Quantum Phase Transitions in CoCl2 salts, and the Nature of the Co-existance of Magnetism and Superconductivity in Y9Co7 and La2-xSrxCuO4+y - DTU Orbit

Quantum Phase Transitions in CoCl2 salts, and the Nature of the Co-existance of Magnetism and Superconductivity in Y9Co7 and La2-xSrxCuO4+y

In this thesis I present two studies of magnetism. First, I present a study of a transverse field quantum phase transition in the quasi-Ising antiferromagnetic CoCl2 salts. Second, I present various studies of phase separation between magnetic and superconducting regions, in the low temperature superconductor Y9Co7 and in high temperature superconductors with chemical formula La2-xSrxCuO4+y.

In the first part of this thesis Neutron scattering is used to study the quasi-Ising antiferromagnet CoCl2·2D2O. As a consequence of crystal field and spin-orbit effects in the monoclinic crystal structure of CoCl2·2D2O, its low-temperature magnetic properties can be considered to approximate an effective S = 1/2 model with anisotropic, primarily Ising-like, exchange interactions and anisotropic g-factors. The dominant interactions are ferromagnetic and couple nearest neighbor spins forming chains. Weaker interchain interactions give rise to commensurate antiferromagnetic order below TN = 17.2 K. Theory predicts that the spin wave excitation spectrum of Ising magnets softens as a magnetic field is applied transverse to the preferred spin direction. This has been observed in the three-dimensional dipolar coupled ferromagnet LiHoF4 and in CoNb2O6, which like CoCl2·2D2O consists of weakly coupled ferromagnetic Ising-like chains. Comparing CoCl2·2D2O to CoNb2O6 one might expect some similarities in the excitation spectra. However, different ratios of interchain to intrainchain interactions and different degrees of deviation from the ideal Ising spin Hamiltonian, can also be expected to modify the spin waves.

We provide evidence that the spin wave mode indeed softens at μ0Hc, and spin excitations reappear at field larger than μ0Hc. Our findings are compared with RPA theory that reaches excellent agreement with our data. These studies indicate that CoCl2·2D2O shares more characteristics with an anisotropic Heisenberg magnet in transverse field than the pure Ising model. We have also addressed the possibility to lower the critical field by chemically substitute NH3 for H2O in CoCl2 salts, in order to search for optimal experimental conditions within a certain class of materials using density functional theory.

The second part of this thesis is subdivided into three separate studies, all focusing on phase separation in superconductors. In the first part I present a muon spin rotation study of the magnetic properties of Y9Co7- an example of a system displaying evidence for weak itinerant ferromagnetism and low temperature i.e. phonon driven superconductivity. With the highest quality sample available, our results provide evidence that the sample phase separates on a length scale of more than 30 Å. Phase separation on this length scale or larger is also observed in the superoxygenated Lanthanum based high temperature superconductor La2-xSrxCuO4+y which separates into an incommensurate magnetic phase similar to the so-called 1/8 stripe phase observed in other Lanthanumbased cuprate compounds such as La1.88Sr0.12CuO4 and La1.48Nd0.4Sr0.12CuO4, and a superconducting phase similar to optimally doped La2-xSrxCuO4. We are able to extract the magnetic transition temperature, the superconducting transitions temperature and respective volume fraction of the magnetic and superconducting regions. Using transverse field muon spin rotation, we present an analysis which is consistent with previously published results but in addition, we extract the penetration depth which allows for a direct comparison of the superconducting phase in these samples and with other superconductors. We find very similar values regardless of Strontium doping in La2-xSrxCuO4+y. Finally, we have combined zero field and transverse field muon spin rotation with neutron spin echo spectroscopy to study the spin freezing process in oxygen stoichiometric La1.88Sr0.12CuO4 which does not phase separate on a length scale visible to the muon spin rotation technique. In this compound the onset temperature of incommensurate magnetic order is dependent on the time scale of the experimental technique used to probe it. Using the ultra-high resolution of the spin echo technique, we present measurements of the quasi-elastic energy width of an incommensurate Bragg peak in La1.88Sr0.12CuO4. Our results on La1.88Sr0.12CuO4 illustrate the complementary aspects of the local probe of muon spin rotation and neutron scattering.