TT 1: Focus Session: Frustration in Mott Insulators and Mott Criticality

When electronic correlations drive metals towards Mott insulators, commonly magnetic order occurs. The strong frustration in triangular- and Kagome-lattice Mott insulators, however, may lead to a quantum spin liquid state. In recent years, broad and intense efforts to explore the organic dimer-Mott systems, Herbertsmithite, α-$RuCl_3$ etc. from the experimental and theoretical side led to significant advances in the understanding of frustrated Mott systems, their dynamics, the interplay of charge, spin and orbital degrees of freedom as well as the coupling of the critical electronic system to the lattice degrees of freedom.

Organization: Martin Dressel, Universität Stuttgart; Michael Lang, Universität Frankfurt; Roser Valentí, Universität Frankfurt

Time: Monday 9:30–12:45 Location: HSZ 03

Invited Talk TT 1.1 Mon 9:30 HSZ 03

Herbertsmithite and the Search for the Quantum Spin Liquid — •Michael Norman — Materials Science Division, Argonne National Lab, Argonne, IL 60439 USA

Quantum spin liquids are a novel class of matter where, despite the existence of strong exchange interactions, spins do not order. Typically, they occur in lattices that act to frustrate the appearance of magnetism, the classic example being the kagome lattice composed of corner sharing triangles. There are a variety of minerals whose transition metal ions form such a lattice. Of particular note is herbertsmithite, composed of copper ions forming a kagome lattice. Over the past decade, this material has been extensively studied, yielding a number of intriguing surprises that have in turn motivated a resurgence of interest in the study of the spin 1/2 Heisenberg model on a kagome lattice. In this talk, I will summarize these developments, and then discuss future directions, including the challenge of doping these materials with the hope that this could lead to novel topological or superconducting phases.

Invited Talk TT 1.2 Mon 10:00 HSZ 03

Anisotropic Magnetism and Spin Gap in α-$RuCl_3$ — •Bernd Büchner — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

Quantum spin liquids are a central theme in current condensed matter physics as they host emergent topological order and fractionalized excitations. An important example are interacting Kitaev spins on a honeycomb lattice which are theoretically predicted to exhibit topological and quantum spin liquids. Identifying signatures of Kitaev physics, however, is extremely challenging as real materials, such as the iridates $(Na,Li)_2IrO_3$, inevitably entail an isotropic Heisenberg and additional spin-exchange interactions, thereby stabilizing a magnetically ordered state. Hexagonal Ru trichloride α-$RuCl_3$ has been recently reported to be near the Kitaev spin-liquid phase boundary. The layered honeycomb structure of α-$RuCl_3$ contains layers weakly coupled by van der Waals interaction, i.e. it is a correlated 2d-material offering many possibilities for *materials engineering*. We have characterized the electronic and magnetic properties of α-$RuCl_3$ by a broad spectrum of experimental techniques. From electron spectroscopy basic parameters determining the insulating state of α-$RuCl_3$ are extracted. Moreover, strongly anisotropic magnetic properties as measured from magnetization, specific heat, thermal conductivity, and NMR measurements will be presented and discussed. Both, the behavior of α-$RuCl_3$ in the paramagnetic phase as well as the properties of the ordered state strongly differ from that found in conventional two-dimensional magnets. In particular, we find a very unusual field-temperature phase diagram with evidence for a novel quantum critical point.

Invited Talk TT 1.3 Mon 10:30 HSZ 03

The Fate of Spinons in Quantum Critical Mott Systems — •Vladimir Dobrosavljevic — Department of Physics and National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL 32310, USA

Recent theoretical and experimental work found evidence of quantum critical scaling behavior around bandwidth-driven Mott transitions in several organic systems of the kappa-family. These experimental results show remarkably universal scaling features, which appear largely identical both in materials displaying long-range antiferromagnetic order on the insulating side, and those showing spin liquid signatures at the lowest temperatures. To provide insight in the role of spin correlations in the critical regime, we blend dynamical mean-field theory (which provided remarkably good description of the high temperature regime), and the RVB-spinon mean-field theory, which describes the spin liquid excitations on the insulating side. Our results indicate that spinon excitations suffer very strong inelastic scattering from dynamical charge fluctuations as soon as the Mott gap closes. We conclude that while spinon excitations dominate the low-temperature insulating regime, they prove largely irrelevant in the entire high-temperature quantum critical regime, in agreement with all available experimental data.

15 min. break.

Invited Talk TT 1.4 Mon 11:15 HSZ 03

Breakdown of Hooke's Law of Elasticity at the Mott Critical Endpoint in an Organic Conductor — •Elena Gati[1], M. Garst[2,3], R.S. Manna[1], U. Tutsch[1], B. Wolf[1], L. Bartosch[4], T. Sasaki[5], H. Schubert[1], J.A. Schlueter[6], and M. Lang[1] — [1]Physikalisches Inst., Goethe Univ., SFB/TR49, Frankfurt, DE — [2]Inst. f. Theo. Physik, Univ. zu Köln, DE — [3]Inst. f. Theo. Physik, TU Dresden, DE — [4]Inst. f. Theo. Physik, Goethe Univ., FFM, DE — [5]IMR, Tohoku Univ., Sendai, Japan — [6]NSF, Arlington, USA

The Mott transition is a prime example of the manifestation of strong electron correlations in solids. Despite its importance for a wide range of materials, however, fundamental properties, such as the universal critical behavior, remain unresolved. An essential, experimentally yet unexplored aspect is the role of electron-lattice coupling on the criticality. In this talk, we will present measurements of the thermal expansion as a function of pressure, P, around the P-induced Mott transition in the organic charge-transfer salt κ-$(BEDT\text{-}TTF)_2Cu[N(CN)_2]Cl$ [1]. We observe a breakdown of Hooke's law of elasticity upon approaching the critical endpoint, revealing an intimate, non-pertubative coupling of the critical electronic degrees of freedom to the crystal lattice. Our results are fully consistent with mean-field (MF) criticality, predicted theoretically for electrons in a compressible lattice with finite shear modulus [2]. We argue that every pressure-tunable Mott transition shows the universal properties of an isostructural solid-solid endpoint with MF criticality rather than a liquid-gas endpoint.

[1] Gati *et al.*, Sci. Adv., submitted;
[2] Zacharias *et al.*, PRL **109**, 176401 (12).

Invited Talk TT 1.5 Mon 11:45 HSZ 03

The Widom Line in Pristine Mott Insulators: Dynamical Properties of Quantum Spin Liquids — •Andrej Pustogow[1], Simone Fratini[2], Tsung-Han Lee[3], Vladimir Dobrosavljevic[3], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart — [2]Institut Néel - CNRS and Université Grenoble Alpes, France — [3]Department of Physics and National High Magnetic Field Laboratory, Florida State University, Tallahassee, USA

In Mott insulators strong electronic interactions prevent the metallic state. As a paradigm of correlated electron systems, the Mott insulating state is under scrutiny theoretically for more than half a century. Still, the low-temperature behavior evaded experimental exploration because it is typically concealed by an antiferromagnetic phase. In quantum spin liquids, however, no magnetic order is reached, offering the unique possibility to elucidate the pristine Mott state. Here we explore the electrodynamic response of three organic quantum spin liquids with different degrees of effective correlation and frustration. The low-frequency behavior strongly depends on the position in the temperature-pressure phase diagram. In particular in the vicinity of the quantum critical point, metallic fluctuations can be identified at low temperatures. Combining our optical data with pressure-dependent transport studies and theoretical calculations, we can construct a universal phase diagram of the correlation-controlled Mott insulator.

This work was done in collaboration with M. Bories, E. Zhukova, B. Gorshunov, M. Pinteric, S. Tomic, J. Schlueter, A. Löhle, R. Hübner, T. Hiramatsu, Y. Yoshida, G. Saito and R. Kato.

Invited Talk TT 1.6 Mon 12:15 HSZ 03

Toward Understanding the Complex Magnetism in Kitaev Spin-Liquid Candidates — •Stephen Winter, Kira Riedl, and Roser Valenti — Institut fur Theoretische Physik, Goethe-Universitat Frankfurt

Intensive study of the magnetic response of 5d honeycomb Iridates A_2IrO_3 and 4d α-$RuCl_3$ has been motivated recently by signatures of strongly anisotropic and frustrated interactions reminiscent of the Kitaev spin-liquid. In these materials the complex magnetic interactions arise from a competition between various similar energy scales, including spin-orbit coupling (SOC), Hund's coupling, and crystal-field splitting. Due to this complexity, the interactions in such systems remain hotly debated. In this contribution, we will review the state of the art - the picture that emerges from a combination of ab-initio calculations, microscopic considerations, and analysis of the static magnetic responses. We also discuss the excitation continua observed in a variety of experiments including Raman, neutron, and inelastic x-ray, and conclude that such signatures of fractionalization can persist even far away from the spin-liquid ground state.