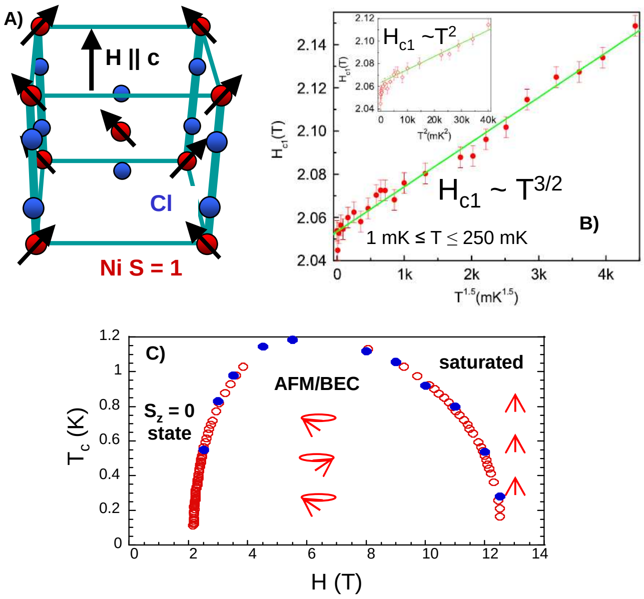
Lee - Osheroff – Richardson North American Science Prize 2010

Vivien Zapf

Dr. Vivien Zapf is the 2010 recipient of the Lee Osheroff Richardson North American Science Prize. She is being recognized for notable achievements in making the definitive experimental verification of the applicability of the Bose-Einstein condensation universality class to magnetic field-induced phases in quantum magnets. She is a scientific staff member at the National High Magnetic Field Laboratory, at Los Alamos National Lab, where she began as a director-funded post-doc. Prior to that she was a Millikan post-doctoral fellow at Caltech, and completed her Ph.D. at the University of California, San Diego with Prof. Brian Maple.

Dr. Zapf focused on the compound $NiCl_2$-$4SC(NH_2)_2$ (DTN) in which a magnetic field induces long-range order of the Ni S = 1 moments between magnetic fields of ~2 and 12 tesla. The spins obey an axial symmetry for magnetic fields along the c-axis, which causes the antiferromagnetic order to become analogous to a Bose-Einstein Condensate. Dr. Zapf built a calorimeter to operate in a dilution refrigerator and 20 T magnet system and then showed that the magnetic field tunes the boson density, and the spin system undergoes a second-order phase transition from zero to finite boson density. Her work proved that in DTN the expected power-law behaviour of the critical field vs temperature obeys a $T^{3/2}$ relation, and that the axial symmetry of the spin holds down to low temperatures.



A. Crystal structure of DTN showing the magnetic ordering of the Ni S = 1 spins at intermediate fields between 2 and 12 T.

B. Critical ordering field H_{c1} vs temperature to the 3/2 power, measured down to 1 mK, showing an agreement with the predictions of BEC. The inset shows that the same data does not follow a T^2 dependence, which is the prediction for an Ising magnet where the necessary symmetry for BEC to occur has been broken.

C. Magnetic phase diagram of DTN showing regions of no ordering (S_z = 0 state), canted antiferromagnetism/Bose-Einstein Condensation (AFM/BEC) and the high-field region where the spins align with the magnetic field (saturated).

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Bose-Einstein condensation occurs when a system of quantum-mechanical particles with integer spin or angular momentum is cooled to its ground state and forms a coherent state of identical particles. The Bose-Einstein condensate (BEC) occurs in systems that satisfy two requirements: bosonic behaviour and number conservation. It is this second requirement that limits the prevalence of BEC systems in nature. BECs were first identified in dilute collections of laser-cooled cold atoms in 1995, leading to the Nobel prize. Superconductors and superfluids can also be considered a close relative to Bose-Einstein condensates, and the existence BEC has been recently proposed in certain exciton systems.

Dr. Zapf has been studying BECs in quantum magnets. When quantum magnets obey certain symmetries, long-range magnetic order of the spins occurs that is analogous to BEC. Unlike collections of cold atoms, BEC occurs in these quantum magnets at temperatures up to fractions of a Kelvin. The systems are in the thermodynamic limit of large numbers of bosons thus their thermodynamic properties can be studied in detail and the boson number can be precisely tuned with magnetic field.

This North American Prize is named after David M. Lee, Douglas D. Osheroff and Robert C. Richardson, who were joint winners of the Nobel Prize in physics in 1996 for their discovery of superfluidity in 3He.