**Recent trends in superfluid atomic gases: ferromagnetic, liquid and supersolid states.**

Alessio Recati

Pitaevskii Cemter on Bose-Einstein Condensation

INO-CNR and Trento University

After almost 30 years from the realisation of atomic Bose-Einstein condensation (BEC), the field of ultra-cold gases is still expanding and providing new insights on quantum states of matter.  The reason is rooted in the strong synergy between theoreticians and experimentalists in the field and the development of new experimental tools to trap and manipulate different atomic species. This talk will focus on some new states recently realised using Bose atomic gases.

The first part of the talk will be devoted to introducing **coherently coupled BECs** and their peculiar ground and excited states due to the explicit breaking of one $U(1)$ symmetry,

and -- for large inter-species interaction -- of a $Z\_{2}$ symmetry leading to ferromagnetic behaviour. I will show how the spin dynamics is well described by a dissipationless Landau-Lifshitz equation, and

report on the first experimental evidence of false vacuum decay and bubble creation for the ferromagnetic first order phase transition.

The second part will focus on the so-called Lee-Huang-Yang (LHY) liquid or droplet phase, where beyond mean-field effects are fundamental for the system's description, leading in particular to new density functional theories.

Such LHY states have been realised in both **Bose-Bose mixtures and dipolar Bose gases**.

The latter platform has notably allowed experimentalists to realise the long sought **supersolid** (SS) phase, which is attracting much attention also outside the cold atomic field.

The properties of the excitation spectrum and the vortices due to the spontaneous breaking of both $U(1)$ and translational invariance are presented.

A brief comparison between the SS phase realized in dipolar gases, in optical cavities and in spin-orbit coupled gases will conclude the talk.