

## **Project 5.5. "NUANCE 2 : Study of novel quantum phases in cold gases using semiclassical methods"**

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### **Background:**

The project concerns gases, cooled to ultra-low temperatures. Since observing the so-called Bose-Einstein condensate a quarter of a century ago, this system seemed to be well understood. The ultra-cold atoms began to enter the application phase.

Unexpectedly in 2016 it was noticed in an experiment that cooled gas can reach another phase of matter, now called quantum drops. This phase occurs when different types of interactions, short-range repulsion and destabilising gas attraction are roughly balanced and the system is stable due to quantum correlations. Last year, supersolid was measured in this system.

Experimental discoveries open up a number of research avenues. It is not known what are the properties of these systems, what is the equation of state, how the quantum drops decay with temperature. Knowing the mechanism of droplet formation, one can look for them in other physical systems, e.g. in resonant cavities.

The subject requires the knowledge of Bose-Einstein condensate physics and the methods of theoretical physics used to study approximately the systems with a large number of atoms (mean field theory, Bogoliubov approximation and functional density approximation).

Planned: training (outside the institute) in methods based on machine learning, and internship at Joint Quantum Centre (Newcastle - Durham).

The PhD will be financed by the Sonata Bis project "NUANCE: Novel quantum phases in cold gases". We will work in team: PI, two PhD students, post-doc, MSc.

### **Aim:**

The subject of this project is to investigate ground states and elementary excitations in a system where non-local attraction and local repulsion are balanced and the stability of the system and its properties are determined by quantum correlations between atoms. The research will be based on ab initio theories.

Physical realizations will be sought in gases of atoms with permanent dipole moment atoms or trapped in resonant cavities.

### **Requirements:**

- basics of programming.
- attitude for cooperation.