Superfluidity and thermodynamics of low-dimensional Bose gases

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Degenerate Bose gas systems in one and two dimensions have many differences to standard Bose-Einstein condensates in three dimensions, and are now beginning to be realised in the laboratory [1, 2]. It is important to be able to apply our theoretical techniques to make predictions for realistic experimental systems, or to analyze existing experimental data and interpret these results from a theoretical viewpoint.

1. Recent experiments by the ENS group and the NIST-Gaithersburg group have probed the existence of the superfluid Berezinskii-Kosterlitz-Thouless (BKT) phase in 2D Bose gas systems [1, 2]. We have been studying a size-matched homogeneous system using classical field methods in order to study the behaviour of vortex pairs, and to develop an understanding of the relationship between BEC and BKT phases in a finite-size system. We have also studied the emergence of bimodality, coherence, and superfluidity in the trapped 2D system in order to try to reconcil a number of different pieces of experimental data [5]. Work on evidence of superfluidity in this system was published this year [6].

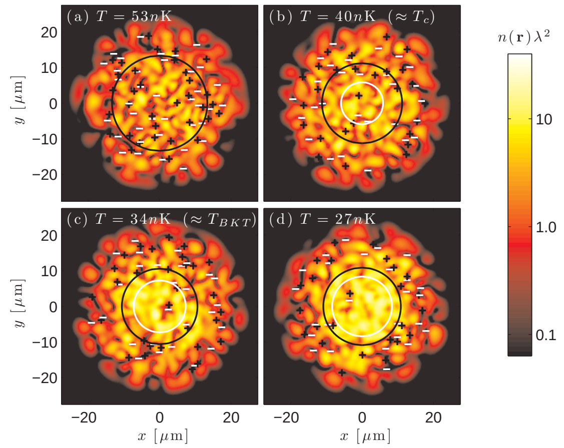

Fig. 1: Regimes of quantum degeneracy (BEC and BKT phases) in a 2D Bose gas.

2. Using perturbation theory it has been suggested that quantum fluctuations in 3D BECs in an infinite system can cause a non-zero drag force on an object in a flow at all velocities [3], in contradiction with our conventional understanding of superfluidity. We have been working on this calculation for a one-dimensional system, which has the advantage that much of it can be done analytically [4]. It is also feasible to numerically simulate this system, and we have begun calculations aimed at conclusively demonstrating this force numerically in a finite system.

3. We have continued a collaboration with the van Druten group in Amsterdam who have been studying the thermodynamics of the 1D Bose gas. They have made measurements of the density profiles of their system over a range of temperatures, and we have fit these using the Yang-Yang thermodynamic solution for the 1D Bose gas in the local density approximation [7]. They have also measured the momentum distribution which cannot be computed using the Yang-Yang solution, and we are trying to do so using classical field methods.

References

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