

Quantum droplets can be considered to be the hottest recent topic in the field of ultra-cold atoms. They were discovered by chance in 2015, and starting from 2016, several experiments have already started producing and studying them. Several more are under construction.

The droplets are small objects made of several thousand to several tens of thousands of ultra-cold atoms in a dilute superfluid state. The necessary temperatures are so low (merely billionth parts of a degree above absolute zero) that they do not occur naturally even in deep space. The only known place where they exist is in laboratories, often in a basement. They are at the centre of interest because they are relatively large, macroscopic objects which display strong phenomena caused by so-called quantum fluctuations – a paradoxical vacuum energy.

Furthermore, despite being very dilute on the scale of single atoms (more similar to a vacuum than even air at this scale), quantum droplets behave more like a liquid than a gas. They are incompressible and produce their own surface tension, which are properties that were not seen before in ultra-cold gases. They are instead properties typical for liquids. For all these reasons, many undiscovered phenomena lie in wait for investigators who are studying them.

Despite the large interest in the topic, an accurate description of the surface of the droplets has eluded theorists so far because the vacuum energy was being described by very simplified models. They have not been able to deal properly with the rapid change of density that occurs at the surface. This has also impacted the overall precision of the theoretical description of droplets because the experiments to date produce small ones that are strongly influenced by their surface.

The principal investigator of the project, Piotr Deuar of IF PAN, and his research group have recently developed a more advanced method to describe such objects. It is able to describe the quantum vacuum energy properly when density is non-uniform, and appears well suited to describe the droplets.

The project intends to do just this. Phenomena that we will simulate and describe include the size of droplets under experimental conditions, their interaction with obstacles (friction phenomena), as well as their fragmentation into smaller droplets. The research will be carried out in collaboration with a leading experimental group in the field, that of Laetitia Tarruell at ICFO in Barcelona.