TT 64: Frustrated Magnets - α-$RuCl_3$ and Cu-based Materials

Time: Wednesday 15:00–18:15 Location: HFT-FT 101

TT 64.1 Wed 15:00 HFT-FT 101

Electronically highly cubic conditions for Ru in α-$RuCl_3$

— •Stefano Agrestini[1], Chang-Yang Kuo[1], Kyung-Tae Ko[1], Zhiwei Hu[1], Deepa Kasinathan[1], Hari Babu Vasili[2], Javier Herrero-Martin[2], Manuel Valvidares[2], Eric Pellegrin[2], Anne Henschel[1], Marcus Schmidt[1], Ling-Yun Jang[3], Arata Tanaka[4], and Liu Hao Tjeng[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]ALBA Synchrotron Light Source, Barcelona, Spain — [3]NSRRC, Hsinchu, Taiwan — [4]Department of Quantum Matter, Hiroshima University, Higashi-Hiroshima, Japan

α-$RuCl_3$ is the most promising candidate for the long-sought materialization of the Kitaev model. Prerequisite for these expectations is that the non-cubic crystal field splitting is small compared to the spin-orbit coupling (SOC) and, hence, does not perturb in a significant way the description of the electronic ground state in terms of the $J_{eff} = 1/2$ state. In this context, contradictory reports are available in literature.

In this talk I present a study of the local Ru 4d electronic structure of $RuCl_3$ by means of polarization dependent x-ray absorption spectroscopy at the Ru-$L_{2,3}$ edges. The observed linear dichroism is vanishingly small indicating that electronically the Ru 4d local symmetry is highly cubic. Consistent with our magnetic circular dichroism measurements, the ratio of the orbital and spin moments is found to be 2.0, the value expected for a $J_{eff} = 1/2$ ground state. The data thus show that as far as the Ru 4d local properties are concerned, $RuCl_3$ is an ideal candidate for the realization of the Kitaev physics.

TT 64.2 Wed 15:15 HFT-FT 101

High pressure magnetization measurements in α-$RuCl_3$

— •Gaël Bastien[1], Randirley Beltrán Rodríguez[1], Paula Lampen Kelley[2], Steven Nagler[2], Ravi Yadav[3], Liviu Hozoi[3], Jeroen Van den Brink[3,4], Anja U B Wolter[1], and Bernd Büchner[1,4] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, 01171 Dresden, Germany — [2]Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [4]Department of Physics, Technical University Dresden, Helmholtzstrasse 10, 01069 Dresden, Germany.

α-$RuCl_3$ is a promising candidate for the realization of the Kitaev quantum spin liquid. Its structure consists of honeycomb layers of J_{eff}=1/2 Ruthenium atoms. However at ambient pressure, α-$RuCl_3$ shows an antiferromagnetic ground state below $T_N \approx$7K: the zig zag order. This order can be suppressed by the application of a magnetic field to induce the Kitaev quantum spin liquid ground state.

Another route to tune the magnetic properties of $\alpha-RuCl_3$ is the application of pressure. The magnetization under hydrostatic pressure was measured with a home built low background pressure cell down to 2K and up to 2GPa. The antiferromagnetic ground state of α-$RuCl_3$ is indeed suppressed under pressure at $P_c \approx$0.2GPa together with a collapse of the magnetic susceptibility for both field applied in and transverse to the basal plane. We discuss possible scenarios to explain the new pressure induced state and its origin and draw the pressure-temperature phase diagram.

TT 64.3 Wed 15:30 HFT-FT 101

Pressure induced structural phase transition and dimer formation in α-$RuCl_3$

— •Maximilian Kusch[1], Quirin Stahl[1], Theo Woike[1], Gaston Garbarino[2], Francisco Javier Martinez[2], Mohamed Mezouar[2], Lisa Leissner[3], Kwang-Yong Choi[4], and Jochen Geck[1] — [1]Institute of Solid State and Materials Physics, TU Dresden, 01069 Dresden, Germany — [2]European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble Cedex, France — [3]Institut für Anorganische Chemie, Technische Universität Bergakademie Freiberg, D-09596 Freiberg, Germany — [4]Department of Physics, Chung-Ang University, Seoul 156-756, Republic of Korea

Currently α-$RuCl_3$ is the most promising candidate for the long sought realization of the Kitaev model, which is believed to be very close to a gapless spin-liquid. Under ambient conditions, however, α-$RuCl_3$ exhibits antiferromagnetic ordering below 7K, but several experimental studies indicate the proximity to the Kitaev limit nonetheless. In accordance very recent magnetization measurements as a function of pressure revealed a significant decrease in the magnetization. We therefore performed single crystal XRD as a function of pressure in the range < 2GPa at 4 - 300K to determine the structural changes related to the magnetic transition. Our study shows that the monoclinic phase under ambient conditions transforms into a metastabile hexagonal phase followed by a trigonal phase featuring strong Ru-Ru dimer bonds. Specifically the latter transition coincides with the observation of a significant decrease in the magnetization. One possible explanation for this effect is the formation of a S=0 singlet state on the Ru-Ru dimers.

TT 64.4 Wed 15:45 HFT-FT 101

Ultrafast relaxation dynamics in a Kitaev spin-liquid candidate α-$RuCl_3$

— •Steinn Ymir Agustsson[1], Vladimir Grigorev[1], Tao Dong[2], Nanlin Wang[2], and Jure Demsar[1] — [1]University of Mainz, Germany — [2]Peking University, China

α-$RuCl_3$, which forms an almost ideal 2D honeycomb lattice with weak interlayer coupling, has been proposed to be a prime candidate for the realization of Kitaev physics. While α-$RuCl_3$ is an antiferromagnet at temperatures below 7-14 K (depending on the stacking configuration), numerous experiments suggest spin liquid behavior at temperatures above the Néel transition. To probe the dynamics in α-$RuCl_3$, we performed systematic temperature and excitation density dependent measurements of reflectivity dynamics with femtosecond time resolution, following photoexcitation via inter-site Ru d-d excitations. The low temperature dynamics is found to span timescales from 0.1 to 100 ps, and is strongly temperature and excitation density dependent near and below the Néel temperature. While the phase transition is clearly resolved, the anomalously slow dynamics extends far above the transition temperature. Finally, a structural transition with clear hysteresis was observed around 100 K, wit yet minor effect on carrier/spin relaxation dynamics.

TT 64.5 Wed 16:00 HFT-FT 101

Microwave absorption studies on the Kitaev-Heisenberg material α-$RuCl_3$

— •Christoph Wellm[1,2], Julian Zeisner[1,2], Alexey Alfonsov[2], Anja Wolter[2], Maria Roslova[3], Anna Isaeva[3], Thomas Doert[3], Matthias Vojta[4], Bernd Büchner[1,2], and Vladislav Kataev[1] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, D-01171 — [2]Institut für Festkörper- und Materialphysik, TU Dresden, D-01062 — [3]Fachrichtung Chemie und Lebensmittelchemie, TU Dresden, D-01062 — [4]Institut für Theoretische Physik, TU Dresden, D-01062

Topologically ordered states of matter have recently gained much attention due to their novel physical properties, the signatures of which can be experimentally probed. A prime example is the spin liquid realized in the Kitaev honeycomb lattice compass model, where fractionalization of particles leads to broad continuum-like features in the magnetic response. We will present the high-field microwave absorption results on the Mott-Hubbard-insulating material α-$RuCl_3$ which is, due to its structure and strong spin-orbit coupling, a promising candidate for the realization of Kitaev physics. Measurements on a single-crystal were conducted over a frequency range of ν = 70-660 GHz at temperatures ranging from 3-30 K. Strikingly, in addition to previously observed conventional gapped magnon modes, we find a highly unusual broad continuum characteristic of fractionalization which extends to energies below the lowest sharp mode and to temperatures significantly higher than the ordering temperature.

TT 64.6 Wed 16:15 HFT-FT 101

Thermal Hall effect in α-$RuCl_3$

— •Richard Hentrich[1,2], Bernd Büchner[1,2], Maria Roslova[3], Anna Isaeva[3], Thomas Doert[3], and Christian Hess[1,2] — [1]IFW Dresden, Germany — [2]Center for Transport and Devices of Emergent Materials, TU Dresden, Germany — [3]Department of Chemistry and Food Chemistry, TU Dresden, Germany

The Kitaev-Heisenberg model is source of a topological quantum spin liquid with Majorana fermions and gauge flux excitations as fractional quasiparticles. The material α-$RuCl_3$ is composed of weakly van der Waals bound honeycomb layers of edge sharing $RuCl_6$ octahedra which has recently emerged as a prime candidate for realising such physics. We studied α-$RuCl_3$ by means of thermal transport measurements, a valuable tool to probe elementary excitations of systems with low dimensional spin structure.

While the in-plane, longitudinal heat transport is governed by heat conduction of phonons that strongly scatter off the magnetic excitations present in the system, studying the thermal Hall effect (Rhighi-Leduc effect) opens up a new path towards detecting a direct contribution of unconventional magnetic excitations to entropy transport. We have observed a sizeable transversal heat conductivity κ_{xy}, the agreement of which with the theoretical predictions for the pure Kitaev model being suggestive of heat transport by fractionalised quasiparticles in α-$RuCl_3$.

15 min. break.

TT 64.7 Wed 16:45 HFT-FT 101

Magnetic excitations and lattice dynamics in the $s = 1/2$ pseudo-kagome system $Cu_3Bi(SeO_3)_2O_2(Br,Cl)$ — Vladimir Gnezdilov[1], Dirk Wulferding[2,3], •Peter Lemmens[2,3], Vladimir Kurnosov[1], Yurii Pashkevich[4], Peter Berdonosov[5], and Alexander Vasiliev[5] — [1]ILTPE, NASU, Kharkov, Ukraine — [2]IPKM, TU-BS, Braunschweig, Germany — [3]LENA, TU-BS, Braunschweig, Germany — [4]DonFTI, NASU, Donetsk, Ukraine — [5]MSU, Moscow, Russia

The francisites $Cu_3Bi(SeO_3)_2O_2Br$ and $Cu_3Bi(SeO_3)_2O_2Cl$ form layered pseudo-kagome structures, resulting in a highly spin frustrated state [1]. Our temperature- and field-dependent study uncovers strong lattice dynamics in $Cu_3Bi(SeO_3)_2O_2Cl$, that are absent in the -Br system. The origin of a low-energy excitation emerging in the magnetically ordered phase is discussed with respect to its magnetic field response and selection rule.

Work supported by DFG Project LE967/16-1.

[1] Gnezdilov, et al., PRB 96, 115144 (2017).

TT 64.8 Wed 17:00 HFT-FT 101

High magnetic field study of the frustrated quantum magnet atacamite — •Stefan Süllow[1], Leonie Heinze[1], Marcelo Jaime[2], Xiaxin Ding[2], Vivian Zapf[2], Anja U.B. Wolter[3], and Kirrily C. Rule[4] — [1]TU Braunschweig, Braunschweig, Germany — [2]NHMFL, Los Alamos, USA — [3]IFW Dresden, Dresden, Germany — [4]The Bragg Institute, ANSTO, Australia

The mineral atacamite $Cu_2Cl(OH)_3$ has been proposed to represent a frustrated quantum magnet [1,2]. From a basic magnetic characterization in low magnetic fields, it can be inferred that long range magnetic order occurs below $T_N = 9$ K and ~ 10 T (ordering vector q = [1/2 0 1/2]), while magnetic saturation is attained only for fields beyond 50 T. This difference in field scales likely reflects low dimensionality and/or geometric frustration of the magnetic system. Therefore, we have carried out a magnetostrictive high magnetic field study, this way establishing the essential features of the magnetic phase diagram for all crystallographic axes in fields up to 65 T. We find rich phase diagrams for all directions and discuss these in terms of possible magnetic models accounting for the properties of atacamite.

[1] X. G. Zheng, et al., Phys. Rev. B **71**, 174404 (2005).
[2] L. Heinze, et al., Physica B (2017),
http://dx.doi.org/10.1016/j.physb.2017.09.073.

TT 64.9 Wed 17:15 HFT-FT 101

Neutron diffraction, muon spin rotation and Raman scattering investigation of the multiferroic antiferromagnetic quantum spin chain system $CuCrO_4$ — J. M. Law[1,5], V. Pomjakushin[2], G. Pascua[2], H. Luetkens[2], Th. Hansen[3], R. Glaum[4], A. Schulz[1], J. Wosnitza[5], and •R. K. Kremer[1] — [1]Max-Planck-Institut für Festkörperforschung, D-70569 Stuttgart, Germany — [2]Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland — [3]Institut Laue Langevin, F-38042 Grenoble, France — [4]Institut für Anorganische Chemie, Universität Bonn, Gerhard-Domagk-Strasse 1, D-53121 Bonn, Germany — [5]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany

Long-range magnetic ordering in multiferroic spin-chain compound $CuCrO_4$ was investigated by powder neutron diffraction and muon spin rotation measurements. Consistently, both methods find incommensurate long- range antiferromagnetic ordering below 9.0(3) K. The magnetic structure was determined from neutron powder diffraction patterns based on the propagation vector τ=(1,0,0.546(1)). The magnetic moment at 2K was refined to 0.67(10) μ_B. Low-temperature high-magnetic-field measurements of the magnetization and the dielectric polarization show the multiferroic phase to extend up to $\approx$ 23 T, after which a new, yet unknown phase appears. Full saturation of the magnetic moment is expected to occur at fields $\gg$ 60 T. Raman scattering and low-temperature x-raypowder diffraction measurements are used to correlate magnetic, structural and dielectric properties.

TT 64.10 Wed 17:30 HFT-FT 101

Thermodynamic investigations of the anisotropic triangular Heisenberg antiferromagnet $Cs_2CuCl_{4-x}Br_x$ — •Ulrich Tutsch[1], Oleksandr Tsyplyatyev[2], Lars Postulka[1], Markus Kuhnt[1], Bernd Wolf[1], Natalija van Well[1], Franz Ritter[1], Cornelius Krellner[1], Burkhard Schmidt[3], Peter Kopietz[2], and Michael Lang[1] — [1]Physikalisches Institut and — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt, SFB/TR 49, 60438 Frankfurt (M), Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany

The system $Cs_2CuCl_{4-x}Br_x$ is known to be a good realization of the $S = 1/2$ 2D anisotropic triangular Heisenberg antiferromagnet. Its border compounds ($x = 0, 4$) have been intensively studied by neutron scattering experiments, ESR and thermodynamic methods, so that the ratio J'/J of the coupling constants of 0.34 ($x = 0$) and 0.41 ($x = 4$) is known with a high degree of accuracy. We will present specific heat results for the two intermediate compounds with $x = 1, 2$ which can be synthesized with a fully ordered halide sublattice when grown at relatively low temperatures from an aqueous solution. A $C \propto T$ behaviour is observed at low temperatures for both compounds although $Cs_2CuCl_2Br_2$ already shows a rather high value $J'/J \approx 0.7$. Our experimental results are in good agreement with our theoretical calculations, which demonstrate that a $C \propto T$ behaviour at low temperatures can be a result of strong quantum fluctuations in $S = 1/2$ 2D anisotropic triangular Heisenberg antiferromagnets, contrary to the general believe that it reflects quasi-1D behaviour.

TT 64.11 Wed 17:45 HFT-FT 101

Magnetic and magneto-elastic couplings in $Cs_2CuCl_{4-x}Br_x$ with x = 0, 1, 2. — •Bernd Wolf, Satya Krishna Thallapaka, Elena Gati, Lars Postulka, Franz Ritter, Cornelius Krellner, and Michael Lang — Physics Institute Goethe University, SFB/TR 49, 60438 Frankfurt, GermanyFrankfurt,

Like for the intensively investigated quasi-2D frustrated triangular quantum antiferromagnet Cs_2CuCl_4, the newly discovered stoichiometric compounds $Cs_2CuCl_{4-x}Br_x$ with x = 1, 2 exhibit a well-ordered local Cu environment due to a site-selective substitution of the halid atoms. We present $\chi(T,p)$ data from which the magnetic coupling constants are extracted based on a $J_1 - J_2$ model. We find that $Cs_2CuCl_3Br_1$ and $Cs_2CuCl_2Br_2$ exhibit a distinctly larger degree of geometric frustration of $J_1/J_2 = 0.47$ and 0.63, respectively, as compared to 0.29 for the pure Cl material. From the variation of the susceptibility under hydrostatic He-gas pressure up to 4 kbar for the different materials we extract the pressure dependence of J_1 and J_2 as well as the magneto-elastic coupling constants. Compared to other low-dimensional spin systems, the magneto-elastic couplings are at least two orders of magnitude smaller. We assign this behavior to structural peculiarities of this class of materials where structural rigid units, containing the magnetic centres, are embedded in a highly compressible matrix.

TT 64.12 Wed 18:00 HFT-FT 101

Anomalous Hall effect in frustrated antiferromagnet HoAgGe — •Kan Zhao and Philipp Gegenwart — Experimentalphysik VI, University Augsburg

Geometric frustration in magnetic systems arises from competing magnetic interactions that cannot be satisfied simultaneously and leads to a variety of exotic ground states. Recent theoretical calculations show frustrated antiferromagnet Mn_3Ir will exhibit the anomalous hall effect (AHE), because of the three rotation symmetry of Mn kagome lattice. Then the AHE is observed in non collinear antiferromagnet Mn_3Sn at 300K due to the Berry curvature in momentum space.

HoAgGe, which crystallize in the hexagonal ZrNiAl-type structure, is an antiferromagnet below 11K. The Ho atoms form a distorted Kagome lattice. With high quality single crystal, we investigate the transport and magnetic property at 2K. Obvious hysteresis can be observed from hall resistance and magnetroresistance between 1T and 3T. However, there is no hysteresis from M(H) curve at the same field region, indication the hysteresis not coming from the magnetization. There are probably some non collinear antiferromagnetic structure under field, which has no contribution to magnetization, but will contribute to the anomalous hall effect (AHE), namely the hysteresis in hall resistance between increasing and decreasing field.

To investigate the origin of AHE in this system, we conduct single crystal neutron diffraction at 2K and under magnetic field. And the determination of the non collinear frustrated magnetic structure of HoAgGe is still in progress.