TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

International Conference

Frustrated Magnetism and Topology

IFW Dresden

Sep 13 - 14, 2021

SFB 1143

ct.qmat
Complexity and Topology in Quantum Matter

Venue: IFW Dresden
Helmholtzstrasse 20
01069 Dresden

WLAN: SFB1143
No password needed.

Coffee breaks are in the Atrium next to the Lecture Hall.

Lecture rooms:
Seminar Room D2E.27 (for speakers and PIs)
Lecture Hall A1E.10

Monday

Mon Sep 13

09:00 – 09:10	M. Vojta	Welcome
09:10 – 09:50	Y. Matsuda	Thermal transport study of Kitaev quantum spin liquid
09:50 – 10:30	M. Zhitomirsky	Saga of fcc antiferromagnet: quantum twist to the old plot
10:30 – 11:00		Coffee break (follow the red signs)
11:00 – 11:40	F. Bert	Quantum spin liquids in kagome materials: herbertsmithite and barlowite
11:40 – 12:20	P. Lemmens	Chirality matters
12:30 – 14:00		Lunch (follow the green signs)
14:00 – 14:40	R. Coldea	Order-by-Disorder from Bond-Dependent Exchange and Intensity Signature of Dirac Magnons in a Honeycomb Cobaltate
14:40 – 15:20	A. Möller	Triangles
15:20 – 15:50		Coffee break (follow the red signs)
15:50 – 16:30	I. Martin	Quantum many-body scars in spin systems
16:30 – 17:10	B. Gaulin	The Case for a $U(1)_\pi$ Quantum Spin Liquid Ground State in the Dipole-Octupole Pyrochlore $Ce_2Zr_2O_7$
17:10 – 17:50	D. Poilblanc	Emergent gapless quantum spin liquid in a square-lattice spin-1/2 frustrated Heisenberg model
18:00 – 19:00		Group discussions
19:00 – 23:00		Dinner & get-together (follow the green signs)

Tuesday

Tue Sep 14

09:00 – 09:40	S. Lee	Duality, deconfinement, and hidden phases of U(1) quantum spin liquids
09:40 – 10:20	M. Lang	Spin liquid and ferroelectricity close to a quantum critical point in $PbCuTe_2O_6$
10:20 – 10:50		Coffee break (follow the red signs)
10:50 – 11:30	K. Behnia	Anomalous Nernst and anomalous thermal Hall effects in topological magnets
11:30 – 12:10	Y.-T. Hsu	Evidence for strong electron correlations in a non-symmorphic Dirac semimetal
12:15 – 13:30		Lunch (follow the green signs)
13:30 – 14:10	F. Assaad	Skyrmion superconductivity
14:10 – 14:50	Y. Su	Topological magnons in 2D van der Waals ferromagnets
14:50 – 15:20		Coffee break (follow the red signs)
15:20 – 16:00	A. Goodwin	Magnetic and pseudospin frustration in metal-organic frameworks
16:00 – 16:40	A. Gibbs	Magnetic phases of topological semimetal Eu_3PbO
17:00		Closing & end of conference

Abstracts

Thermal transport study of Kitaev quantum spin liquid

Yuji Matsuda

Department of Physics, Kyoto University, Japan

Half-integer thermal quantum Hall conductance has recently been reported for the two-dimensional honeycomb material α-$RuCl_3$ [1]. Here we discuss the Chern number [2], Majorana gap [3], and topological phase transition [4] of the Kitaev spin liquid in the magnetic field based on recent studies of thermal transport and thermodynamic measurements of α-$RuCl_3$.

[1] Y. Kasahara et al. Nature 559, 227 (2018).
[2] T. Yokoi et al. Science 373, 567 (2021).
[3] O. Tanaka et al. arXiv:2007.06757.
[4] S. Suetsugu et al. in preparation.

Saga of fcc antiferromagnet: quantum twist to the old plot

Mike E. Zhitomirsky

Univ. Grenoble Alpes & CEA, IRIG, PHELIQS, Grenoble, France

The J_1-J_2 spin model on an fcc lattice is one of the longest-discussed frustrated models relevant to numerous magnetic materials. Our recent results for the order by disorder effect will be presented for both classical and quantum versions of this model. For the nearest-neighbor Heisenberg antiferromagnet ($J_2 = 0$) the two prime candidates for the quantum ground state are the collinear AF1 and AF3 structures described by different propagation wave vectors. Using the self-consistent spin-wave calculations we compute the energy for each of the two states as a function of spin length S. Contrary to the harmonic theory, which predicts the AF3 state, the nonlinear quantum fluctuations stabilize the AF1 state for all physical values of spin. The spin wave results are in good overall agreement with the recent coupled-cluster calculations by J. Richter and co-workers.

Quantum spin liquids in kagome materials: herbertsmithite and barlowite

Fabrice Bert

Laboratoire de Physique des Solides, Université Paris-Saclay, Orsay, France

Quantum spin liquids are fascinating states of matter where quantum fluctuations are strong enough to prevent any kind of magnetic ordering and which sustain exotic fractionalized excitations. Kagome materials offer one route to realize such states, although the exact nature of the spin liquid state on the kagome lattice remains elusive theoretically. Herbertsmithite has been for long a unique realization of this physics. Using delicate NMR studies to separate out defect contributions, there is a consensus that the magnetic excitations are not fully gapped or at least the spin gap is much smaller than the formerly predicted J/20. The more recently discovered Zn-barlowite which also features structurally perfect kagome layers of Cu^{2+} but with a different stacking and thus different interlayer defects, offers an ideal case for comparison. Recent µSR results [2] confirm unambiguously the suppression of the magnetic order of the pristine barlowite upon Zn-doping.

[1] K. Tustain et al., npj Quantum Mater. 5, 74 (2020).
[2] P. Khuntia et al., Nature Physics 16, 469 (2020).

Chirality Matters

Peter Lemmens

Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

A complete characterization of quantum systems implies the detection of both amplitude and phase. This relates to the use of interferometric techniques. On the other side, there exist a large number of recent quantum phases in solids that involve nonlocal invariants, phases, and chiral degrees of freedom. So the question arises, whether methods that are supplemented by phase factors could lead to relevant information [1, 2]. We have recently started to extend our repertoire of experimental techniques by considered structured light for inelastic light scattering. Such photon states carry orbital angular momentum (OAM) in addition to spin angular momentum (SAM, chirality). Presently, applications of OAM exist in super resolution microscopy and the manipulation of trapped ions and BECs, using intensity singularities and transfer of quantized angular momenta [3].

In the limit of paraxial beams, so called twisted (or vortex) light has a helical phase front that can be described, e.g. by Laguerre-Gaussian functions. They can be prepared from circularly polarized light (SAM) using spiral plates that introduce a topological charge into the wave front. Despite its simple generation, the coupling of optical OAM to matter is far from trivial. In lowest order (dipole approximation) there exist no coupling and early studies of so called chirooptical effects, i.e. circular dichroism or the rotation of OAM beams in chiral media did not achieve a clear result [4]. More recently, it has been claimed that strong focusing (optical spin-orbit entanglement), higher order couplings, and electronic resonances could lead to large effects [5].

We have performed exploratory experiments on chiral / topological model systems to search for OAM features different from SAM. Here chiral liquid crystals, Skyrmion systems, semimetals from synthesis within the present SFB, and other spin liquid materials have been and will be investigated. We will demonstrate low energy, diffusive fluctuations in chiral phases possibly related to OAM transfer and a Hanle - like effect (resonant scattering, polarization anomaly). Such observations could lead to an avenue of novel optical phenomena using OAM.

[1] L. Allen et al., Phys. Rev. A 45, 8185 (1992).
[2] A. Forbes et al., AVS Quantum Sci. 1, 011701 (2019).

Order-by-disorder from bond-dependent exchange and intensity signature of nodal quasiparticles in a honeycomb cobaltate

Radu Coldea

Department of Physics, University of Oxford, UK

Recent theoretical proposals have argued that cobaltates with edge-sharing octahedral coordination can have significant bond-dependent exchange couplings thus offering a platform in 3d ions for such physics beyond the much-explored realizations in 4d and 5d materials. We report inelastic neutron scattering data within the magnetically ordered phase of the stacked honeycomb magnet $CoTiO_3$ revealing the presence of a finite energy gap and argue that this arises from bond-dependent anisotropic exchanges through an order-by-disorder mechanism. We also provide an experimental observation of a universal winding of the scattering intensity in angular scans around linear band-touching points for Dirac magnons and spin-orbit excitons, which is directly related to the non-trivial topology of the quasiparticle wavefunction in momentum space near nodal points.

M. Elliot et al., Nat. Commun. 12, 3936 (2021).

Triangles

Angela Möller

Department of Chemistry, Johannes Gutenberg-Universität Mainz, Germany

Antiferromagnetic compounds based on the motif of a triangle are usually associated with frustration phenomena. Here, we will discuss model examples of undistorted/distorted triangular lattices, the diamond chain, and the butterfly motif. The focus will be on the aspect of dynamics in the temperature range of the corresponding magnetic phase transitions in the light of ^{57}Fe-Mössbauer spectroscopy.

Quantum many-body scars in spin systems

Ivar Martin

Argonne National Laboratory, Lemont, USA

Recently it has been experimentally discovered that magnetically ordered states can persist far from equilibrium even at energy densities that correspond to infinite temperature. In contrast to their equilibrium counterparts, such states show persistent oscillations of a macroscopic order parameter. This phenomenon defies the conventional principles of thermalization, according to which high energy initial states are supposed to relax very quickly on a microscopic time scale. It has been proposed that the reason for this exotic behavior is the existence of quantum many-body scars (QMBS): atypical many-body eigenstates with low entanglement and sometimes equidistant spectrum. I will show that even that is not needed: static disorder can destroy QMBS, without eliminating order parameter oscillations. This dynamical robustness parallels the robustness of the equilibrium spontaneously ordered states and hints at the possibility of stable states of matter that break continuous time translation symmetry.

The Case for a $U(1)_\pi$ Quantum Spin Liquid Ground State in the Dipole-Octupole Pyrochlore $Ce_2Zr_2O_7$

Bruce D. Gaulin

Department of Physics and Astronomy, McMaster University, Ontario, Canada

The Ce^{3+} pseudospin - 1/2 degrees of freedom in the pyrochlore magnet $Ce_2Zr_2O_7$ are known to possess dipole-octupole (DO) character, making it a candidate for novel quantum spin liquid (QSL) ground states at low temperatures. Earlier neutron scattering measurements, by ourselves [1] and others [2], saw dynamic correlations resembling spin ice, similar to that displayed by the well-studied $Ho_2Ti_2O_7$ [3].
We report new heat capacity (Cp) measurements [4] on $Ce_2Zr_2O_7$ which rise sharply at low temperatures, initially plateauing near 0.08 K, before falling off beyond 3 K. Above 0.5 K, the Cp data set can be fit to the results of a numerical linked cluster calculation, that allows robust estimates for the terms in the XYZ Hamiltonian expected for such DO pyrochlore systems. These results are shown to be consistent with new polarized neutron diffraction results. We conclude that $Ce_2Zr_2O_7$ realizes a $U(1)_\pi$ QSL state at low temperatures, and one that resides near the boundary between dipolar and octupolar character.

[1] J. Gaudet et al., Phys. Rev. Lett. 122, 187201 (2019).
[2] B. Gao et al., Nat. Phys. 15, 1052 (2019).
[3] S. T. Bramwell and M. J. P. Gingras, Science 294, 1495 (2001).
[4] E. M. Smith et al., arXiv:2108.01217.

Emergent gapless quantum spin liquid in a square-lattice spin-1/2 frustrated Heisenberg model

Didier Poilblanc

CNRS & Université de Toulouse, France

A quantum spin liquid (QSL) is a novel phase of matter where localized spins are highly correlated with vanishing of magnetic order. Such exotic quantum states typically host emergent gauge fields and fractional excitations. Through large-scale tensor network computations (both iPEPS [1,3] and finite PEPS [2,3] calculations) of a square-lattice spin-1/2 frustrated Heisenberg model, we find that the gapless QSL emerges in a large region of tuning parameters [2,3]. We argue the QSL can gradually develop from a deconfined quantum critical point (DQCP) — originally proposed to describe Landau-forbidden second-order phase transitions between antiferromagnetic (AFM) and valence-bond solid (VBS) phases — by tuning the couplings [3]. We expect experimental realizations in solid state materials and cold atom systems.

[1] J. Hasik et al., SciPost Phys. 10, 012 (2021).
[2] W.-Y. Liu, arXiv:2009.01821.
[3] W.-Y. Liu, in preparation.

Duality, deconfinement, and hidden phases of U(1) quantum spin liquids

SungBin Lee

Department of Physics, KAIST; Daejeon, Republic of Korea

In classical spin ice, we evaluate the coefficient of electric field energy term when it is mapped on to the electrostatics. Then, considering the duality between the electrostatic problem and the three dimensional xy model, we discuss the way to understand the deconfinement of monopoles and their finite temperature transition. When quantum fluctuation is involved, on the other hand, the coefficient of electric field energy term is again evaluated including the artificial photons and discuss the deconfinement of U(1) quantum spin liquids. Next, we develop a new formalism of parton construction which allows effective interactions between partons, based on the physical Hilbert space constraint. Exemplifying a U(1) quantum spin liquid, we address many possible hidden phases in between U(1) quantum spin liquids and ordered phases.

Spin liquid and ferroelectricity close to a quantum critical point in $PbCuTe_2O_6$

Michael Lang

Physikalisches Institut, J.W. Goethe-Universität Frankfurt, Germany

$PbCuTe_2O_6$ has been recently identified as a candidate material for a 3D frustrated quantum spin liquid featuring a highly-connected hyperkagome lattice, where S = ½ Cu^{2+} spins are coupled by isotropic antiferromagnetic interactions [1-3]. According to these magnetic studies, mainly on polycrystalline material, this system lacks long-range magnetic order down to 0.02 K, a small fraction of the 1st and 2nd nearest-neighbor interactions, and shows diffuse continua in the magnetic spectrum [3] consistent with fractional spinon interactions. Some puzzling issues relate to the observation of small anomalies in the powder samples around 1 K of unknown origin and signs of a phase transition around this temperature in 1st generation single crystals.

In this talk, we present results of a comprehensive study of thermodynamic, magnetic and dielectric properties on single crystalline and pressed-powder samples of $PbCuTe_2O_6$. Whereas the low-temperature properties of the powder samples are consistent with the proposed quantum liquid state, an even more exotic behaviour is revealed for the single crystals. For the latter we find a ferroelectric transition around $T_{FE} \approx 1$ K, accompanied by strong lattice distortions, and a modified magnetic response – still consistent with a quantum spin liquid – but with clear indications for quantum critical behaviour.

[1] B. Koteswararao et al., Phys. Rev. B 90, 035141 (2014).
[2] P. Khuntia et al., Phys. Rev. Lett. 116, 107203 (2016).
[3] S. Chillal et al., Nat. Commun. 11, 2348 (2020).

Anomalous Nernst and anomalous thermal Hall effects in topological magnets

Kamran Behnia

Ecole Supérieure de Physique et de Chimie Industrielles (ESPCI), Paris, France

During the past few years, a sizeable anomalous Hall effect was detected in the magnetically ordered state of numerous solids with Weyl points in their band structure. The order of magnitude of the experimentally observed signal is in good agreement with what is expected by Ab Initio calculations of the band structure and the Berry spectrum. In this talk, I will present studies of the thermoelectric and thermal counterparts of the anomalous Hall effect, which show what kind of information can be obtained by monitoring the flow of entropy of topological electrons. The list of such topological magnets studied by measuring their anomalous Nernst and thermal Hall effects include Mn_3Sn [1], Mn_3Ge [2], $Co_3Sn_2S_2$ [3] and Co_2MnGa [4].

[1] X. Li et al., Phys. Rev. Lett. 119, 056601 (2017).
[2] L. Xu et al., Sci. Adv. 6 : eaaz3522 (2020).
[3] L Ding et al., Phys. Rev. X 9, 041061 (2019).
[4] L. Xu et al., Phys. Rev. B 101, 180404(R) (2020).

Evidence for strong electron correlations in a non-symmorphic Dirac semimetal

Yu-Te Hsu

High Field Magnet Laboratory (HFML-EMFL), Radboud University, Nijmegen, Netherlands

Metallic iridium oxides (iridates) provide a fertile playground to explore new phenomena resulting from the interplay between topological protection, spin-orbit and electron-electron interactions. To date, however, few studies of the low energy electronic excitations exist due to the difficulty in synthesising crystals with sufficiently large carrier mean-free-paths. In this talk, we will present a quantum oscillation study in high-quality single crystals of monoclinic $SrIrO_3$ in magnetic fields up to 35 T. Analysis of the oscillations reveals a Fermi surface comprising multiple small pockets with effective masses up to 4.5 times larger than the calculated band mass. Ab-initio calculations reveal robust linear band-crossings at the Brillouin zone boundary, due to its non-symmorphic symmetry, and overall we find good agreement between the angular dependence of the oscillations and the theoretical expectations. Further evidence of strong electron correlations is realized through the observation of signatures of non-Fermi liquid transport as well as a large Kadowaki-Woods ratio. These collective findings, coupled with knowledge of the evolution of the electronic state across the Ruddlesden-Popper iridate series, establishes monoclinic $SrIrO_3$ as a topological semimetal on the boundary of the Mott metal-insulator transition.

Skyrmion superconductivity

Fakher Assaad

Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Germany

A quantum spin Hall insulating state that arises from spontaneous symmetry breaking has remarkable properties: skyrmion textures of the SO(3) order parameter carry charge 2e.
Doping this state of matter opens a new route to superconductivity via the condensation of skyrmions. We define a model amenable to large-scale negative sign free quantum Monte Carlo simulations that allows us to study this transition [1]. Our results support a direct and continuous doping-induced transition between the quantum spin Hall insulator and an s-wave superconductor. We can resolve dopings away from half-filling down to 0.0017.

[1] Z. Wang et al., Phys. Rev. Lett. 125, 205701 (2021).

Neutron scattering studies of correlated topological materials

Yixi Su

Jülich Centre for Neutron Science, MLZ Forschungszentrum Jülich, Germany

Recent theoretical predictions and experimental realizations of exotic quasi-particles and topological excitations in condensed matter have led to tremendous research interests in topological quantum materials. Especially, correlated topological materials, such as e.g. magnetic Dirac and Weyl semimetals, and intrinsic magnetic topological insulators, in which both non-trivial topology of single-electron band structures and electron-electron correlations are essential ingredients, have emerged as an exciting platform to explore novel electronic and magnetic phenomena. In this talk, I will present a couple of selected examples of our recent neutron scattering studies of correlated topological materials, including magnetic semimetals [1] and topological magnon insulators in two-dimensional van der Waals ferromagnets [2].

[1] F. Zhu et al., Phys. Rev. Research 2, 043100 (2020).
[2] F. Zhu et al., arXiv:2107.03835 / Science Advances (in press).

Magnetic and pseudospin frustration in metal-organic frameworks

Andrew Goodwin

Department of Chemistry, University of Oxford, UK

Framework materials are a class of solids for which the chemist has particularly strong control over network topology. Consequently, it is possible in principle to target systems that support geometric frustration, emergence, or topological structures of interest. This talk will survey the key design principles and explore a handful of examples from our own work, based on either magnetic or pseudospin degrees of freedom.

Magnetic phases of topological semimetal Eu_3PbO

Alexandra Gibbs

School of Chemistry, University of St. Andrews, UK

3D Dirac semimetals are currently of wide interest for their unique magnetotransport characteristics, many of which are related to the topological properties of their low energy band structure. A recent focus is on the introduction of magnetism to such systems, allowing access to new phenomena. The inverse perovskite compound Eu_3PbO is a rare example of the success of this approach.

I will discuss key aspects of the inverse perovskite family and present magnetotransport, thermodynamic and neutron scattering experiments on Eu_3PbO. These have been combined with DFT band structure calculations to establish the low temperature phase diagram of this intriguing material as a function of applied magnetic field. The results demonstrate that Eu_3PbO hosts multiple topological phases that are easily controllable by field, providing a key opportunity to control the interplay of band topology, magnetism, and transport in this material class.