TT 16: Focus Session: Dynamics, Topology, and Fractionalisation

The "breaking-up" of electronic excitations into fractionalised quasiparticles such as spinons and holons is one of the most surprising phenomena in the quantum physics of solids. It represents one of the core concepts of topological and stronlgy correlated electron physics that features even exotic particles such as magnetic monopoles, Majorana fermions, anyons or emergent gauge fluxes.

Very recently, a number of important theoretical and experimental advances in studying fractionalisation have been reported. Experimentally a series of model systems has been identified, predominantly by advanced neutron scattering techniques that offer direct access to the investigation of fractionalised quasiparticles. On the theoretical side, it has become possible to describe the real-time dynamics of such systems in sufficient detail to be predictive for experiment. The dynamical properties provide thereby information on the entire spectrum of excited states, probing in particular also the fractionalised quasiparticles. This Focus Session summarizes important recent developments in this field.

Organizers: Roderich Moessner (MPI PKS Dresden), Christian Pfleiderer (TU München)

Time: Monday 15:00–17:45 Location: HSZ 01

Topical Talk TT 16.1 Mon 15:00 HSZ 01
Dynamics in Heisenberg Chains: From Fractional Excitations to New Out-of-Equilibrium States of Matter — •Jean-Sébastien Caux — Institute for Theoretical Physics, University of Amsterdam, Science Park 904, Postbus 94485, 1090 GL Amsterdam, The Netherlands

The Heisenberg chain has long been a fertile laboratory for the investigation of strongly-correlated many-body quantum physics. The spin-1/2 Heisenberg model has been the theoretical paradigm of exactly-solvable (integrable) systems since Bethe wrote down its wavefunctions in 1931, but recent years have witnessed much progress on the theoretical understanding and experimental observation of its dynamical properties. This talk will review a number of recent results, focusing on the characterization and observation of fractional excitations in the vicinity of the ground state, and on the exotic situations which can occur when one puts the system strongly out of equilibrium, for example after a quantum quench.

Topical Talk TT 16.2 Mon 15:30 HSZ 01
Inelastic Neutron Scattering on Candidate Kitaev Compounds — •Radu Coldea — Clarendon Laboratory, University of Oxford Physics Department, United Kindom

We explore the spin dynamics in the frustrated honeycomb magnets Na_2IrO_3 [1] and Li_2IrO_3 , candidates to display novel magnetic states stabilized by the strong spin-orbit coupling at the 5d Ir ions. Theory [2] predicts composite spin-orbital J=1/2 moments at the Ir ions coupled by strongly-anisotropic and bond-directional exchanges, the so-called Kitaev honeycomb model, which has in its phase diagram novel magnetically-ordered ordered phases and a quantum spin liquid with exotic excitations. To search for such physics the experimental technique of choice is inelastic neutron scattering to probe the spin dynamics, however this is technically very challenging due to the large absorption cross-section of neutrons by the Ir nuclei. Using an optimised setup to minimise neutron absorption we have been successful in observing strongly dispersive spin-wave excitations of the Ir moments in both compounds and results are compared with predictions for a Kitaev-Heisenberg model as well as a Heisenberg model with further neighbour couplings.

[1] S. K. Choi, R. Coldea, A. N. Kolmogorov, T. Lancaster, I. I. Mazin, S. J. Blundell, P. G. Radaelli, Yogesh Singh, P. Gegenwart, K. R. Choi, S.-W. Cheong, P. J. Baker, C. Stock, and J. Taylor, Phys. Rev. Lett. 108, 127204 (2012)
[2] J. Chaloupka, G. Jackeli, and G. Khaliullin, Phys. Rev. Lett. 105, 027204 (2010).

Invited Talk TT 16.3 Mon 16:00 HSZ 01
Dynamics of Majorana Fermions in a Quantum Spin Liquid — •John Chalker[1], Johannes Knolle[2], Dmitry Kovrizhin[3], and Roderich Moessner[2] — [1]Physics Department, Oxford University, Oxford, U.K. — [2]Max Planck Institute for Physics of Complex Systems, Dresden — [3]Cavendish Laboratory, Cambridge University, U.K.

The study of spin liquids has been central to advancing our understanding of correlated phases of quantum matter ever since Anderson's 1973 proposal of the resonating valence bond liquid state. However, detailed theoretical investigations of dynamics in spin liquids are hampered by the lack of suitable approaches, with analytical descriptions restricted to general features and numerical methods limited to small systems sizes, to models with a robust excitation gap, or ones that avoid the sign problem in quantum Monte Carlo. In this setting the Kitaev honeycomb model provides a benchmark: it gives an exactly solvable model in which spins dissolve into new degrees of freedom – fluxes of a Z_2 gauge field and Majorana fermions moving in this field – and is representative of a broad class of systems. I will present results from a numerically exact calculation of the dynamical structure factor for this system. These include counter-intuitive manifestations of quantum number fractionalisation, such as a neutron scattering response with a gap even in the presence of gapless excitations, and a sharp component despite the fractionalisation of electron spin.

[1] J. Knolle, D. L. Kovrizhin, J. T. Chalker, and R. Moessner, arXiv:1308.4336

15 min. break.

Invited Talk TT 16.4 Mon 16:45 HSZ 01
Molecular Quantum Magnetism in $LiZn_2Mo_3O_8$ — •Collin Broholm — Johns Hopkins University, Baltimore, USA

I shall discuss the unusual quantum magnetism of $LiZn_2Mo_3O_8$ where Mo_3O_{13} molecules realize spin-1/2 degrees of freedom on a triangular lattice and the spin system remains in a quantum fluctuating state deep into the low temperature regime [1]. Neutron scattering experiments on a powder sample show apparently gapless ($\Delta < 0.2$ meV) magnetic excitations extending at least to 2.5 meV [2]. The data are consistent with a disordered valence bond solid or a resonating valence bond state involving nearest-neighbor and next-nearest-neighbor spins.

[1] J. P. Sheckelton, J. R. Neilson, D. G. Soltan, and T. M. McQueen, Nature Mater. **11**, 493496 (2012)
[2] M. Mourigal, W. T. Fuhrman, J. P. Sheckelton, A. Wartelle, J. A. Rodriguez-Rivera, T. M. McQueen, C. L. Broholm, arXiv:1309.1165 (2013).

Topical Talk TT 16.5 Mon 17:15 HSZ 01
Unwinding a Skyrmion Lattice: Emergent Monopoles in Chiral Magnets — •Achim Rosch — University of Cologne, Cologne, Germany

Small magnetic fields and thermal fluctuations stabilize lattices of magnetic whirls, so-called skyrmions, in chiral magnets. These skyrmions are characterized by a topological winding number and couple very efficiently to electric currents by Berry phases. The effect of these Berry phases can be described by emergent electromagnetic fields [1].

The skyrmion lattice can be destroyed by a change of magnetic field [2]. The associated change of the topology of the magnetic structure has to occur by singular magnetic configurations which act as sources and sinks of the emergent magnetic flux. Thereby they can be viewed as emergent magnetic monopols. Combining numerical simulations, magnetic force microscopy and neutron scattering [2], we investigate the signatures and the dynamics of a topological first-order phase transition driven by the creation of monopoles and antimonopoles.

[1] T. Schulz, R. Ritz, A. Bauer, M. Halder, M. Wagner, C. Franz, and C. Pfleiderer, K. Everschor, M. Garst, and A. Rosch, Nature Physics, 8, 301 (2012).
[2] P. Milde, D. Köhler, J. Seidel, L. M. Eng, A. Bauer, A. Chacon, J. Kindervater, S. Mühlbauer, C. Pfleiderer, S. Buhrandt, C. Schütte, A. Rosch, Science 340, 1076 (2013).