Quantum simulations of thermal Bose-Einstein condensates.

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This project makes use of the truncated Wigner method for solving the quantum evolution of a Bose-condensed gas [1]. The inclusion of initial quantum noise means the technique can represent quantum corrections to the classical field equations of motion, and so can treat a different set of problems to the classical field method. The validity of the approximation relies on simulations either being for short times, or for more particles than modes. This project involves collaborations with the University of Otago, as well as both theory groups within ACQAO at the ANU, and relates the atom-laser project at ANU, as well as the He∗ and atom-chip BEC projects.

The truncated Wigner method has been applied to the problem of the “Bosenova” [2]. In these experiments the scattering length was of a ⁸⁵Rb BEC was switched to negative values for controlled periods using a Feshbach resonance, and the time evolution of the condensate studied. While GPE studies incorporating three body recombination have qualitatively agreed with the experimental results, there is a lack of quantitative agreement [3]. We have postulated that this may be due to quantum effects that are included in the Wigner description. We are also studying soliton formation in BEC collapse as observed other experiments [4, 5].

The Wigner technique has been applied to the loading of BECs into the band edge in an optical lattice combined with a magnetic trapping potential. The effects of interactions cause a loss of coherence in the Rabi cycling between momentum states, and the rapid generation of a large thermal component. The results can be understood in terms of energy conservation, and are in good agreement with experiments performed at Otago University. A joint paper is close to submission. In related work, the entanglement properties of degenerate four-wave mixing of a BEC in a 1D optical lattice has been calculated and accepted for publication [6].

We have been simulating the loading of a trapped BEC into an optical lattice which is then accelerated towards the band edge, similar to the experiments performed by De Sarlo et al. [7]. The numerical solution of the GPE results in unphysical spikes in the density indicating instabilities. The addition of quantum noise seems to smooth these spikes and results in the generation of a thermal component, in line with the results of the previous project. In certain situations soliton trains are observed to form.

Recent analytic work has suggested that quantum fluctuations in BECs in an infinite system can cause a non-zero drag force on an object in a flow at all velocities [8], in contradiction with our conventional understanding of superfluidity. We have recently begun calculations aimed at conclusively demonstrating this force in a finite system.

References