

Title: Bose-Einstein Condensation in Frustrated Quantum Magnets

Keywords: Magnetism, Bose-Einstein Condensate

Scientific description: In 1924, Bose and Einstein presented the idea that a noninteracting gas of bosons – when cooled below a certain critical temperature T_c – condenses into a coherent state of matter that later became known as Bose-Einstein condensate (BEC). In this unusual phase, a large number of particles occupies the lowest-energy quantum state and leads to a truly macroscopic quantum state. After its proposal it was not until 1995 that the first BEC was realized in experiment by cooling a dilute gas of atoms down below 170 nK.

In the present Master thesis project, the candidate will investigate the formation of BECs in a different type of system: Instead of cooling bosonic atoms down to very low temperatures, the formation of a bosonic condensate will be studied in a low-dimensional frustrated quantum magnet. In recent years, such systems have attracted a lot of interest both from theory and experiment and in this Master project, a novel quantum magnet will be studied and checked for its possibilities to host BEC phases at low temperatures.

In the crystalline system of interest, the spins of the magnetic atoms form a long-range magnetic order at low temperatures. Most interestingly, the oriented spins can be flipped by applying an external magnetic field and the emergent excitations of the system turn out to be of bosonic nature. Focussing on these bosonic excitations it is in principle possible to realize a BEC as a function of applied magnetic field strength.

The aim of this theory project will be twofold: First, effective spin and boson models of the quantum magnet will be derived based on an electronic description of the system. Secondly, the putative BEC phase of these models will be investigated. Depending on the student's previous knowledge and preferences the project can also focus on one of the two parts.

This is a theory project with a strong focus on numerical modelling, thereby it involves some programming. It offers the student the possibility to pursue a theoretical investigation of the formation of Bose-Einstein condensates in frustrated quantum magnets based on realistic models and allows him/her to gain insight into a currently hot research area of theoretical solid state physics.

Techniques/methods in use: Mean-field calc.; Exact Diagonalization; Quantum Monte Carlo

Applicant skills: Intermediate to advanced programming skills; basic knowledge of solid state physics, in particular of magnetism and/or correlated material physics

Industrial partnership: N

Internship supervisor: Benjamin LENZ, benjamin.lenz@upmc.fr

Internship location: Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie (IMPMC), Sorbonne Université, Campus Jussieu

Possibility for a Doctoral thesis: N