Formation of topological defects in Bose-condensed gases

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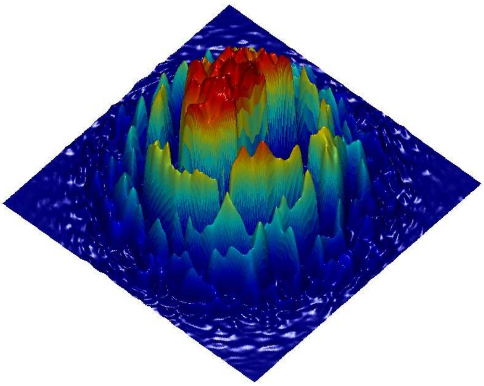
Quenches of quantum degenerate Bose gases are expected to result in the formation of topological defects such as solitons, vortices, or domain walls depending on the particular system. This project aims to simulate such quenches using the stochastic Gross-Pitaevskii formalism at finite temperature and the truncated Wigner method at zero temperature [1] to understand the formation and subsequent evolution of the defects [2].

1. We have continued the study of the formation of vortices in evaporatively cooled Bose-Einstein condensates [3]. Over the past twelve months we have focussed on the development of first and second order coherence, and the origin of the vortices from the apparently turbulent initial stages of condensation. We are aiming to develop an experimental scheme that would for the first time experimentally demonstrate the predicted Kibble-Zurek scaling of the number of defects with the quenching rate in a highly oblate trap [2].

2. Quench cooling and condensate formation experiments have recently been performed in a cigar-shaped trapping potential in the Engels group at Washington State University, and have observed what appear to be dark solitons in the density profile. This year we have simulated a one dimensional version of this experiment, and indeed observe the appearance of solitons during condensation. We have developed a robust algorithm for the detection of solitons, and tracked their evolution as equilibrium is attained [4].

3. We have established a quantum Kibble-Zurek scenario in a two-component BEC that is naturally immiscible [5]. By turning on a coupling between two hyperfine states of a BEC it is possible to load the system into a dressed state which is miscible (i.e. spatially homogeneous.) By ramping off the coupling the system returns to the immiscible state, with faster ramps resulting in more domain walls forming between the two components. We have demonstrated a power law scaling of the number of domain walls in a both a 1D homogeneous and 1D trapped system, but with different exponents. The figure shows the 2D density of one of the components after the coupling is turrned off.



4. The first experiment observing spontaneous symmetry breaking in a spinor BEC was performed in the Stamper-Kurn group at Berkeley [6]. Over the past year we have been performing quantitative simulations of the quantum dynamics of this experiment in a effort to understand the experimental data on correlations and number of defects. In particular we wish to understand the details of quantum and thermal noise in the initial state.

References

[1] P. B. Blakie *et al.*, Advances in Physics **57**, 363 (2008).
[2] W. H. Zurek, Physics Reports, **276**, 177 (1996).
[3] C. N. Weiler *et al.*, Nature **455**, 948 (2008).
[4] G. M. Lee, S. A. Haine and M. J. Davis, in preparation.
[5] J. Sabbatini and M. J. Davis, in preparation.
[6] L. E. Sadler *et al.*, Nature **433**, 312 (2006).