TT 14: Correlated Electrons: Low-Dimensional Systems - Models 2

Time: Monday 15:00–18:30 Location: H9

TT 14.1 Mon 15:00 H9

Topological parity invariant in interacting two-dimensional systems from quantum Monte Carlo — •Stefan Wessel[1], Thomas Lang[1], Victor Gurarie[2], and Andrew Essin[2] — [1]RWTH Aachen, Aachen, Germany — [2]University of Colorado, Boulder, USA

We report results on calculating the parity invariant from imaginary-time Green's functions in quantum Monte Carlo simulations of strongly interacting electron systems. The topological invariant is used to study the trivial- to topological-insulator transitions in the Kane-Mele-Hubbard model with an explicit bond dimerization. We explore the accessibility and behavior of this invariant based on quantum Monte Carlo calculations.

TT 14.2 Mon 15:15 H9

Series expansions in topologically-ordered systems — Michael Kamfor[1], Sebastien Dusuel[2], Julien Vidal[3], and •Kai Phillip Schmidt[1] — [1]Lehrstuhl für Theoretische Physik I, TU Dortmund, Germany — [2]Lycee Saint-Louis, 44 Boulevard Saint-Michel, 75006 Paris, France — [3]Laboratoire de Physique Théorique de la Matiere Condensee, CNRS UMR 7600, Universite Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris Cedex 05, France

We establish high-order series expansions as a powerful tool to study topologically-ordered quantum systems. In recent years, this has been demonstrated for various magnetic models including the toric code in an external magnetic field. The main focus of these studies were the determination of the zero-temperature phase diagram which demands to pinpoint and to characterize topological phase transitions. To this end the calculation of zero- and one-quasi-particle properties is essential. Here we study for the first time two-quasi-particle properties for the perturbed toric code. We identify bound states, formed by interacting anyons and determine dynamical correlation functions.

TT 14.3 Mon 15:30 H9

Topological order in classical string-net models — •Maria Hermanns, Mascha Baedorf, and Simon Trebst — Institute for Theoretical Physics, Cologne, Germany

Topological order has recently attracted a great deal of interest, because it allows for exotic emergent excitations that are robust against local perturbations. It is most commonly thought of as a quantum effect, which is strongly related to an effective low-energy description of the quantum system as a topological field theory. However, topological order can also occur in classical models that have local constraints. Most prominent among these are loop and string-net models. Here, we consider such classical models that are topologically ordered and analyze the relation between the classical topological order and its counter part in the quantum system.

TT 14.4 Mon 15:45 H9

Topological Phases in gapped edges of fractionalized systems — •Johannes Motruk[1], Erez Berg[2], Ari M. Turner[3], and Frank Pollmann[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel 76100 — [3]Institute for Theoretical Physics, University of Amsterdam, Science Park 904, P.O. Box 94485, 1090 GL Amsterdam, The Netherlands

We extend the classification scheme for symmetry protected topological phases of fermions in one-dimensional systems to chains of parafermions. We find that parafermionic chains support both topological as well as symmetry-broken phases. The topological phases can be identified by the structure of their entanglement spectrum, while the symmetry broken ones are characterized by a condensation of parafermions. Furthermore, we show that it is not possible to create new topological phases by combining chains. In several recent works, it has been proposed to realize parafermions experimentally at the edge of a fractional topological insulator coupled to superconducting and ferromagnetic domains. The parafermions arise as effective low-energy degrees of freedom. Based on this, we suggest a concrete physical realization at the edge of a $\nu = 1/3$ fractional topological insulator which we can tune into all possible topological phases. We identify the different phases by numerically determining their entanglement spectra.

TT 14.5 Mon 16:00 H9

Topological phases in ultracold polar-molecule quantum magnets — •Salvatore R. Manmana[1,2], Miles E. Stoudenmire[3], Kaden R.A. Hazzard[2], Ana Maria Rey[2], and Alexey V. Gorshkov[4] — [1]Institut für Theoretische Physik, Universität Göttingen, Germany — [2]JILA, University of Colorado and NIST, and Department of Physics, CU Boulder, USA — [3]Department of Physics and Astronomy, University of California, Irvine, USA — [4]Institute for Quantum Information & Matter, Caltech, Pasadena (California), USA

We show how to use polar molecules in an optical lattice to engineer quantum spin models with arbitrary spin $S \geq 1/2$ and with interactions featuring a direction-dependent spin anisotropy. This is achieved by encoding the effective spin degrees of freedom in microwave-dressed rotational states of the molecules and by coupling the spins through dipolar interactions. We demonstrate how one of the experimentally most accessible anisotropies stabilizes symmetry protected topological phases in spin ladders. Using the numerically exact density matrix renormalization group method, we find that these interacting phases – previously studied only in the nearest-neighbor case – survive in the presence of long-range dipolar interactions. We also show how to use our approach to realize the bilinear-biquadratic spin-1 and the Kitaev honeycomb models. Experimental detection schemes and imperfections are discussed.

TT 14.6 Mon 16:15 H9

Topological phase transitions in a perturbed Fibonacci string-net model — •Marc Daniel Schulz[1,3], Sébastien Dusuel[2], Kai Phillip Schmidt[1], and Julien Vidal[3] — [1]Lehrstuhl für Theoretische Physik I, Technische Universität Dortmund, Otto-Hahn-Straße 4, 44221 Dortmund, Germany — [2]Lycée Saint-Louis, 44 Boulevard Saint-Michel, 75006 Paris, France — [3]Laboratoire de Physique Théorique de la Matière Condensée, CNRS UMR 7600, Université Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris Cedex 05, France

Topological order has gained enormous interest during the last years. This is also due to the fact that topologically-ordered systems harbour excitations with exotic exchange statistics, the so-called non-Abelian anyons, which are of interest for the purpose of topological quantum computation. Here, we present a study on the simplest model of Levin-Wen type featuring non-Abelian Fibonacci anyons in the presence of a local perturbation. The phase diagram is obtained by means of high-order series expansions and exact diagonalizations. Most interestingly, evidences for first-order and second-order quantum phase transitions are found.

15 min. break

TT 14.7 Mon 16:45 H9

Formation of Magnetic Moments at Grain Boundaries of High Temperature Superconductors — •Iris Xhango and Thilo Kopp — Zentrum für Elektronische Korrelationen und Magnetismus, Institut für Physik, 86135 Augsburg, Deutschland

Understanding the physics of grain boundaries in high temperature superconductors is of considerable value for applications of these materials. In this context the investigation of the normal state at the grain boundaries is as important as that of the superconducting state. From various experiments it is known that the normal state resistance at grain boundaries increases for decreasing temperature in contrast to the bulk behavior. A simple theoretical realization of the grain boundary builds on an inhomogeneous one-band Hubbard model. It is shown that local magnetic moments are formed at the grain boundary for finite on-site Coulomb interaction. The impact of the grain boundary and of the magnetic moments on the transport properties of the system are discussed. An increasing resistance for low temperature is obtained.

TT 14.8 Mon 17:00 H9

Quantum spin models from π fluxes in correlated quantum spin hall insulators. — •Martin Bercx, Martin Hohenadler, and Fakher F. Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We analyze the signatures of π fluxes in quantum spin hall insulators.

We have shown in a recent work [1] that in the presence of repulsive electronic interactions each π flux gives rise to a Kramers doublet of spinon states. Free spinon states show up in a Curie law behaviour of the magnetic susceptibility. The interaction between spinon states is mediated by a bosonic mode which can be tuned with the electron-electron interaction. This has opened the possibilty to study models of interacting spin 1/2 magnetic moments hosted in the gap of a topological insulator. These effective quantum spin models can be simulated numerically with the quantum Monte Carlo method. In this contribution we present results for spin chains, spin ladders and for various other geometries.

[1] F. F. Assaad, M. Bercx, and M. Hohenadler, arXiv:1204.4728 (2012)

TT 14.9 Mon 17:15 H9

Flat-band ferromagnetic transition on a Bethe lattice — •Mykola Maksymenko[1], Kirill Shtengel[2], and Roderich Moessner[1] — [1]MPIPKS, 01187 Dresden, Germany — [2]Department of Physics and Astronomy, University of California, Riverside, California 92521, USA

An exotic example of itinerant-electron magnetism is the so-called "flat-band ferromagnetism", in a wide class of geometrically frustrated lattices. Here electrons become trapped in restricted parts of the lattice and interactions may favor a ferromagnetic state across a range a electronic fillings.

We provide an exact solution for the problem of the para-ferro transition in a Hubbard model on lattices in which trapping cells form a Bethe lattice. This can be studied as a Pauli-correlated percolation transition in which due to spin-rotational degeneracy, different clusterings of electrons obtain different statistical weights [1]. As in the case of recent numerical studies for the 2D case, we show that the paramagnetic phase persists beyond the uncorrelated percolation point and the transition is via a first-order jump to an unsaturated ferromagnetic phase.

[1] M. Maksymenko, A. Honecker, R. Moessner, J. Richter, and O. Derzhko, Phys. Rev. Lett. 109, 096404 (2012)

TT 14.10 Mon 17:30 H9

Multi-Orbital Effects in Functional Renormalization Group: A Weak-Coupling Study of the Emery model — •Stefan A. Maier and Carsten Honerkamp — Institut für theoretische Festkörperphysik, RWTH Aachen, Germany and JARA - FIT Fundamentals of Future Information Technology

We perform an instability analysis of the Emery three-band model at hole doping and weak coupling within a channel-decomposed functional renormalization group flow proposed in Phys. Rev. B **79**, 195125 (2009). In our new approach, momentum dependencies are taken into account with less bias than in the truncated formfactor expansions used previously. Around a generic parameter set, we find a strong competition of antiferromagnetic and *d*-wave Cooper instabilities with a smooth behavior under a variation of doping and oxygen-oxygen hopping. For increasingly incommensurate ordering tendencies in the magnetic channel, signatures of *d*-wave Cooper pairing between electrons in non-neighboring unit cells of the direct lattice can be observed. Comparing our results for the Emery model to those obtained for the two-dimensional one-band Hubbard model with effective parameters, we find that, despite considerable qualitative agreement, multi-orbital effects have a significant impact on a quantitative level.

TT 14.11 Mon 17:45 H9

Magnetic order-by-disorder in a distorted Heisenberg-Kitaev model — •Max Henner Gerlach[1], Eran Sela[1,2], Hong-Chen Jiang[3], Oliver Wohak[1], and Simon Trebst[1] — [1]Institut für Theoretische Physik, Universität zu Köln — [2]Tel Aviv University, Ramat Aviv, Israel — [3]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA

Motivated by the recent experimental observation of Mott insulating states for the layered iridates Na_2IrO_3 and Li_2IrO_3, we discuss possible ordering states of the effective iridium moments in the presence of strong spin-orbit coupling and weak exchange anisotropies induced by lattice distortions. We find that the Heisenberg-Kitaev model – suggested to capture the exchanges of the effective $j = 1/2$ Iridium moments – in the presence of distortions exhibits a rich phase diagram of both conventionally ordered magnetic states as well as exotic topologically ordered and spin liquid states, which we will discuss in detail in this talk. Particular emphasis will be put on the classical counterpart of this model and the order-by-disorder physics that stabilizes certain ordering patterns over wide ranges of its phase diagram.

TT 14.12 Mon 18:00 H9

Correlations of quantum spin chains from functional equations and su(2) diagrammatics — •Andreas Klümper — Bergische Universität Wuppertal, Theoretische Physik, Gauss-Strasse 20, 42119 Wuppertal

For integrable quantum spin chains a lattice path integral formulation with finite but arbitrary Trotter number allows to derive a set of discrete functional equations with respect to the spectral parameters appearing in the R-matrices of local interactions. We show that these equations yield a unique characterisation of the density operator and present solutions for the S=1/2 and S=1 Heisenberg chains.

For generic cases, we report on a systematic implementation of su(2) invariance for matrix product states (MPS) with concrete computations cast in a diagrammatic language. As an application we present a variational MPS study of a spin-1/2 quantum chain. For efficient computations, we make systematic use of the su(2) symmetry at all steps of the calculations: (i) the matrix space is set up as a direct sum of irreducible representations, (ii) the local matrices with state-valued entries are set up as superposition of su(2) singlet operators, (iii) products of operators are evaluated algebraically by making use of identities for 3j and 6j symbols.

Results on quantum phase transitions in the considered models are discussed.

TT 14.13 Mon 18:15 H9

Adiabatic loading of one-dimensional $SU(N)$ alkaline earth fermions in optical lattices — •Lars Bonnes[1], Hazzard Kaden[2], Salvatore Manmana[2], Ana Maria Rey[2], and Stefan Wessel[3] — [1]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]JILA, NIST and University of Colorado, and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [3]Institute for Theoretical Solid State Physics, JARA-FIT, and JARA-HPC, RWTH Aachen University, Otto-Blumenthal-Str. 26, D-52056 Aachen, Germany

Hubbard models with effective SU(N) symmetry have successfully been implemented in ultra-cold alkaline earth experiments. This paves the way towards the regime of exotic magnetism emerging in the low-energy sector but requiring ultra-cool temperatures below the superexchange scale. Loading N>2 fermions onto optical lattices, however, provides a cooling benefit with respect to conventional SU(2) fermions emerging from the N-scaling of the entropy. Hence the accessible temperature regime is lowered drastically, as already observed in recent experiments by Tanaka et al. We present large-scale quantum Monte Carlo simulations combined with series expansion results to quantitatively study the Pomeranchuk cooling effect for SU(N) fermions loaded onto a one-dimensional optical lattice and find a significant temperature decrease as N is increased. Furthermore, we examine the crossover behavior to the magnetic regime and show that the systems do not only become cooler but also become closer to the magnetic (ground-state) regime with respect to the appearance of magnetic correlations.