.

TT 90.2 Thu 11:45 H 3010

Robustness of Symmetry Protected Topological Order in spin-2 quantum chains — •Augustine Kshetrimayum[1], Hong-Hao Tu[2], and Román Orús[1] — [1]Johannes Gutenberg University Mainz — [2]MPQ Munich

Topological order is a new kind of order that cannot be described using the Landau theory. It is associated to a non-local pattern of entanglement. When such non-local properties are protected by specific symmetries, it is known as Symmetry Protected Topological Order.

The existence of such a symmetry protected topologically ordered Intermediate Haldane phase for a spin-2 Heisenberg chain was suggested by Oshikawa in 1992. However, the evidence for its existence has remained quite elusive. More recently, it has been proven that such a phase exists in a family of generalized spin-2 quantum Heisenberg chains.

In this work, we study the robustness of this phase for generalized spin-2 quantum Heisenberg chains with uni-axial anisotropy, and in the thermodynamic limit. We find very robust symmetry-protected topologically ordered SO(5)-Haldane and Intermediate-Haldane phases, which we assess by a variety of methods including the entanglement spectrum of the system and the behavior of string-order parameters. Moreover, we study time-evolution properties of these phases. Our numerical results are based on using Matrix Product States (MPS) to represent the wave function, in combination with the infinite Time-Evolving Block Decimation (iTEBD) method.

TT 90.3 Thu 12:00 H 3010

Wire deconstructionism of two-dimensional topological phases — •Ronny Thomale[1], Titus Neupert[2], Claudio Chamon[3], and Christopher Mudry[4] — [1]Institut für Theoretische Physik, Universität Würzburg, Germany — [2]Princeton University, USA — [3]Boston University, USA — [4]PSI Zürich, Switzerland

A scheme is proposed to construct integer and fractional topological quantum states of fermions in two spatial dimensions. We devise models for such states by coupling wires of non-chiral Luttinger liquids of electrons, that are arranged in a periodic array. Which inter-wire couplings are allowed is dictated by symmetry and the compatibility criterion that they can simultaneously acquire a finite expectation value, opening a spectral gap between the ground state(s) and all excited states in the bulk. First, with these criteria at hand, we reproduce the tenfold classification table of integer topological insulators, where their stability against interactions becomes immediately transparent in the Luttinger liquid description. Second, we construct an example of a strongly interacting fermionic topological phase of matter with short-range entanglement that lies outside of the tenfold classification. Third, we expand the table to long-range entangled topological phases with intrinsic topological order and fractional excitations.

TT 90.4 Thu 12:15 H 3010

Symmetry Protected Phases in Geometrically Frustrated 1D Antiferromagnets — •Alexander Nietner, Emil J. Bergholtz, and Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

Geometrically frustrated (GF) systems admit an exotic phenomenology, such as spin liquid states, which lack any local order parameter. To reach a better understanding of such behaviour we realize the spin one Heisenberg antiferromagnetic Δ-chain (HAD) as a simple GF system in a numerically feasible regime. Inspired by a projected entangled pairs picture, we relate this system to a double layered ferromagnetically coupled $s = 1/2$ HAD. We use the time dependent variational principle to compute the ground states of these systems and investigate their phase diagramme in the thermodynamic limit, analysing the entanglement spectra and the projective representations of the symmetry groups. Despite the simplicity of these systems, we find evidence of a topological phase transition for the latter one from the trivial phase in the weak ferromagnetic limit towards a symmetry protected non-trivial phase for a finite coupling strength. This is in good agreement with the fact that the corresponding $s = 1$ system is found to be in the topological Haldane phase.

TT 90.5 Thu 12:30 H 3010

Route to Topological Superconductivity via Magnetic Field Rotation — •Florian Loder, Arno P. Kampf, and Thilo Kopp — Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany

Apart from the very few spin-triplet superconductors with p-wave pairing symmetry, a candidate system for topological superconductivity is a conventional, two-dimensional s-wave superconductor in a magnetic field with a sufficiently strong Rashba spin-orbit coupling. Typically, the required magnetic field to convert the superconductor into a topologically non-trivial state is however by far larger than the upper critical field H_{c2}, which excludes its realization. Here we argue that this problem is overcome by rotating the magnetic field into the superconducting plane. We explore the topological transitions which occur upon changing the strength and the orientation of the magnetic field and show that an unusual superconducting state with finite-momentum pairing exists, which preserves its topological nature up to an in-plane field orientation. We discuss the realizability of this state at the superconducting interface between $LaAlO_3$ and $SrTiO_3$.

TT 90.6 Thu 12:45 H 3010

Topological phases of a chain of twist defects — •Abhishek Roy[1], Xiao Chen[2], and Jeffrey Teo[3] — [1]Institute of Theoretical Physics, University of Cologne, Koeln, Germany — [2]Department of Physics, University of Illinois at Urbana-Champaign, USA — [3]Department of Physics, University of Virgina, USA

A twist defect acts on a system of abelian anyons by permuting anyon labels in a manner that preserves their braiding properties.

We investigate a one dimensional chain of twist defects. The Hamiltonian consists of Wilson loop operators, each enclosing a pair of neighbouring defects. We explore both gapped and gapless phases. For the former, we use anyon pumping to classify the ground states. For the latter, we present mappings to known critical models.

We extend the above results from twofold defects (which are similar to Z_k parafermions) to threefold defects introduced by us earlier in an exactly solvable lattice model [1].

[1] J. C.Y. Teo, A. Roy, X. Chen. Phys. Rev. B 90, 115118