Excitations and nonlocal spatial pair correlations in 1D Bose gases

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Physics in low-dimensional systems has long provided a rich source of fascinating and often unexpected phenomena. With the steady progress of experimental methods in ultra-cold gases, effective one-dimensional (1D) systems are beginning to be realized in the laboratory. The integrability of certain many-body problems in 1D – such as the 1D Bose gas with delta-function interactions [1] – provides an opportunity to reliably examine many-body quantum physics beyond mean-field theory. In 2007 we have made progress on several fronts in the study of 1D Bose gases.

1. We have numerically solved the equations arising from the Bethe ansatz solution for the many-body wave function, and found the excitation spectrum for a periodic finite-size system of up to 20 particles for attractive interactions and 50 particles for repulsive interations [2]. We found new analytic string solutions in the limit of infinite attractive interactions corresponding to independent solitons on the ring.

2. In collaboration with I. Bouchoule and G. V. Shlyapnikov (Universite Paris Sud IX), we have analysed the crossover transition from a fully decoherent to a (quasi)condensate regime in a harmonically trapped 1D Bose gas with weak repulsive interactions. We found explicit analytic expressions for the characteristic crossover temperature and crossover atom number. The details are given in the ACQAO Annual Report for 2006. The results have been published in Ref. [3].

3. In collaboration with M. G. Raizen's experimental group (University of Texas at Austin) and D. M. Gangardt (University of Birmingham), we have have calculated the nonlocal spatial pair correlation function for a repulsive uniform 1D Bose gas at finite temperature [4]. Our results span six different physical realms, including the weakly and strongly interacting regimes. We show explicitly that the characteristic correlation lengths are given by one of four length scales: the thermal de Broglie wavelength, the mean interparticle separation, the healing length, or the phase coherence length. In all regimes, we identify the profound role of interactions and find that under certain conditions the pair correlation may develop a global maximum at a finite interparticle separation due to the competition between repulsive interactions and thermal effects (examples are shown in Figure 1).

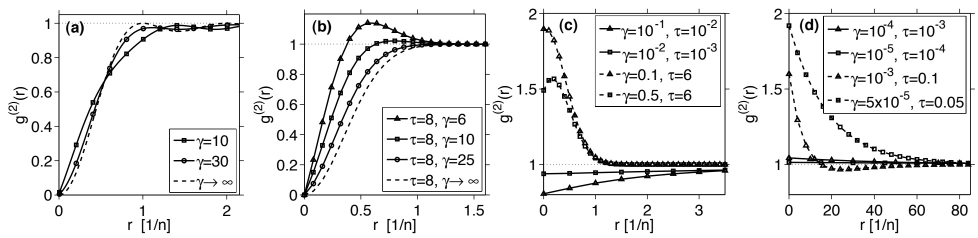

Figure 1: Pair correlation $g^{(2)}(r)$ as a function of the relative distance r (in units of $1/n$) in the following regimes: (a) strongly interacting (Tonks-Girardeau) regime, $\gamma \gg 1$, at temperatures τ below quantum degeneracy, with $\tau = 0.01$; (b) regime of high-temperature "fermionization"; (c) Solid lines – low-temperature weakly interacting gas at $\tau \ll \gamma \ll 1$, dashed lines – decoherent classical regime; (d) solid lines – weakly interacting gas at $\gamma \ll \tau \ll \sqrt{\gamma}$, dashed lines – decoherent quantum regime.

References

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