THU 8: Frustrated Quantum Systems: Contributed Session to Symposium

Time: Thursday 14:15–16:00 Location: ZHG009

THU 8.1 Thu 14:15 ZHG009

Stretched Drude response in doped Mott insulators: Peculiar charge dynamics in molecular quantum spin liquids — Savita Priya[1], •Martin Dressel[1], and Simone Fratini[2] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Néel Institute - CNRS and Université Grenoble Alpes, Grenoble, France

Among the extensively studied class of low-dimensional molecular quantum-spin-liquid compounds κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ is of particular interest because the incommensurate anion layer results in a extraordinary charge transfer: the strongly correlated system remains metallic down to the superconducting transition. Our comprehensive investigations of its optical properties reveal a peculiar charge dynamics and show that the strange-metal behavior in the resistivity is tightly related to a stretched Drude response in the optical conductivity, i.e. a generalized form of the Drude absorption representing a stretched exponential relaxation. Our study may help to solve the longstanding puzzle of unusual metallic properties frequently observed in high-T_c cuprate and other transition metal oxides.

We thank our collaborators: J. Liebman, N. Drichko, K. Kanoda, H. Taniguchi, T. Kobayashi, J. Ovčar, I. Lončarić

THU 8.2 Thu 14:30 ZHG009

Majorana Fermi Surface and Transient Localization from Coherent Disorder — •Shi Feng[1], Penghao Zhu[2], Kang Wang[3], Tao Xiang[3], Nandini Trivedi[2], Michael Knap[1], and Johannes Knolle[1] — [1]Technical University of Munich, Garching, Germany — [2]The Ohio State University, Columbus, USA — [3]Institute of Physics, Chinese Academy of Sciences, Beijing, China

We propose a mechanism to explain the emergence of the intermediate gapless spin liquid phase in the Kitaev material under an external magnetic field. In moderate fields, flux-trapped localized Majorana resonances are nucleated in the ground state. As the density of these fluxes increases with field strength, the Majorana modes begin to overlap, leading to the formation of an emergent Z2 quantum Majorana metallic state with a Fermi surface at zero energy. Our analysis shows that the Majorana spectral function obtained by our mean-field approach captures the dynamical spin and dimer correlations computed via infinite projected entangled pair states and density matrix renormalization group methods. The identification of the intermediate gapless phase as a quantum Majorana metal at zero temperature suggests a new class of gapless quantum spin liquids that is complementary to the conventional Dirac spin liquids and U(1) spinon Fermi surface states found in prevailing theories. Based on the picture of a Majorana metal induced by zero-temperature coherent disorders in the emergent gauge field, we further discuss the possibility of transient localization and unconventional transport properties, and comment on potential realization in Rydberg atom array experiments.

THU 8.3 Thu 14:45 ZHG009

Optical investigations of incommensurate κ-BEDT-TTF based molecular quantum materials — •Savita Priya[1], Juraj Ovčar[2], Maxim Wenzel[1], Jesse Liebman[3], Takuya Kobayashi[4], Hiromi Taniguchi[4], Dita Puspita Sari[5], Yasuyuki Ishii[5], Kazushi Kanoda[1,6,7], Ivor Lončarić[2], Natalia Drichko[3], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Ruder Bošković Institute, Zagreb — [3]Department of Physics and Astronomy, Johns Hopkins University — [4]Department of Physics, Saitama University — [5]Global Course of Engineering and Science, SIT, Tokyo — [6]Department of Advanced Materials Science, University of Tokyo — [7]MPI-FKF, Stuttgart

κ-BEDT-TTF based charge transfer salts are correlated electron system. Their distinct triangular lattice arrangement is highly susceptible to geometric and magnetic frustration, leading to exotic phases like quantum-spin liquids, antiferromagnetism, charge ordering, Mott-insulator and superconductivity at low temperatures. In our study, we focus on κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ and κ-(BEDT-TTF)$_4$Hg$_{2.78}$Cl$_8$ by broadband infrared spectroscopy and Raman scattering spectroscopy to examine the effects of the non-stoichiometric anion layer as a crucial parameter on geometric frustration and their unusual response. Optical spectroscopy methods allow us to study these compounds by probing the electronic and structural responses (by molecular and lattice vibrations) with temperature. The well-resolved electronic response enables us to employ theories of correlated physics, strengthening our understanding of these unusual κ-phase salts.

THU 8.4 Thu 15:00 ZHG009

Control of the carrier distribution in a quasi-2D Mott-Hubbard solid via ultrafast photodoping and pressure-tuning revealed by terahertz-infrared spectroscopy — Konstantin Warawa[1], Yassine Agarmani[1], Sheng Qu[1], Harald Schubert[1], Martin Dressel[2], Michael Lang[1], Hartmut G. Roskos[1], and •Mark D. Thomson[1] — [1]Physikalisches Institut, J. W. Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]1. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, Germany

Electronic correlations in solids can yield a rich phase diagram including a Mott metal-insulator transition (MIT), superconductivity and magnetic order, not only due to the interplay between bandwidth (W) and Coulomb repulsion (U), but also the concerted response of the band structure to charge-carrier excitation. This can lead to drastic effects in Mott-Hubbard insulators with small energy gaps (Δ of some 10 meV), such as the organic charge-transfer salt presented here, κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl. We present two experimental approaches using terahertz-infrared (THz-IR) pulses to probe the carrier distribution/conductivity: 1. Ultrafast photodoping, where the quasi-equilibrium is a hot electronic state with a non-thermal phonon distribution and significant deformation of the Hubbard bands (even for low excited carrier densities $\sim$1%). 2. Pressure-tuning across the MIT (below 30 MPa), where the THz dynamic conductivity senses metallic domains within the MI coexistence regime, complementary to DC transport where the MIT is dominated by a macroscopic percolation threshold.

THU 8.5 Thu 15:15 ZHG009

Pressure control of magnetic frustration — •Björn Wehinger — European Synchrotron Radiation Facility, 71, avenue des Martyrs, CS 40220, 38043 Grenoble Cedex 9, France.

Low-dimensional materials with strong magnetic frustration and enhanced quantum fluctuations embody the characteristics of the long-sought spin liquid where magnetic order is suppressed and fractional excitations and entanglement are expected. Significant progress in materials science has been made in realizing copper-based quantum magnets where localized spin-1/2 moments are arranged in low dimensions allowing for geometrical frustration.

In this contribution I will show how external pressure can be used to control magnetic frustration. Using single crystal x-ray diffraction at high-pressure and low temperature together with density functional theory calculations we investigate how pressure-induced modifications in the structure influences the strength of the magnetic exchange [1]. In presence of anisotropy in the system the various super-exchange paths are affected differently by hydrostatic pressure which allows direct control of magnetic frustration [2]. Stabilizing new quantum phases at high pressure opens the possibility to drive systems close to quantum critical points which in-turn enables to investigate the development of spin and lattice correlations as the system approaches criticality.

Finally, I will give a broader overview of research possibilities on quantum materials at the European Synchrotron.

[1] B. Wehinger et al., Phys. Rev. Lett. 121, 117201 (2018).
[2] D. Chatterjee et al., arXiv:2502.09733 (2025).

THU 8.6 Thu 15:30 ZHG009

Diamond-decorated quantum antiferromagnets in two dimensions — •Andreas Honecker[1], Katarína Karľová[1], Malo Rouxel[1], Jozef Strečka[2], Taras Verkholyak[3], Stefan Wessel[4], and Nils Çaçi[5] — [1]Laboratoire de Physique Théorique et Modélisation, CNRS, CY Cergy Paris Université, France — [2]Department of Theoretical Physics and Astrophysics, P.J. Šafárik University, Košice, Slovakia — [3]Institute for Condensed Matter Physics, National Academy of Sciences of Ukraine, L'viv — [4]Institute for Theoretical Solid State Physics, RWTH Aachen University, Germany — [5]Laboratoire Kastler Brossel, Collège de France, France

The spin-$\frac{1}{2}$ Heisenberg antiferromagnet on the diamond-decorated square and honeycomb lattices is a highly frustrated quantum spin system that in the presence of a magnetic field displays a rich phase diagram, including the Lieb-Mattis ferrimagnetic, dimer-tetramer, monomer-dimer, and spin-canted phases, in addition to the fully saturated state. We investigate the thermodynamic properties of this model using exact diagonalization, an effective monomer-dimer description, and sign-problem-free quantum Monte Carlo simulations. In the parameter region favoring the dimer-tetramer phase, the ground-state problem can be represented by a classical hard-dimer model and retains a macroscopic degeneracy even under a magnetic field. We detect an enhanced magnetocaloric effect on the square lattice. The ground-state degeneracy in the zero-field dimer-tetramer phase can be lifted by a small distortion. In a particular case on the honeycomb lattice, this gives rise to a Kastelyn-type phase transition.

THU 8.7 Thu 15:45 ZHG009

Quantifying entanglement in frustrated transverse-field Ising model — •Leonardo dos Santos Lima — lslima@cefetmg.br

In this paper, we analyzed the effect of quantum phase transition (QPT) on quantum correlation and entanglement in the frustrated antiferromagnetic transverse-field Ising model on ruby lattice. We get the reduced density matrix entropy as a function of exchange interactions J_i $(i = 1, 2, 3)$ and external transverse-field h which induces phases transitions in the system, with the aim to verify its influence on quantum correlation and entanglement. We get that the effect of opening of the gap in the spectrum generates a small variation in the behavior of the von Neumann entropy (VN) due to the fact that analyzing the influence of QPT on entanglement in quantum spin systems is a complex field and an intriguing task in recent years. We focus on how these frustrating competing interactions and the different phases affect the quantum correlation and entanglement.