TT 52: Frustrated Magnets: Strong Spin-Orbit Coupling

Time: Thursday 15:00–17:30 Location: HSZ 201

TT 52.1 Thu 15:00 HSZ 201

Finite temperature nonlinear optical response of the Kitaev magnet — •Wolfram Brenig[1] and Olesia Krupnitska[1,2] — [1]Institute for Theoretical Physics, Technical University Braunschweig, D-38106 Braunschweig, Germany — [2]Institute for Condensed Matter Physics, NASU, Svientsitskii Str. 1, 79011 Lviv, Ukraine

One of the key properties of a quantum spin liquid is fractionalization. In the spin liquid hosted by the Kitaev model, this occurs in terms of two types of quasiparticles, i.e., itinerant Majorana fermions and localized gapped Z_2 fluxes. A multitude of probes have been suggested to provide evidence for the response and spectral continua related to such fractionalization. Here we report results on the nonlinear optical response of a Kitaev magnet at finite temperature. Our analysis is based on complementary calculations in the low-temperature homogeneous gauge and a mean-field treatment of thermal gauge fluctuations, valid at intermediate and high temperatures.

TT 52.2 Thu 15:15 HSZ 201

Thermal decomposition of the Kitaev material α-$RuCl_3$ and its influence on the low-temperature properties — •Franziska Breitner[1], Anton Jesche[1], Vladimir Tsurkan[2], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany

Thermally driven decomposition and reduction of honeycomb ruthenium-trichloride has been known long before the material attracted considerable interest as a Kitaev system [1,2]. We systematically explore the effect of heat treatment in argon atmosphere under various temperatures up to 500°C on single crystals by study of the mass loss, microprobe energy dispersive x-ray spectroscopy, powder x-ray diffraction, as well as low-temperature magnetic susceptibility and specific heat experiments. For annealing temperatures beyond 300°C we detect clear signatures of dechlorination and oxidation of Ru. The specific heat is consistently described by the sum of a major α-$RuCl_3$ and minor RuO_2 volume fraction, whose latter C∼T contribution dominates the total specific heat below 1 K. Comparison with measurements on unannealed crystals suggests that even therein a tiny RuO_2 metal fraction cannot be excluded, which could be relevant also for other physical properties.

[1] A.E. Newkirk and D.W. McKee, J. Catal. 11, 370 (1968)
[2] J.A. Sears et al., Phys. Rev. B 91, 144420 (2015)

TT 52.3 Thu 15:30 HSZ 201

Spin-phonon dynamics in α-$RuCl_3$ probed by ultrasound — •Andreas Hauspurg[1,2], S. Zherlitsyn[1], T. Helm[1], V. Tsurkan[3], K. Y. Choi[4], S. H. Do[5], W. Brenig[6], N. Perkins[7], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden, HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Institute of Physics, University of Augsburg, Germany — [4]Department of Physics, Sungkyunkwan University, Republic of Korea — [5]Oak Ridge National Lab, USA — [6]Institute for Theoretical Physics, TU Braunschweig, Germany — [7]School of Physics and Astronomy, University of Minnesota, USA

Among the most studied honeycomb-lattice materials predicted to host Kitaev interactions is the spin-orbit-coupled Mott insulator α-$RuCl_3$. Despite antiferromagnetic ordering at 7 K, α-$RuCl_3$ is considered proximate to the Kitaev quantum spin liquid (QSL) state, which features fractionalized quasiparticle excitations. A promising approach to study such excitations is to investigate the spin-phonon interaction in this material. Our studies of the elastic properties of α-$RuCl_3$ by means of ultrasound pulse-echo technique indicate unconventional physics of the debated QSL phase. Here, we present low-temperature results of the sound velocity and attenuation in external magnetic fields and discuss their behavior with respect to the quasiparticle excitations in α-$RuCl_3$. In our studies we observed a linear temperature dependence of the attenuation beyond the ordered state at 8 T that follows a characteristic C_6 symmetry. Anomalies in the acoustic properties shed new light on the H-T phase diagram.

TT 52.4 Thu 15:45 HSZ 201

Rethinking α-$RuCl_3$ again — •Marius Möller[1], Roser Valentí[1], and Alexander L. Chernyshev[2] — [1]Institute for Theoretical Physics, Goethe University Frankfurt, Max-von-Laue-Strasse 1, 60438 Frankfurt am Main, Germany — [2]Department of Physics and Astronomy, University of California, Irvine, California 92697, USA

The honeycomb Kitaev material α-$RuCl_3$ is widely investigated due to its originally suspected proximity to a spin liquid state suggested by unusual neutron scattering results. The magnetic Hamiltonian was initially formulated as a generalized Kitaev model K_1-J_1-Γ_1-$\Gamma_1^{'}$-J_3 in a cubic spin reference orientated along the Ru-Cl bonds. Recent studies, however, suggest that a crystallographic parametrization of the Hamiltonian in a spin-ice-like language $J(XY)$-Δ-$J_{\pm\pm}$-$J_{z\pm}$-J_3 could lead to significant reduction of the parameter space, hinting towards a potential minimal model of α-$RuCl_3$. We present the classical and quantum phase diagram of this $J(XY)$-$J_{z\pm}$-J_3 minimal model candidate obtained by Luttinger-Tisza method (LT), Exact Diagonalization (ED) and Density Matrix Renormalization Group (DMRG). Further, we present the phase diagrams of three interesting parameter regions with constrained anisotropic exchanges K_1,Γ_1,$\Gamma_1^{'}$ leading to effective J_1-J_3 models which possibly capture the relevant region to describe the essential physics of α-$RuCl_3$.

M.M. and R.V. gratefully acknowledge funding by the DFG(German Research Foundation): TRR 288 - 422213477; M.M. gratefully acknowledges funding by Studienwerk Villigst.

TT 52.5 Thu 16:00 HSZ 201

Evolution of electronic and magnetic properties of the Kitaev-type compound $Ru(Br_{1-x}I_x)_3$ — •Jihuan Gu[1], Tomohiro Takayama[1,2], Alexander Yaresko[1], and Hidenori Takagi[1,2] — [1]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Institut für Funktionelle Materie und Quantentechnologien, University of Stuttgart, 70550 Stuttgart, Germany

Kitaev magnets like α-$RuCl_3$ have attracted great attention in the field of solid-state physics as a potential realization of exotic quantum spin-liquid state. If such Kitaev materials are turned into a metallic state, exotic electronic properties may be realized near the critical phase boundary, such as unconventional superconductivity. So far, carrier doping via intercalation or application of pressure has been attempted to induce a metal-insulator transition (MIT), but no metallic state has been obtained. Recently, the two honeycomb compounds $RuBr_3$ and RuI_3, which are isostructural to α-$RuCl_3$, have been reported. While $RuBr_3$ is a Mott insulator with a zigzag magnetic order, RuI_3 was reported to be a correlated semimetal, likely induced by the enhanced d-p hybridization. Hence, the MIT phase boundary should be expected between $RuBr_3$ and RuI_3. We thus synthesized $Ru(Br_{1-x}I_x)_3$ with various doping levels x. The successful substitution of Br with I was confirmed by the systematic change of lattice parameters. The MIT phase boundary seems to be at x around 0.7. We will discuss the evolution of electronic and magnetic properties in the series of $Ru(Br_{1-x}I_x)_3$ and a marginal metallic state near MIT.

15 min. break

TT 52.6 Thu 16:30 HSZ 201

Milli-Kelvin thermal conductivity of $YbAlO_3$, a quasi-one-dimensional quantum magnet — •Parisa Mokhtari[1,2,3], Ulrike Stockert[1], Stanislav Nikitin[4], Leonid Vasylechko[5], Manuel Brando[2], and Elena Hassinger[1] — [1]Institute of Solid State and Materials, Dresden, Germany — [2]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [3]Physics Department, Technical University of Munich, Garching, Germany — [4]Paul Scherrer Institute, Villigen, Switzerland — [5]Lviv Polytechnic National University, Lviv, Ukraine

In 2019, Wu *et al.* found the typical excitation spectrum of the fractionalised magnetic excitations, so-called spinons, in the Q-1D material $YbAlO_3$ via neutron scattering at 1 K. $YbAlO_3$ exhibits AFM (J_c=2.3 K) and FM (J_{ab}=0.8 K) exchange interaction along and perpendicular to the chain direction, respectively [1, 2]. In zero field (B), a 3D AFM order is established at 0.88 K. For $B \parallel a$, this order is suppressed and replaced by an incommensurate-AFM state, until the field-polarised state occurs for B >1.5 T.

In this work, we investigate the thermal conductivity (κ) of $YbAlO_3$

down to 30 mK in B up to 4 T, with a focus on the magnetic excitations' contribution in thermal transport within different phases and their interactions with lattice vibrations. Notably, our results are in agreement with the previous reports, as well as providing new anomalies compared to thermodynamics' probes and theoretical predictions.
[1] L. S. Wu *et al.*, Nat. Commun. 10, 698 (2019).
[2] L. S. Wu *et al.*, Phys. Rev. B 99, 195117 (2019).

TT 52.7 Thu 16:45 HSZ 201

Thermal expansion and magnetostriction as the probe of exotic magnetism in honeycomb $BaCo_2(AsO_4)_2$ — •Prashanta K. Mukharjee[1], Bin Shen[1], Anton Jesche[1], Julian Kaiser[1], Philipp Gegenwart[1], and Alexander Tsirlin[2] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [2]Felix Bloch Institute for Solid-State Physics, University of Leipzig, 04103 Leipzig, Germany

The $3d^7$ Co-based honeycomb materials have received wide attention as a possible platform for the experimental realization of the celebrated Kitaev model. Here, we elucidate the thermodynamic properties of the candidate material $BaCo_2(AsO_4)_2$ using high-resolution thermal expansion and magnetostriction measurements. At 2 K, with an increase in field, the linear magnetostriction coefficient shows two well-separated anomalies around critical field $H_{c1} \sim 0.2$ T and $H_{c2} \sim 0.5$ T transition around H_{c1} is hysteretic, pointing towards a first-order type transition, whereas the transition at H_{c2} lacks hysteresis, reflecting the second-order nature. The linear thermal expansion coefficient shows a sharp positive peak in 0 T, which decreases, then changes its sign with the rise in the field and smears out entirely above H_{c2}. Below T_N, for $H_{c1} \ll H \ll H_{c2}$, our angle-dependent magnetization shows an apparent six-fold symmetry, whereas significant deviations have been observed below Hc1 and above H_{c2}. We draw the in-plane phase diagram from the above experiments and other complementary techniques and discuss the interplay of first and second-order transitions in this material.

TT 52.8 Thu 17:00 HSZ 201

Phononic-magnetic dichotomy of the thermal Hall effect in the Kitaev-Heisenberg candidate material $Na_2Co_2TeO_6$ — Matthias Gillig[1], Xiaochen Hong[2,1], Christoph Wellm[1], Vladislav Kataev[1], Weiliang Yao[3], Yuan Li[3], Bernd Büchner[1], and •Christian Hess[2,1] — [1]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [2]Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, 42097 Wuppertal, Germany — [3]International Center for Quantum Materials, School of Physics, Peking University, 100871 Beijing, China

We investigate the thermal Hall effect of the Kitaev quantum spin liquid candidate material $Na_2Co_2TeO_6$ in both the magnetically ordered and the paramagnetic phase, with a magnetic field perpendicular to the honeycomb layers of this material. The transversal heat conductivity κ_{xy} is sizeable, but remains at all temperatures investigated significantly smaller than one half of the thermal conductance quantum which has been predicted as fingerprint of topologically protected Majorana edge modes in a Kitaev quantum spin liquid. κ_{xy} is negative in the paramagnetic phase but becomes positive deep in the antiferromagnetically ordered phase suggesting a non-phononic origin. However, distinct similarities are present in κ_{xy} and the longitudinal thermal conductivity κ_{xx} concerning both their temperature and field dependences. Thus our findings imply an at least two-component, i.e. magnetic and phononic origin of the thermal Hall effect in $Na_2Co_2TeO_6$.

TT 52.9 Thu 17:15 HSZ 201

Triple-Q order in $Na_2Co_2TeO_6$ from proximity to hidden-SU(2)-symmetric point — •Wilhelm Krüger[1], Wenjie Chen[2], Xianghong Jin[2], Yuan Li[2,3], and Lukas Janssen[1] — [1]Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, 01062 Dresden, Germany — [2]International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, China — [3]Collaborative Innovation Center of Quantum Matter, Beijing 100871, China

In extended Heisenberg-Kitaev-Gamma-type spin models, hidden-SU(2)-symmetric points are isolated points in parameter space that can be mapped to pure Heisenberg models via nontrivial duality transformations. Such points generically feature quantum degeneracy between conventional single-Q and exotic multi-Q states. We argue that recent single-crystal inelastic neutron scattering data place the honeycomb magnet $Na_2Co_2TeO_6$ in proximity to such a hidden-SU(2)-symmetric point. The low-temperature order is identified as a triple-Q state arising from the Néel antiferromagnet with staggered magnetization in the out-of-plane direction via a 4-sublattice duality transformation. This state naturally explains various distinctive features of the magnetic excitation spectrum, including its surprisingly high symmetry and the dispersive low-energy and flat high-energy bands. Our result demonstrates the importance of bond-dependent exchange interactions in cobaltates, and illustrates the intriguing magnetic behavior resulting from them.