TT 41: Frustrated Magnets - Spin Liquids - Experiments

Time: Tuesday 10:15–13:00 Location: H 3005

TT 41.1 Tue 10:15 H 3005

Yb- delafossites as pseudo spin 1/2 triangular magnets: magnetism, specific heat, NMR and the quest for spin liquids — •M. Baenitz[1], K.M. Ranjith[1], P. Schlender[2], J. Sichelschmidt[1], R. Sarkar[3], S. Khim[1], D.A. Sokolov[1], H.H. Klauss[3], H. Yasuoka[1], A.P. Mackenzie[1], D.S. Inosov[3], and Th. Doert[2] — [1]MPI for Chemical Physics of Solids, 01187 Dresden, Germany — [2]TU Dresden, Department of Chemistry and Food Chemistry, D-01062 Dresden, Germany — [3]TU Dresden, Institute of Solid State Physics, D-01062 Dresden, Germany

$S = 1/2$ triangular quantum magnets (TQM) are rare and discussed as ideal quantum spin liquids (QSL)[1]. Recently the pseudo $S = 1/2$ TQM $YbMgGaO_4$ was identified as a QSL candidate [2]. Delafossites share the same space group and the planar triangular spin arrangement so we started working on Yb based delafossites. These systems are rare ($AYbO_2$ (A=Ag,Na)) and a low T pseudo spin S=1/2 state is in question. As for T-> 0 the magnetism of Yb compounds is determined by i)the crystalline electric field (CEF) and ii) the exchange frustration, replacing the oxygen by another chalcogen might tune the magnetism. $NaYbS_2$, $LiYbS_2$ and $NaLuS_2$ were synthesized in poly- and single- crystalline form and bulk- (magnetization, specific heat) and local- methods (Na- Li- NMR, ESR, μSR) were applied. Our studies evidence pseudo spin $S = 1/2$ magnetism and an absence of magnetic order (T > 300 mK) which identifies $(AM)YbS_2$ (AM=Li, Na) as a new promissing candidate for a QSL ground state.

[1] L.Savary et al., Rep. Prog. Phys. 80 (2017).
[2] J.A.M. Paddison et al., Nature Phys. 13,(2017).

TT 41.2 Tue 10:30 H 3005

Low temperature properties of the triangular antiferromagnet $KBaYb(BO_3)_2$ — •K. Kavita, S. Bachus, Y. Tokiwa, A. A. Tsirlin, and P. Gegenwart — Experimental Physics VI, University of Augsburg, Germany

Geometrically frustrated magnetic materials host new exotic states such as quantum spin liquids (QSL). A recent example is the QSL candidate $YbMgGaO_4$, with the triangular lattice of pseudospin-1/2 Yb^{3+} ions. A crucial part, to understand the physics of $YbMgGaO_4$, is to identify leading interaction terms that may extend beyond nearest neighbors. To this end, we studied $KBaYb(BO_3)_2$, where the Yb^{3+} ions are also arranged on a triangular lattice, whereas the distance between nearest neighbors is comparable to the next nearest neighbor distance in $YbMgGaO_4$. Our polycrystalline samples confirm the rhombohedral symmetry of $KBaYb(BO_3)_2$ with the space group $R\bar{3}m$. Magnetic susceptibility data down to 1.8 K revealed a Curie-Weiss temperature of about 20 mK with antiferromagnetic couplings. Furthermore, we report heat capacity down to 60 mK, which also indicates a very small exchange coupling.

TT 41.3 Tue 10:45 H 3005

Spin-1 triangular antiferromagnet $BaMoP_2O_8$ — •Jan Hembacher[1], Alexander Tsirlin[1], Danis Badrtdinov[2], and Clemens Ritter[3] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Ural Federal University, Yekaterinburg, Russia — [3]Institute Laue Langevin, B. P. 156, 38042, Grenoble, France

We present magnetic properties of a spin-1 antiferromagnet $BaMoP_2O_8$. It crystallizes in the $C2/m$ space group, resulting in a layered crystal structure with the triangular arrangement of the magnetic Mo^{+4}-ions. Frustrated interaction geometry leads to a broad maximum in the magnetic susceptibility around 50 K followed by the long-range ordering at 21 K. Neutron diffraction reveals the collinear stripe order with the reduced ordered moment of 1.48 μ_B compared to 2 μ_B expected for a spin-1 ion. The effects of spatial anisotropy, spin-orbit coupling, and metal-ligand covalency will be discussed.

TT 41.4 Tue 11:00 H 3005

A new three dimenisional quantum spin liquid — •Shravani Chillal[1], Yasir Iqbal[2], Harald O. Jeschke[3], Jose A. Rodriguez-Rivera[4,5], Robert Bewley[6], Pascal Manuel[6], Dmitry Khalyavin[6], Paul Steffens[7], Ronny Thomale[8], A. T. M. Nazmul Islam[1], Johannes Reuther[1,9], and Bella Lake[1,10] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Indian Institute of Technology Madras, Chennai , India — [3]Okayama University, Okayama, Japan — [4]NIST Center for Neutron Research, Gaithersburg, USA — [5]University of Maryland, USA — [6]ISIS Facility, STFC Rutherford Appleton Laboratory, UK — [7]Institut Laue-Langevin, Grenoble, France — [8]Julius-Maximilian's University of Würzburg, Würzburg, Germany — [9]Freie Universität Berlin, Berlin, Germany — [10]Technische Universität Berlin, Berlin, Germany

Quantum spin liquid (QSL) is a highly entangled magnetic state characterized by the lack of static magnetism, however, accompanied by highly correlated excitations known as spinons. While there are few experimental examples of QSL in two dimensionally frustrated lattices, very little is known about the possibility in three dimensional (3D) Heisenberg systems. Here we report a new type of 3D lattice that enables spin liquid behavior in a so called hyper-hyperkagome lattice which manifests in the compound $PbCuTe_2O_6$. Using a combination of experiment and theory we show that this system satisfies all the requirements for a quantum spin liquid including the absence of static magnetism and the characteristic continuum of spinon excitations.

TT 41.5 Tue 11:15 H 3005

Crystal growth and magnetic characterization of novel kagome-type materials — •Christian Klein, Mahmoud Abdel-Hafiez, and Cornelius Krellner — Goethe-University, D-60438 Frankfurt am Main, Germany

Kagome-lattices are promising materials to investigate frustrated quantum spin systems with a possible quantum spin liquid (QSL) ground state [1]. High-quality single crystals are essential to distinguish between disordered magnetic ground-states and a true QSL.

We report on synthesis and characterization of Co-derivates of the spin-1/2 antiferromagnet material Barlowite ($Cu_{4-x}Co_x(OH)_6BrF$). The kagome-layers are build up by copper ions and separated from each other through a transition-metal cation, so that a quasi-two-dimensional system is created [2]. The non-magnetic material $Zn_4(OH)_6BrF$ was synthesized to determine the magnetic contributions to the kagome-physicsThe synthesis was carried out under hydrothermal conditions. Single Crystals of Co-doped Barlowite were obtained as well as polycrystalline samples of the Zn-analogue of Barlowite. Characterization of the samples was done by magnetic measurements to determine the susceptibility and magnetic ordering. Furthermore heat capacity measurements were performed to investigate phase transitions and magnetic ordering at low temperature.

[1] P. A. Lee, Science 321, 1306 (2008).
[2] H. Jeschke et al., PRB 92, 094417, (2015).

15 min. break.

TT 41.6 Tue 11:45 H 3005

Frozen state and spin-gap behavior in a new kagome magnet $Fe_4Si_2Sn_7O_{16}$: An NMR study — •S. Dengre[1], R. Sarkar[1], M.C. Allision[2,3], T. Söhnel[2], C.D. Ling[3], J. Gardner[4], and H.-H. Klauss[1] — [1]Institute of Solid State and Materials Physics, TU Dresden, 01062 Dresden, Germany — [2]School of Chemical Sciences, University of Auckland, Auckland 1142, New Zealand — [3]School of Chemistry, The University of Sydney, Sydney 2006, Australia — [4]Australian Centre for Neutron Scattering, Australian Nuclear Science and Technology Organization, Menai 2234, Australia

$Fe_4Si_2Sn_7O_{16}$ is a new Fe based kagome system with a $f = \theta/T_N \approx 3.6$. The system consists of alternate stacking of kagome layer formed from edge sharing FeO_6 ($S = 2$) and SnO_6 octahedra and stannate layer $FeSn_6$ ($S = 0$). $Fe_4Si_2Sn_7O_{16}$ is a classical homologue to a famous kagome compound herbertsmithite, a suitable candidate to realize quanum spin liquid phase. $^{(117/119)}Sn$ nuclear magnetic resonance (NMR) allows us to selectively probe the static and dynamic magnetism of different Fe-layers. While the NMR shift vs bulk susceptibility plot follows linear relation down to 10 K confirming the absence of foreign phases in the vicinity of kagome plane, the considerable line broadening below 10 K indicates the distribution of static internal field. NMR spin-lattice/spin relaxation rate $(1/T_1)/(1/T_2)$ reflect the slowing down of spin fluctuations at $\sim$3 K associated with the static magnetism of Fe-kagome layer. Additionally, $(1/T_1)$ and $(1/T_2)$ temperature dependency show a spin-gap behavior with $\Delta \sim 6.5\,K$.

[1] Ling *et al.* Phys. Rev. B 96, 180410(R).

TT 41.7 Tue 12:00 H 3005

NMR investigations on doped kagomé lattice mott insulator $Ga_xCu_{4-x}(OD)_6Cl_2$ — •Ranjith Kumar Kizhake Malayil[1], Pascal Puphal[2], Cornelius Krellner[2], and Michael Baenitz[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Institute of Physics, Goethe- University Frankfurt, 60438 Frankfurt am Main, Germany

Herbertsmithite ($ZnCu_3(OH)_6Cl_2$),[1] which is reported as a prototype kagome quantum spin liquid (QSL) triggers the search for new QSL materials among its polymorphs. Replacing the divalent Zn by the trivalent Ga was proposed to form a new correlated Dirac-kagome metal combining Dirac electrons, strong interactions, and frustrated magnetism[2]. Polycrystalline samples of $Ga_xCu_{4-x}(OD)_6Cl_2$ were synthesized with Ga-doping level of $0 < x < 1$. We have employed ^{71,69}Ga and ^{2}H nuclear magnetic resonance (NMR) experiments together with bulk studies to explore the ground state properties of $Ga_xCu_{4-x}(OD)_6Cl_2$. Ga-NMR proof a homogeneous Ga distribution and narrow Ga-lines which is typical for Ga-based quantum magnets. Magnetic ordering is found to be suppressed with increasing Ga-concentration similar to that observed for Zn- Herbertsmithite. Spin-lattice relaxation measurement reveals the existence of a spin gap in the excitation spectrum which is increasing linearly with the applied field.

[1] P. Mendels et al., J. Phys. Soc. Jpn. 79, 011001 (2010).
[2] I. Mazin et al., Nature Communications 5, 4261 (2014)

TT 41.8 Tue 12:15 H 3005

Spinon Excitations in Quantum Spin-Liquids Identified by Optical Spectroscopy — Andrej Pustogow[1], Yohei Saito[1], Elena Zhukova[2], Boris Gorshunov[2], Reizo Kato[3], and •Martin Dressel[1] — [1]1. Physikalisches Inst., Universität Stuttgart, Germany — [2]Moscow Inst. Phys. Techn., Dolgoprudny, Moscow Region, Russia — [3]RIKEN, Saitama, Japan

The electrodynamic response of several organic quantum spin-liquids with highly-frustrated triangular lattices has been measured in a wide energy range. Even below the Mott-Hubbard gap, large non-thermal contributions to the optical conductivity are observed in the vicinity of the metal-insulator phase boundary; such metallic quantum fluctuations are most pronounced in κ-(BEDT-TTF)$_2$Cu$_2$(CN)$_3$.

Only when investigating the more strongly correlated Mott insulator β'-EtMe$_3$Sb[Pd(dmit)$_2$]$_2$ at very low frequencies and temperatures, we succeeded identifying an excess conductivity that cannot be explained by the charge response of the correlated electrons. Upon subtracting the smooth power-law background of the Mott-Hubbard band, a broad dome-like mode is identified, delimited by $J \approx 20$ meV at its high-energy end; the low-frequency decrease is consistent with the ω^2 dependence expected for spinons. Due to this fast decay, the effective range of well-defined spinons is confined to the microwave and THz energy ranges. Our findings are in excellent agreement with recent dynamical mean field theory calculations stating that the controversially discussed spinon Fermi surface is damped away upon approaching the Mott metal-insulator transition.

TT 41.9 Tue 12:30 H 3005

Exploration of the quantum spin liquid state in $Ca_{10}Cr_7O_{28}$ — Christian Balz[1,2], •Bella Lake[1,3], ATM Nazmul Islam[1], Ulrich Tutsch[4], Michael Lang[4], Yuji Matsuda[5], Lars Opherden[6,7], Thomas Herrmannsdoefer[6], and Jose A. Rodriguez-Rivera[8] — [1]Helmholtz Zentrum Berlin, Germany — [2]Oak Ridge National Lab, USA — [3]Technical University Berlin, Germany — [4]Goethe University, Germany — [5]Kyoto University, Japan — [6]Helmholtz Zentrum Dresden Rossendorf, Germany — [7]Technical University Dresden, Germany — [8]NIST, MD, USA

$Ca_{10}Cr_7O_{28}$ is a new candidate spin liquid where the magnetic Cr^{5+} ions (S-$\frac{1}{2}$) form breathing Kagome bilayers. Both kagome layers consist of alternating ferromagnetic/antiferromagnetic corner-sharing triangles and the two layers are stacked so that the ferromagnetic triangles lie on top of antiferromagnetic triangles and vice versa. Previous measurements revealed the absence of long-range magnetic order and the presence of persistent spin dynamics in the ground state. Here we present a detailed exploration of the ground state and excitations using magnetisation, heat capacity, thermal conductivity and inelastic neutron scattering. The heat capacity and thermal conductivity are linear in temperature suggesting the presence of a gapless spinon Fermi surface while the excitations are diffuse revealing the presence of spinon continuua. The excitations appear gapless and form a distinct pattern that evolves gradually with energy. Together these results provide strong evidence that $Ca_{10}Cr_7O_{28}$ is a gapless quantum spin liquid. The origins of this spin liquid state will be discussed.

TT 41.10 Tue 12:45 H 3005

Low-temperature spin-liquid phase in a S = 3/2 undistorted triangular lattice: $RbAg_2Cr[VO_4]_2$ — •Angela Möller[1], Joshua Tapp[1], Clarina R. dela Cruz[2], Michaela Bratsch[3], Ngozi E. Amuneke[3], Lars Postulka[4], Bernd Wolf[4], Michael Lang[4], Harald O. Jeschke[5], Roser Valentí[4], and Peter Lemmens[6] — [1]JGU Mainz, D — [2]ORNL, USA — [3]University of Houston, USA — [4]GU Frankfurt, D — [5]Okayama University, Jpn — [6]TU Braunschweig, D

We present a series of distorted and undistorted antiferromagnetic triangular lattice (TL) compounds, $AAg_2Cr[VO_4]_2$ with A = Ag, K, or Rb. The A-site cation induces slight symmetry changes of the [CrO_6] complex and thereby alters the relative orientation of the vanadate with respect to the TL. This aspect of fine-tuning allows for distinct alterations of the magnetic exchange interactions between the Cr^{3+} ($3d^3$) ions, J^{Ag}=3K, J^K=1K, J^{Rb}=0.5K. We observe for the distorted TL collinear antiferromagnetic long-range order at T_N=10K (A = Ag), whereas the high-symmetry cases (A = K, Rb) even evade the theoretically predicted 120° long-range order in zero field down to 0.03K.[1] Our experiments support a spin liquid ground state for the latter compounds which is unconventional for antiferromagnetic TL systems and points towards the relevance of additional competing interaction mechanisms.

This work received support from NSF, ORNL-DOE, Carl-Zeiss Stiftung, and DFG.

[1] J. Tapp et al. Phys. Rev. B 96, 064404 (2017).