The 1/Z method for determining the quasi-particle excitation spectrum of any arbitrary quantum lattice systems

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Abstract:
Quantum lattice systems are encountered in many field of physics: solid states, ultracold gas and photonic band gap materials.

We establish a set of hierarchy equations describing the time evolution of the N-points spatial correlation reduced density matrix for such systems and apply it specifically to Bose and Fermi Hubbard gases or spin Heisenberg magnets.

This set of equations is solved through a 1/Z expansion where Z is the coordination number i.e. number of interaction of a site with its nearest neighbors [1,2]. For a large class of quantum systems, we show how the generic leading order equation for the one-site reduced density matrix allows to derive linearized equation of motion for quasi-particle excitation operators whose solutions reproduce correctly the spectra found in the literature. In the next order in 1/Z, using the variable separation technique for the two-sites reduced correlated density matrix, we find that these excitations can be virtually produced in pairs in order to generate quantum fluctuations.

We illustrate the powerfulness of these general concepts for several cases such as virtual particle-hole pairs in the Hubbard models that lower the ground state energy in the Mott phase or two virtual magnons of opposite spins in Heisenberg models that tend to reduce antiferromagnetism [3].

[1] "Emergence of coherence in the Mott-superfluid quench of the Bose-Hubbard model", P. Navez, R. Schützhold, Phys. Rev. A 82, 063603
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[2] "Correlations in the Bose & Fermi Hubbard Model", Friedemann Queisser, Konstantin Krutitsky, Patrick Navez, Ralf Schützhold, arXiv:1203.2164.

[3] "Quasi-particle approach for general lattice Hamiltonian", Patrick Navez, Friedemann Queisser, Ralf Schützhold (in preparation)