

Master thesis project: Bose-Einstein condensation, quantum droplets and supersolids in strongly magnetic ultracold quantum gases

The project deals with the experimental study of the quantum phases that appear in a quantum gas of ultracold magnetic atoms. Dysprosium atoms have the largest magnetic moment available in nature, $\mu=10 \mu_B$, resulting in a large dipole-dipole interaction that competes with the more common contact interaction (van der Waals) in atomic gases. The long-range, anisotropic nature of the dipolar interaction leads to various novel quantum phases. In a bosonic system, beyond the standard Bose-Einstein condensate, a liquid phase stabilized by quantum fluctuations, the so-called quantum droplet phase, has been observed [1]. In addition, an intriguing supersolid phase has been speculated to exist in some regimes [2]. The dipolar supersolid should show at the same time a property of solids, a periodic structure in the density, and a property of quantum fluids, superfluidity. The challenge is to identify such supersolid phase, which should appear between the BEC and the quantum droplet phases.

The thesis project consists in investigating experimentally a Dysprosium quantum gas trapped in optical potentials and subjected to controlled magnetic fields. A series of techniques will allow to control the interaction nature (dipolar or contact) and interaction strength [3], and to probe the excitation spectrum and the dynamical properties of the system. The measurements will be analyzed and compared to basic theory results, to identify the peculiar properties of the supersolid phase.

The experimental part of the project will employ an experimental setup located in the CNR area in Pisa, in the frame of a collaboration between LENS and CNR-INO. More information on the Dy quantum gas and on the experiment can be found here: <http://quantumgases.lens.unifi.it/exp/dy>. Please contact the thesis supervisor for further information:

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[1] H. Kadau et al. Observing the Rosensweig instability of a quantum ferrofluid, *Nature* 530, 194 (2016).

[2] R. Bombin et al. Dipolar Bose Supersolid Stripes, *Phys. Rev. Lett.* 119, 250402 (2017).

[3] E. Lucioni et al. Dysprosium dipolar Bose-Einstein condensate with broad Feshbach resonances, *Phys. Rev. A* 97, 060701 (2018).

