TT 73: Low-Dimensional Systems: Topological Order

Time: Thursday 15:00–18:00 Location: H19

TT 73.1 Thu 15:00 H19

Trivial and topological phases protected by symmetries in spin-2 quantum chains — •Augustine Kshetrimayum[1], Hong-Hao Tu[2], and Román Orús[1] — [1]Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Symmetry-protected trivial (SPt) phases of matter are the product-state analogue of symmetry-protected topological (SPT) phases. This means, SPt phases can be adiabatically connected to a product state by some path that preserves the protecting symmetry. Moreover, SPt and SPT phases can be adiabatically connected to each other when interaction terms that break the symmetries protecting the SPT order are added in the Hamiltonian. It is also known that spin-1 SPT phases in quantum spin chains can emerge as effective intermediate phases of spin-2 Hamiltonians. In this talk, we show that a similar scenario is also valid for SPt phases. More precisely, we show that for a given spin-2 quantum chain, effective intermediate spin-1 SPt phases emerge in some regions of the phase diagram, these also being adiabatically connected to non-trivial intermediate SPT phases. We characterize the phase diagram of our model by studying quantities such as the entanglement entropy, symmetry-related order parameters, and 1-site fidelities. Moreover, we provide a field theory description of the quantum phase transitions between the SPt phases.

TT 73.2 Thu 15:15 H19

Exact tensor network states for the Kitaev honeycomb model — •Philipp Schmoll and Román Orús — Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany

The spin-1/2 Kitaev honeycomb model was originally proposed in the context of topological quantum computation. This analytically solvable model realizes a spin liquid and exhibits rich physical behaviour, such as abelian and non-abelian anyons as excitations. Our aim is to describe the eigenstates of the model using tensor network methods, which offer efficient descriptions of quantum many-body systems. In particular we exploit parity preservation and build a fermionic tensor network to express the eigenstates of the Hamiltonian in the different vortex sectors. We implement the network for small lattices with periodic boundary conditions in order to verify the approach for the model in the thermodynamic limit.

TT 73.3 Thu 15:30 H19

Projective construction of the Zk Read-Rezayi fractional quantum Hall states and their excitations on the torus geometry — •Cecile Repellin[1,2], Titus Neupert[3], B. Andrei Bernevig[4], and Nicolas Regnault[2,4] — [1]Max-Planck-Institut fur Physik complexer Systeme, Dresden, Germany — [2]Laboratoire Pierre Aigrain, Ecole Normale Superieure, Paris, France — [3]Princeton Center for Theoretical Science, Princeton, USA — [4]Princeton University, Princeton, USA

Multilayer fractional quantum Hall wave functions can be used to construct the non-Abelian states of the Zk Read-Rezayi series upon symmetrization over the layer index. Unfortunately, this construction does not yield the complete set of Zk ground states on the torus. We develop an alternative projective construction of Zk Read-Rezayi states that complements the existing one. On the multi-layer torus geometry, our construction consists of introducing twisted boundary conditions connecting the layers before performing the symmetrization. We give a comprehensive account of this construction for bosonic states, and numerically show that the full ground state and quasihole manifolds are recovered for all computationally accessible system sizes. Furthermore, we analyze the neutral excitation modes above the Moore-Read on the torus through an extensive exact diagonalization study. We show numerically that our construction can be used to obtain excellent approximations to these modes. Finally, we extend the new symmetrization scheme to the plane and sphere geometries.

TT 73.4 Thu 15:45 H19

Density matrix renormalization group on a cylinder in mixed real and momentum space — •Johannes Motruk[1], Michael P. Zaletel[2], Roger S. K. Mong[3], and Frank Pollmann[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Station Q, Microsoft Research, Santa Barbara, CA 93106, USA — [3]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260, USA

We present a variant of the density matrix renormalization group (DMRG) algorithm for two-dimensional cylinders that uses a real space representation along the cylinder and a momentum space representation in the perpendicular direction. This mixed approach allows us to use the momentum around the circumference as a conserved quantity in the DMRG algorithm which greatly reduces computational costs compared to the traditional purely real space approach. Applying the method to the interacting fermionic Hofstadter model at integer and fractional fillings, we demonstrate a considerable speedup in computation time and a substantial reduction of memory usage.

TT 73.5 Thu 16:00 H19

Topological edge states in a one-dimensional ladder system — •Kai-Simon Guther, Nicolai Lang, and Hans Peter Büchler — Institut für Theoretische Physik III, Universität Stuttgart

We consider an interacting, particle number conserving model of fermions in a two-wire system. An exact solution for the ground state is possible for a special choice of parameters, and the occurence of topological edge states with non-Abelian statistics has been proven previously analytically [1].

We analyze the stability of the edge states and the corresponding ground state degeneracy away from the exactly solvable point. Therefore, we empoly both a perturbative approach using bosonization as well as the numerical method of density matrix renormalization group. We demonstrate the stability of the edge state under certain perturbations while other perturbations lead to the occurence of a phase separation. We derive the phase diagram in which the exactly solvable point is located at a phase boundary similar to that appearing in a model considered in [2].

[1] N. Lang and H. P. Büchler, PRB **92**, 041118 (2015)
[2] F. Iemini et al., PRL **115**, 156402 (2015)

TT 73.6 Thu 16:15 H19

Interaction-driven strong topology on the boundary of a weak topological superconductor — •Daniel Mendler[1,2], Panagiotis Kotetes[1,3], and Gerd Schön[1,2] — [1]Inst. für theo. Festkörperphysik, Karlsruhe Inst. of Technology — [2]Inst. of Nanotechnology, Karlsruhe Inst. of Technology — [3]Center for Quantum Devices, Niels Bohr Inst., U. of Copenhagen

We focus on a class of topological superconductors (TSCs) which exhibit a bulk energy gap and support Majorana flat bands (MFBs) on the surface. In contrast to previous proposals relying on strong TSCs with nodal bandstructure, here MFBs are solely protected by a weak topological invariant reflecting a global or local strong anisotropy. In the present case interactions play a dual role, on one hand driving the spontaneous symmetry breaking to an anisotropic superconducting phase and on the other, gapping out the arising MFBs yielding a strong topological phase on the boundary. The prototype system showing this kind of behavior is the nematic p_z-superconductor, which supports surface MFBs. While the interactions stabilize the p_z-SC phase in the bulk and induce the MFBs, suppressed bulk p-wave pairing terms occur on the surface, thus lifting the MFB-degeneracy. A similar situation can take place if the nematic features are only local, a scenario which is realizable in a heterostructure consisting of a conventional superconductor in proximity to a topological insulator surface with intrinsic magnetic order.

15 min. break

Invited Talk TT 73.7 Thu 16:45 H19

Imaging currents in 2D quantum materials — •Katja Nowack — Cornell University, Ithaca, United States

Magnetic imaging is uniquely suited to the non-invasive imaging of current densities, particularly in 2D devices. In this talk, I will showcase this approach by discussing our measurements on HgTe quantum well devices in the quantum spin Hall (QSH) regime. In a nutshell, we scan a superconducting quantum interference device (SQUID) to obtain maps of the magnetic field produced by the current flowing in a device. From the magnetic image we reconstruct a 2D current distribution with a spatial resolution of several microns. This allowed us to directly visualize that the edges of the devices carry most of the current when tuned into their insulating gaps - a key feature of the QSH state. In addition, from the images we disentangle conduction through the edges and the interior of a device, allowing us to study the resistance of only the edges even when the interior becomes conductive through either gating or raising the temperature. If time permits, I will both discuss strategies to improve the spatial resolution of our measurements to sub-micron length scales through a combination of improved image reconstruction and smaller sensor sizes and outline interesting opportunities for current imaging.

TT 73.8 Thu 17:15 H19

Temperature induced crossover in the collision-dominated Dirac semimetal Cd_3As_2 — Azat Sharafeev[1], Vladimir Gnezdilov[1,2], •Peter Lemmens[1], Raman Sankar[3], and Fangcheng Chou[3] — [1]IPKM, TU-BS, Braunschweig — [2]ILTPE NAS, Ukraine — [3]CCMS, National Taiwan Univ., Taipei, Taiwan

The 3D topological Dirac semimetal Cd_3As_2 was studied in a wide range of temperatures and excitation energies using Raman spectroscopy. The temperature evolution of the phononic and the quasielastic electronic scattering is discussed in terms of a collision-dominated regime with pronounced electronic energy density fluctuations. A crossover is observed in the intensity of the signals attributed to a collision-dominated phonon regime.

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TT 73.9 Thu 17:30 H19

Magnetic behaviour of the honeycomb antiferromagnet $BaNi_2V_2O_8$ — •Ekaterina Klyushina[1,2], Bella Lake[1,2], Nazmul Islam[1], Bastian Klemke[1], Astrid Schneidewind[3], Jitae Park[3], and Martin Mansson[4] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [3]Heinz Maier-Leibnitz Zentrum, TU München, Garching, Germany — [4]Paul Scherrer Institute, Switzerland

Here we present our recent investigations of a spin-1 honeycomb antiferromagnetic $BaNi_2V_2O_8$ which is a highly 2D antiferromagnet with XY anisotropy making this compound a potential candidate for the Berezinsky-Kosterliz-Thouless topological phase transition [1,2]. Single crystal inelastic neutron scattering measurements in the honeycomb plane at 4 K reveal that the magnetic excitations extend from 0.3-26 meV and consist of two anisotropy-split gapped modes with gaps of 0.3 meV and 3.3 meV arising from the anisotropy within the a-b plane and XY anisotropy respectively . The excitations agree well with simulations based on linear spin - wave theory and are completely dispersionless in the out-of-plane direction suggesting negligible interplane coupling in spite of the long range magnetic order below $T_N = 48$ K. A detailed investigation of the order parameter and correlation length are presented and compared to various theories.

[1] J. M. Kosterlitz, D. J. Thouless J. Phys. C **6**, 1181 (1973)
[2] A. Cuccoli et al., PRB **67**, 104414 (2003)

TT 73.10 Thu 17:45 H19

Nonabelian hierarchies of fractional quantum Hall states — •Yoran Tournois and Maria Hermanns — Institute for Theoretical Physics, Cologne

The fractional quantum Hall effect is one of the paradigmatic examples of topological order in condensed matter physics. It harbors anyonic quasiparticle excitations which carry fractional charge and obey fractional exchange statistics, i.e. when these identical particles are exchanged the wavefunction picks up a complex phase which may take any value between 1 and -1. While the physics of the fractional quantum Hall effect is well understood in the lowest Landau level by means of the Haldane-Halperin hierarchy, this is not the case for the second Landau level. The latter is of particular interest as it is believed that in the second Landau level, even more exotic excitations - nonabelian anyons - may be realized. Several proposals on how to generalize the Haldane-Halperin hierarchy to the second Landau level exist. In this talk, we will consider these different proposals, and discuss how to obtain the properties of their nonabelian excitations.