Finite temperature effects for a single vortex in a rotating BEC

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In this talk we explain how to describe temperature effects in Bose Einstein Condensates and apply the formalism to the case of a single vortex configuration. First, we recall the context of this study: the experiments at ENS. Unfortunately, in this experimental configuration as explained in the talk of Yvan Castin, the vortex bends. This behaviour complicates a lot the numerical approach as one need to diagonalize very big matrices. Our strategy has been then to reduce the complexity of the problem by considering an axi-symmetric trap such that the vortex is straight at zero temperature. In this situation, we can use the rotational symmetry with respect to the azimutal angle, so that one can handle the numerical approach on standard computers.

The first part of the talk is an introduction to the basic tools of the physicist for studying quantum Bose gases. We introduce the powerful notion of Bose atomic field for describing the system at a quantum level. We point out the problem of divergencies arising because of the modelling of the interaction between two atoms by a simple Dirac distribution and explain the need of a regularisation by using, for example, the pseudo-potential approach. Then, we briefly describe the Bogoliubov theory in the canonical set (in this formulation due to Castin and Dum, the number of atoms is kept constant). Finally, we present the temperature dependence for the mean values of observables such as the “out of condensate density” and the contrast (ratio between the density on the vortex line and the maximum density). These results permit to understand the poor contrast observed in ENS experiments.

In the second part of the talk, we insist on the fact that the previous approach do not lead to a complete description of the experimental results as we have averaged over the different realisations of the many-body density operator. As an example, it is not hard to imagine that the density profile in a single measurement breaks the azimutal symmetry of the problem, whereas if one averages over all possible realisations, the symmetry is restored. Hence, to have a clear link with experiments, we have decided to mimic a single realisation of the many-body density operator. For this purpose, we use the so-called Glauber-P representation. This technique borrowed from quantum optics is especially well suited for describing thermal fluctuations in the low density regime as it is the case here. As a conclusion, we present the results for typical realisations, showing large fluctuations in the phase (the thermal occupation of surface modes leads to the apparition of satellite vortices at the border of the condensate) and also in the number of atoms in the core of the line (the line fluctuates around the rotation axis because of the thermal occupation of the kelvon modes described also in the talk of Gora Shlyapnikov).