TT 19: Frustrated Magnets - Spin Liquids - Theory

Time: Monday 15:00–18:15 Location: H 3010

TT 19.1 Mon 15:00 H 3010

Thermal transport of the Kitaev spin ladder in a magnetic field — •Alexandros Metavitsiadis and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, Braunschweig, Germany

The Kitaev spin ladder (KSL) is a minimum quasi one-dimensional (1D) representative of the celebrated two-dimensional Kitaev model on the Honeycomb lattice. The frustration caused by the compass interactions leads to fractionalization which combined with the spatial confinement of 1D leads to localization in the absence of disorder and consequently to vanishing dc transport coefficients. Furthermore, the KSL exhibits an interesting phase diagram with gapless, as well as trivial and topological gapped phases. In this work, we present results for the thermodynamical as well as for the thermal transport properties of the Kitaev spin ladder in the presence of a magnetic field, which gives rise to finite dc transport coefficients. We provide results at finite temperatures for a wide range of the magnetic field's strength, from the insulating to the diffusive regime, and for different sets of Kitaev couplings, starting from gapless or gapful phases in KSL's phase diagram. We primarily rely on numerical techniques, namely exact diagonalization and the quantum typicality but we also provide comparison with an effective fermionic model, valid for weak magnetic fields.

TT 19.2 Mon 15:15 H 3010

Thermal conductivity of a two-dimensional $\mathbb{Z}_2$ spin liquid — •Angelo Pidatella[1], Alexandros Metavitsiadis[2], and Wolfram Brenig[2] — [1]Institute for Theoretical Physics, Technical University of Dresden — [2]Institute for Theoretical Physics, Technical University of Braunschweig

We study the dynamical thermal conductivity of the two-dimensional Kitaev spin model on the honeycomb lattice. Mapping to Majorana particles, the transport properties are described in terms of itinerant matter fermions interacting with a localized $\mathbb{Z}_2$ gauge field. Analyzing isotropic as well as anisotropic cases, in order to incorporate both, gapless and gapful phases of the Kitaev model, we discuss our findings for the thermodynamic properties and the transport coefficients, at finite temperature and frequency. Our analysis is based on complementary calculations of the current correlation function, comprising exact diagonalization by means of a complete summation over all gauge sectors, as well as a phenomenological mean-field treatment of thermal gauge fluctuations, valid over a wide range of temperatures. We find the system to be a dissipative heat conductor in the isotropic case. Results for the anisotropic cases will also be discussed.

TT 19.3 Mon 15:30 H 3010

Global phase diagram for the extended Kitaev – Heisenberg model via cluster mean field theory — •Dorota Gotfryd[1,2], Juraj Rusnacko[3,4], and Jiri Chaloupka[3,4] — [1]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, PL-02093 Warsaw, Poland — [2]Marian Smoluchowski Institute of Physics, Jagellonian University, Lojasiewicza 11, PL-30348 Krakow, Poland — [3]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic — [4]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlarska 2, CZ-61137 Brno, Czech Republic

We present the global phase diagram for the extended Kitaev – Heisenberg model [1-4] obtained via cluster mean field theory (CMFT) [5]. We use (a) linearized and (b) full self – consistent CMFT to determine most of the magnetically ordered (Neel, FM, zigzag, stripy, vortex) and disordered (spin liquid) regions in the phase diagram. As the final outcome CMFT gives us the magnetic ordered moment direction and value for each phase. We conclude with the comparison of the characteristics of the ordered moment for CMFT, other methods and the experimental findings.

[1] J.G. Rau et al., Phys. Rev. Lett.112, 077204 (2014).
[2] J.G. Rau et al., arXiv: 1408.4811, (2014).
[3] J. Chaloupka et al., Phys. Rev. B, 92, 024413 (2015).
[4] J. Chaloupka et al., Phys. Rev. B, 94, 064435 (2016).
[5] D. Gotfryd et al., Phys. Rev. B, 95, 024426 (2017).

TT 19.4 Mon 15:45 H 3010

Existence of spin-liquid states in the Kitaev-Heisenberg ladder — •Cliò Efthimia Agrapidis[1], Jeroen van den Brink[1,2], and Satoshi Nishimoto[1,2] — [1]IFW Dresden, Dresden, Germany — [2]Technical University Dresden, Dresden, Germany

It is widely accepted that the Kitaev-Heisenberg (KH) model on a honeycomb lattice is a good minimal model for some candidate spin liquid materials (e.g. α-$RuCl_3$). Though the KH hamiltonian has been studied in 2D, systematic analysis including finite-size scaling is still lacking due to numerical difficulties. Whereas very precise analysis is possible for 1D and quasi-1D KH systems

We study the KH ladder using the exact diagonalization and density matrix renormalization group techniques. We present its phase diagram as a function of an angle parameter ϕ, having defined the Kitaev interaction as $\sin\phi$ and the Heisenberg one as $\cos\phi$. Remarkably, we find that the phase diagram has a resemblance to the one suggested for the same model on the honeycomb lattice [1], showing the same phases, namely spin-singlet (or Néel), zig-zag, ferromagnetic, stripy and two spin liquid states.

We also present some results in the presence of magnetic field and discuss the spin-liquid properties.

[1] J. Chaloupka, G. Jackeli, G. Khaliullin, PRL **110** 097204 (2013)

TT 19.5 Mon 16:00 H 3010

Majorana zero modes in the Kitaev honeycomb model — •Daniel Otten, Ananda Roy, and Fabian Hassler — JARA-Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

Kitaev's honeycomb model is a quantum spin liquid that gives rise to an emergent static $\mathbb{Z}_2$ gauge field coupled to Majorana fermions. In presence of an applied external magnetic field, the system is, dependent on the choice of interaction strength, in a gapped, non-abelian phase. In this phase, the vortex excitations of the emergent $\mathbb{Z}_2$ gauge field have Majorana zero modes bound to them. We investigate the properties of these Majorana zero modes. Using Jordan-Wigner transformation, we map the effective Hamiltonian to that of a chiral p-wave superconductor. We analytically calculate the wave functions of the Majorana zero modes in the continuum limit and the energy splitting that arises when two vortices approach each other. Furthermore, to understand the implications of the zero modes in the original spin model, we calculate the spin-spin correlator and the dynamical structure factor in presence of these vortices. These results are relevant for possible experimental observations and characterizations of the Majorana zero modes in systems that are dominated by the interaction of the Kitaev honeycomb model.

TT 19.6 Mon 16:15 H 3010

Probing α-$RuCl_3$ beyond magnetic order: Effects of temperature and magnetic field — •David Kaib[1], Stephen Winter[1], Kira Riedl[1], Radu Coldea[2], and Roser Valenti[1] — [1]Institut für Theoretische Physik, Goethe-Universität Frankfurt — [2]Clarendon Laboratory, University of Oxford

Recent studies have brought α-$RuCl_3$ to the forefront of experimental searches for materials realizing Kitaev spin-liquid physics. This material exhibits strongly anisotropic exchange interactions afforded by the spin-orbit coupling of the 4d Ru centers. Under strong scrutiny is the nature of the unconventional continuum of magnetic excitations [1, 2], as well as reported unconventional paramagnetic states that emerge at finite temperature [3] and finite magnetic field [4] after suppression of magnetic order. Using exact diagonalization calculations of an ab-initio guided spin model complemented by semi-classical analysis, we find a very rich evolution of the spin dynamics and the stabilization of a quantum paramagnetic state as the zigzag order is suppressed [5].

[1] A. Banerjee et al., Science **356**, 1055-1059 (2017).
[2] S. M. Winter et al., Nature Communications **8**, 1152 (2017).
[3] S.-H. Do et al., Nature Physics **13**, 1079-1084 (2017).
[4] Z. Wang et al., arXiv: 1706.06157 (2017).
[5] S. M. Winter et al., arXiv:1707.08144 (2017).

TT 19.7 Mon 16:30 H 3010

Lattice disorder and spin-orbital behaviour in $Ba_3CuSb_2O_9$ — •Andrew Smerald[1,2] and Frederic Mila[1] — [1]Institute of Physics, Ecole Polytechnique Federale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland — [2]Max Planck Institute for Solid State Research,

Heisenbergstraße 1, 70569 Stuttgart, Germany

The material $Ba_3CuSb_2O_9$ has elicited attention recently due to the proposal that it realises a spin-orbital liquid state. One difficulty in understanding this behaviour comes from the fact that the lattice structure of the Cu^{2+} ions is disordered. In order to better understand the lattice we study a model of charged Sb^{5+}-Cu^{2+} dumbbells living on a triangular lattice. We find a complicated 'branch' lattice with correlated disorder of the dumbbells. Starting from this lattice structure we speculate on the possible spin-orbital state, proposing a state with delocalised orphan spins.

15 min. break.

TT 19.8 Mon 17:00 H 3010

Doping a 2d Mott insulator - Study of a quantum dimer model — •Sebastian Huber[1], Johannes Feldmeier[1], Fabian Grusdt[2], and Matthias Punk[1] — [1]Arnold Sommerfeld Center, Ludwig-Maximilians University, 80333 Munich, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

Experiments with quantum gas microscopes have started to explore the antiferromagnetic phase of the Fermi-Hubbard model and effects of doping with holes away from half filling [1]. We show in this talk that the read-out of the two-particle reduced density matrix enables to distinguish magnetically ordered and interesting topologically ordered spin-liquid phases, which might occur in the Hubbard model close to half filling. Fractionalized Fermi liquids (FL*) [2] are a promising candidate for this parameter regime. The generalized quantum dimer model introduced in Ref. [3] is an effective lattice realization of such an FL* with a Hilbert space spanned by configurations of fermionic and bosonic short-range bound states. We compute the corresponding electron spectral functions using exact diagonalization on lattices of size 6x6 to verify the existence of a pseudogap.

[1] A. Mazurenko, C. Chiu et al., Nature 545, 7655 (2017)
[2] T. Senthil, S. Sachdev and M. Vojta, PRL 90, 21 (2003)
[3] M. Punk, A. Allais and S. Sachdev, PNAS 112, 31 (2015)

TT 19.9 Mon 17:15 H 3010

Negative sign free auxiliary field algorithm for frustrated Kondo systems — •Johannes S Hofmann[1], Fakher F Assaad[1], and Tarun Grover[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany — [2]Department of Physics, University of California at San Diego, La Jolla, CA 92093, USA

The absence of negative sign problem in quantum Monte Carlo simulations of spin and fermion systems has different origins. Worldline based algorithms for spins require positivity of matrix elements whereas auxiliary field approaches for fermions depend on symmetries such as particle-hole. For negative-sign-free spin and fermionic systems, we show that one can formulate a negative-sign-free auxiliary field quantum Monte Carlo algorithm that allows Kondo coupling of fermions with the spins.

In this talk we will present preliminary results on the Kondo coupling between local moments participating in a $\mathbb{Z}_2$ spin liquid (based on Balents-Fisher-Girvin model) and conduction electrons on a honeycomb lattice. Our setup allows us to address the question of the relevance of the Kondo coupling at the quantum critical point corresponding to the destruction of the spin-liquid.

TT 19.10 Mon 17:30 H 3010

Fractionalized Fermi liquids and exotic superconductivity in the Kitaev Kondo lattice — •Urban F. P. Seifert[1], Tobias Meng[1], and Matthias Vojta[1,2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Center for Transport and Devices of Emergent Materials, Technische Universität Dresden, 01062 Dresden, Germany

Fractionalized Fermi liquids (FL*) have been introduced as non-Fermi-liquid metallic phases, characterized by coexisting electron-like charge carriers and local moments which itself form a fractionalized spin liquid. Here we investigate a Kondo lattice model on the honeycomb lattice with compass interactions among the local moments, a concrete model hosting FL* phases based on Kitaev's $\mathbb{Z}_2$ spin liquid. We characterize the FL* phases via perturbation theory, and we employ a Majorana-fermion mean-field theory to map out the full phase diagram. Most remarkably we find triplet superconducting phases which mask the quantum phase transition between fractionalized and conventional Fermi liquid phases. Their pairing structure is inherited from the Kitaev spin liquid, i.e., superconductivity is driven by Majorana glue.

TT 19.11 Mon 17:45 H 3010

Looking at an antiferromagnet from a spin-liquid point of view — •Marc Daniel Schulz — TU Dortmund, Germany

The $\mathbb{Z}_2$ topological phase in the quantum dimer model on the Kagome-lattice is a candidate for the description of the low-energy physics of the anti-ferromagnetic Heisenberg model on the same lattice. We study the extend of the topological phase by interpolating between the exactly solvable parent Hamiltonian of the topological phase and an effective low-energy description of the Heisenberg model in terms of a quantum-dimer Hamiltonian. Therefore, we perform a perturbative treatment of the low-energy excitations in the topological phase including free and interacting quasi-particles. We find a phase transition driven by the condensation of bound states formed of topological excitations. The condensed phase corresponds to a valence bond solid and is characterized by a spontaneously broken rotational symmetry and a unit cell containing six sites.

TT 19.12 Mon 18:00 H 3010

Jammed spin liquid in the bond-disordered kagome Heisenberg antiferromagnet — •Thomas Bilitewski[1], Mike Zhitomirsky[2], and Roderich Moessner[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Universite Grenoble Alpes, CEA, INAC-Pheliqs, 38000 Grenoble, France

We study a class of disordered continuous classical spin systems including the kagome Heisenberg magnet. While each term in its local Hamiltonian can be independently minimised, we find discrete degenerate ground states whose number grows exponentially with system size. These states do not exhibit zero-energy 'excitations' characteristic of highly frustrated magnets but instead are local minima of the energy landscape, albeit with an anomalously soft excitation spectrum. This represents a spin liquid version of the phenomenon of jamming familiar from granular media and structural glasses. Correlations of this jammed spin liquid, which upon increasing the disorder strength gives way to a conventional spin glass, may be algebraic (Coulomb-type) or exponential.