Collapse of the Attractive Bose-Einstein Condensates

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In recent years, since the experimental obtaining of Bose-Einstein condensates (1995), there has been a rapid development in this area. The first stable condensates were obtained from the atoms with repulsive interaction (with a positive scattering length) – atoms of rubidium and sodium. Further experimental studies have shown that atoms condensation with attractive interaction is also possible (with negative scattering length), such as lithium atoms [1,2]. Moreover, it was found that the usage of Feschbach resonances allows to change the scattering length value, and even to revert its sign from positive to negative. As a result the condensate (if the particle density exceeds some critical value) begins to shrink indefinitely (to collapse). In the process of collapse, instead of expected formation of condensate drops, atoms are emitted from the trap in the form of "implosions" and "jets"[3]. This phenomenon is called Bosenova because of the similarities with the supernovae explosion.

Existing theoretical models are currently have significant difficulties with the experimental data description (one of them is the error in the collapse time prediction [3,4]). These models are based on the mean-field theory – Gross-Pitaevskii equation with additional terms. These terms are intended to describe the phenomena occurring during the condensate collapse, they are arise as senior expansion terms of the Hamiltonian in the small gas parameter. In addition, it's believed that during the collapse at sufficiently high densities, the role of atomic inelastic collisions with molecules (dimers) formation is decisive. This process should correspond to additional dissipative terms in the Hamiltonian.

Our hypothesis is that the condensate quantum state coherence is destroyed during the collapse. It's due to the fact, that the atoms gain very high velocities during the collapse, exceeding the sound velocity in the condensate. In this case decoherence occurs earlier than the above-mentioned additional terms in the Gross-Pitaevskii equation come to play. Once coherence is lost, we should take (quasi) classical Boltzman kinetic equation. In this case the characteristic times of processes are greatly enhanced. Consequently, particle interaction strength is decreased significantly and the atoms leave the trap by the inertia.

The first part of the work is the estimation of particles energies getting while collapse and comparing with the Bose-condensation temperature. We are analysing the collapse stability in the quasi-classical regime with respect to the condensate shape perturbation to explain experimental observations of jets formation.

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References

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