# Symposium Quantum Phase Transitions (SYPT)

jointly organized by
Low Temperature Physics Division (TT),
Magnetism Division (MA), and
Dynamics and Statistical Physics Division (DY)

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# Overview of Invited Talks and Sessions

(lecture room H 0105)

## Invited Talks

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| SYPT 1.1 | Mon | 14:00–14:35 | H 0105 | **Dark order in the metallic state** — •Andrew John Schofield |
| SYPT 1.2 | Mon | 14:35–15:10 | H 0105 | **Quantum criticality in $YbRh_2Si_2$** — •Philipp Gegenwart |
| SYPT 1.3 | Mon | 15:10–15:45 | H 0105 | **Elementary Excitations in Quantum Critical Antiferromagnets** — •Christian Ruegg |
| SYPT 1.4 | Mon | 16:00–16:35 | H 0105 | **How to have fun with frustrated ferromagnets** — •Nic Shannon, Tsutomu Momoi, Philippe Sindzingre |
| SYPT 1.5 | Mon | 16:35–17:10 | H 0105 | **Towards Quantum Magnetism with Ultracold Quantum Gases in Optical Lattices** — •Immanuel Bloch |
| SYPT 1.6 | Mon | 17:10–17:45 | H 0105 | **Correlated inhomogeneous systems: from trapped atoms to heterostructures** — •Achim Rosch |

## Sessions

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| SYPT 1.1–1.6 | Mon | 14:00–17:45 | H 0105 | **SYPT** |

## SYPT 1: SYPT

Time: Monday 14:00–17:45 Location: H 0105

**Invited Talk** SYPT 1.1 Mon 14:00 H 0105
**Dark order in the metallic state** — •Andrew John Schofield — School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom

Recent years have seen a growing number of materials which exhibit thermodynamic phase transitions between metallic states where the order parameter distinguishing these metals is transparent to current probes. Understanding the nature of this "Dark Order" remains an important challenge. Here we focus on $Sr_3Ru_2O_7$ which shows a dark order state in the vicinity of the metamagnetic quantum critical endpoint whose existence relies on extreme sample purity [1]. There we proposed that the dark order might be a Pomeranchuk distorted metal. I will review the current status of this and discuss recent work calculating the disorder dependence of such an instability [2]. We show that $T_c$ for a Pomeranchuk distortion shows the same disorder dependence as an unconventional superconductor with finite angular momentum pairing. This then provides an experimental signature pointing towards the identification of this exotic state of matter.

[1] S. A. Grigera, P. Gegenwart, R. A. Borzi, F. Weickert, A. J. Schofield, R. S. Perry, T. Tayama, T. Sakakibara, Y. Maeno, A. G. Green, A. P. Mackenzie Science **306**, 1154-1157 (2004).
[2] A. F. Ho and A. J. Schofield: arXiv:0706.1955

**Invited Talk** SYPT 1.2 Mon 14:35 H 0105
**Quantum criticality in $YbRh_2Si_2$** — •Philipp Gegenwart — I. Physik Institut, Georg-August Universitaet Goettingen, Friedrich-Hund Platz 1, 37077 Goettingen

In the talk, I will discuss different scenarios for quantum criticality in heavy fermion systems. In particular, I will focus on the system $YbRh_2Si_2$ which displays a new type of quantum critical point with multiple vanishing energy scales [1] and present most recent results on this system.

Work in collaboration with T. Westerkamp, J.-G. Donath, C. Krellner, M. Brando, C. Stingl, Y. Tokiwa, S. Paschen, C. Geibel, F. Steglich, E. Abrahams and Q. Si.

[1] P. Gegenwart *et al.*, Science 315, 5814 (2007).

**Invited Talk** SYPT 1.3 Mon 15:10 H 0105
**Elementary Excitations in Quantum Critical Antiferromagnets** — •Christian Ruegg — London Centre for Nanotechnology, University College London, London, UK

Spin singlet formation is ubiquitous in condensed matter physics, and occurs in systems as seemingly disparate as the Kondo insulators, structurally dimerized quantum antiferromagnets, and potentially as resonating valence bonds in magnets with Kagome, square-lattice, and ladder exchange geometry. In dimerized antiferromagnets, e.g. $TlCuCl_3$, the ground state is quantum disordered at low temperature and a product of such singlets ($S = 0$), with triplet excited states ($S = 1$ quasi-particles). In a magnetic field or as a function of the ratio between exchange interactions, quantum phase transitions (QPT) to phases with magnetic order can be realized if the spin gap $\Delta(p, H)$ to the excited states vanishes. Recent inelastic neutron scattering results are presented about the spin dynamics in the proximity of such QPTs. In this region of the phase diagram, where magnetic order is continuously suppressed, novel elementary excitations appear.

**15 min. break**

**Invited Talk** SYPT 1.4 Mon 16:00 H 0105
**How to have fun with frustrated ferromagnets** — •Nic Shannon[1], Tsutomu Momoi[2], and Philippe Sindzingre[3] — [1]H. H. Wills Physics Laboratory, University of Bristol, Royal Fort, Bristol BS8 1TL, UK — [2]Condensed Matter Theory Laboratory, RIKEN, Wako, Saitama 351-0198, Japan — [3]LPTMC, UMR 7600 of CNRS, UPMC, case 121, 4 Place Jussieu, 75252 Paris Cedex, France

The search for a true quantum "spin liquid" – a quantum magnet which remains disordered at the very lowest temperatures – has been central to research on quantum magnets for more than three decades. Following Anderson, most models of quantum spin liquids proposed to date have been based on frustrated antiferromagnetic interactions. The resulting spin liquid states involve strong singlet bonds between spins, which give rise to a gap in the spin excitation spectrum. None the less, the best characterized experimental realization of a quantum spin liquid is believed to occur in two-dimensional films of solid He III, where the interactions between spins are predominantly ferromagnetic, and the resulting state is gapless. This raises the interesting question of whether the breakdown of long ranged ferromagnetic order offers a new route exotic magnetic ground states? In this talk I review experimental results on unconventional magnetic order in (quasi) two-dimensional spin systems with predominantly ferromagnetic interactions, and present recent theoretical results for novel order parameters in related models [1,2].

[1] Momoi et al., Phys. Rev. Lett. 97, 257204 (2006)
[2] Shannon et al., Phys. Rev. Lett. 96, 027213 (2006)

**Invited Talk** SYPT 1.5 Mon 16:35 H 0105
**Towards Quantum Magnetism with Ultracold Quantum Gases in Optical Lattices** — •Immanuel Bloch — Institut für Physik, Johannes Gutenberg Universität, 55099 Mainz

Quantum mechanical superexchange interactions form the basis of quantum magnetism in strongly correlated electronic media and are believed to play a major role in high-Tc superconducting materials. We report on the first direct measurement of such superexchange interactions with ultracold atoms in optical lattices. After preparing a spin-mixture of ultracold atoms with the help of optical superlattices in an antiferromagnetically ordered state, we are able to observe a coherent superexchange mediated spin dynamics down to coupling energies as low as 5 Hz. Furthermore, it is shown how these superexchange interactions can be fully controlled in magnitude and sign. The prospects of using such superexchange interactions for the investigation of dynamical behaviour in quantum spin systems and for quantum information processing will be outlined in the talk. In addition, we present novel results on the experimentally measured phase diagram of a bosonic quantum gas across the quantum phase transition from a superfluid to a Mott insulator and report on results of strongly interacting Bose-Fermi and Fermi-Fermi mixtures in a three-dimensional optical lattice.

**Invited Talk** SYPT 1.6 Mon 17:10 H 0105
**Correlated inhomogeneous systems: from trapped atoms to heterostructures** — •Achim Rosch — Institute of Theoretical Physics, University of Cologne, 50937 Cologne

How does a metal penetrate into a Mott insulator? This fundamental question is not only relevant for the physics of heterostructures but governs also the physics of domain formation close to a phase transition or the Mott transition of fermionic atoms in a trap. We use an adaptation of dynamical mean field theory for inhomogeneous system (in combination with the numerical renormalization group) to study the interface of a metal and a Mott insulator close to its quantum critical point. Furthermore, we investigate the interplay of Coulomb interaction and domain formation and study experimental signatures of the Mott transition of atoms confined in an optical lattice and a harmonic trap.