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Neutron scattering for quantum magnetism

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Arguably, materials magnetism has benefited from neutron scattering experiments more than almost any other field of condensed matter physics. For this there are good reasons. Neutron diffraction directly couples to the magnetic order parameter, even in complex structures with non-trivial propagation vectors. In many cases it is the only experimental tool available to study the latter. At the same time, inelastic neutron scattering has a large contribution from elementary excitations (spin waves). Using modern neutron instrumentation measuring magnon dispersion relations, structure factors and lifetimes has become almost ridiculously easy. Once we know the ground state and elementary excitations, we know almost all there is to know about a magnetic material. In this way, a comprehensive neutron scattering investigation has definitively "closed the book" on many a problem in magnetism. At least, such was the state of affairs in **quasiclassical** magnetism…

The focus today is on **quantum** magnets. To understand the beautiful and complex physics of these deceptively simple systems we need neutron scattering more than ever. Unfortunately, its advantages are less overwhelming than in the quasiclassical case. First of all, many of the more interesting quantum magnets do not have any dipolar order in the ground state, making neutron diffraction essentially useless. Some systems remain truly disordered even at T=0 due to zero point spin fluctuations. Others, such as spin nematics, have order parameters that are invisible to neutron scattering. Spin liquids, presently the "hottest" topic in quantum magnetism have peculiar topological order that entirely eludes detection. The situation with excitations is no better. Elementary excitations in quantum spin systems are often not magnons but exotic quasiparticles with fractional quantum numbers. Magnetic inelastic scattering is of course present, but is a diffuse and often rather featureless multiparticle continuum. Dispersion relations of the actual elementary excitations are inaccessible.

Does this mean that neutron scattering is useless in the study of quantum magnetism? Of course not! It only means that neutrons are no longer the ultimate silver bullet and should be intelligently combined with other methods: magnetic thermodynamics, local probe techniques (NMR, muSR), light scattering and even dielectric measurements. For correct data interpretation quantitative theoretical numerical modeling of neutron spectra becomes crucially important. So does sample quality and a good control of materials-related issues. Neutron experiments themselves need to be taken to a new level in terms of resolution, intensity and quantitative accuracy.

My talk will be divided into two parts. In the first half I will illustrate the above-mentioned points with some recent examples of successful (and not-so-successful) neutron scattering studies of novel quantum spin systems from literature. In the second half I will present a more in-depth case study from my own research: the investigation of "presaturation" phases in frustrated quantum ferro-antiferromagnets and the ongoing search for the quantum spin nematic state.

Speakers Gender

Male

Level of Expertise

Expert

Do you wish to take part in the poster slam

No

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