Formation of topological defects in Bose-condensed gases

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Quenches of quantum degenerate Bose gases are expected to result in the formation of topological defects such as solitons, vortices, or domain walls depending on the particular system. This project aims to simulate such quenches using the stochastic Gross-Pitaevskii formalism [?] and understand the formation and subsequent evolution of the defects.

1. In collaboration with the Anderson group at the University of Arizona we have performed simulations of an evaporative cooling quench through the BEC critical point in a weak pancake-shape harmonic trap. In the experiment it was observed that a large fraction of individual runs resulted in vortices trapped in the condensate. Calculations using the stochastic Gross-Pitaevskii equation [?] matched to the experimental growth curves also observed vortices, with statistics in excellent agreement with the experimental data. This work was published in Nature this year [?]. Ongoing work is attempting to vary the rate of condensate formation to study its effect on the density of vortices and to make a connection to the Kibble-Zurek mechanism for continuous phase transitions.

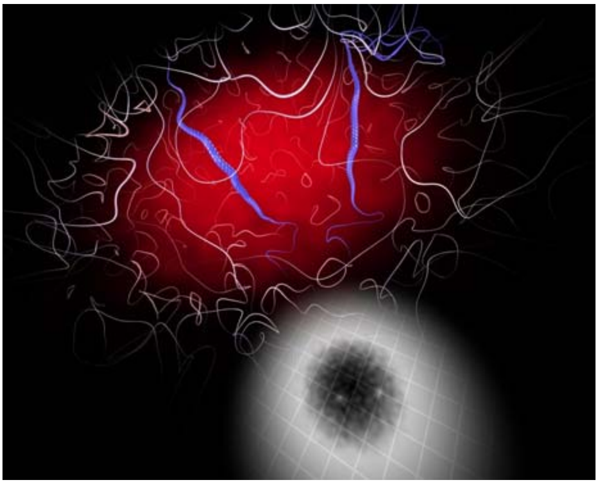

Fig. 1: Visualisation of spontaneously formed vortices in a Bose-Einstein condensate.

2. Similar quench experiments have been performed in the Engels group at Washington State University but in a cigar-shaped trapping potential. For this system geometry it is expected that dark solitons may form along the length of the growing condensate, and this appears to be confirmed by experiment. We have been simulating evaporative cooling in this system and early results suggest that solitons form in a similar fashion to vortices in a pancake trap.

3. Quenches in multi-component Bose systems can result in the formation of domain walls. We have begun simulating the experiments of the Stamper-Kurn group at Berkeley on a magnetic field quench in an F=1 rubidium BEC that results in the preferred ground state changing from being polar to ferromagnetic. In particular we wish to understand the effects of quantum and thermal noise in the initial state.

4. Finally, recent experiments by in the Wieman group at JILA Colorado have evaporatively cooled a ^{85}Rb-^{87}Rb system to quantum degeneracy, and observed the formation of bubbles of different condensates seperated by domain walls [?]. We have begun simulations of cooling in this system in order to understand the dynamics of the observed phase separation.

References

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