Classical field simulations of thermal Bose-Einstein condensates

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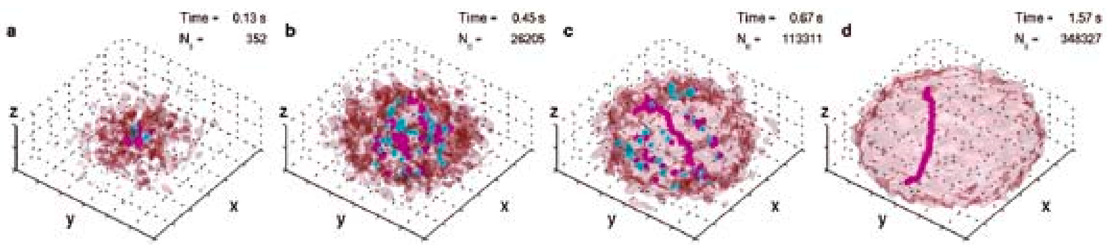
The aim of this project is to continue to develop and apply methods for describing the dynamics of Bose-Einstein condensates at finite temperature. The techniques being utilised are approximate; however they are aimed at performing non-perturbative calculations for realistic experimental systems. A focus for 2007 has been the dynamics of condensate formation using the stochastic Gross-Pitaevskii formalism [1]. Beginning from slightly above the critical temperature, we assume an instaneous quench of the thermal cloud and study the resulting condensation dynamics.

Firstly, we have studied rapidly rotating systems in two-dimensions. In contrast to stirring a vortex-free condensate, where topological constraints require that vortices enter from the edge of the condensate, we find that phase defects in the initial non-condensed cloud are trapped en masse in the emerging condensate. Bose-stimulated condensate growth results in a disordered vortex configuration. At sufficiently low temperature the vortices then order into a regular Abrikosov lattice in thermal equilibrium with the rotating cloud. We determined the effect of thermal fluctuations on vortex ordering in the final gas at different temperatures, and found that the BEC transition is accompanied by lattice melting associated with diminishing long range correlations between vortices across the system [2].

Secondly, we have studied condensate formation in a three-dimensional system for parameters matching the experimental conditions in the Anderson lab at the University of Arizona. We have made the exciting observation that in a significant fraction of simulations a vortex is observed to be trapped in the condensate as it grows. We have made comparisons with the available experimental data, and find excellent quantitative agreement. An example of condensate formation where a vortes is trapped is shown in the figure below, and a joint theoretical and experimental paper is in preparation.



An example of the formation of a Bose-Einstein condensate in a 3D harmonic trap where a vortex is spontaneously trapped. Each plot (a–d) shows an isodensity surface at the time indicated, and the magenta (cyan) lines indiate where positive (negative) 2π phase windings have been identified in the atomic field. The condensate number is determined using the Penrose-Onsager criterion over 300 simulations.

Finally, we have continued with work on a 1D model of a continuously pumped atom laser using a stochastic Gross-Pitaevskii model. In this description the condensate is continuously replenished from a thermal atomic reservoir using a realistic growth scenario, and the atom laser beam is generated from this by Raman outcoupling. The project focuses on the properties of the output beam and will provide realistic estimates of the linewidth and coherence limitations of a cw atom laser at finite temperature.

References

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