Two-dimensional hard-core bosons in the superfluid phase: Excitation spectra

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The spectra of elementary excitations of the hard-core bosons on square and triangular lattices in the superfluid phase are investigated using the second order spin-wave theory. The nearest neighbor repulsion and next nearest neighbor interaction (repulsive or attractive) are taken into account. The behavior of the spectra along different directions in the Brillouin zone at fixed particle density is analyzed in detail at various relations between the parameters of the system. Particular attention is given to the spectrum minima with the aim to find out the conditions for instability of the superfluid phase. In the case of the triangular lattice with the next nearest neighbor repulsion, alongside with the known minima on the zone boundary, a true roton minimum inside the Brillouin zone is found. Expressions for the spin-wave velocity are obtained in an explicit form for both types of lattices. Account for the spin-wave interaction considerably improves the quantitative description of the excitation spectra. Our analytical results are in very good agreement with the corresponding data known from literature.[1,2]

1. K. Bernardet, G. G. Batrouni, J.-I. Meunier et al., Phys. Rev. B **65**, 104519 (2002).
2. T. Bryant and R. R. P. Singh, Phys. Rev. B **76**, 064520 (2007).