Trabajo de fin de Master (TFM)

Departamento de Física Teórica de la Materia Condensada

Project title: ***"Dynamics of correlations in strongly interacting Bose-Einstein condensates"***

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Background and short description

Ultracold atomic gases have thus far provided a veritable playground in which to explore quantum many-body phenomena. The field success relies on the ability to tune accurately the system parameters, allowing to explore a wealth of novel physics phenomena. Recently much attention has been devoted to the possibility to tune the effective two-body inter-atomic interaction via magnetic-field Feshbach resonances, thus allowing one to access regimes of strong correlations in a controllable manner.

Ultracold atomic Bose-Einstein condensates with tunable interactions have recently been proved a rich and very active field of research. The experimental access of the strongly interacting regime in equilibrium conditions has been limited by the short lifetime of the gas due to three-body recombination processes. Thus the experimental attention has turned to the dynamical properties of the gas following a sudden interaction quench, disclosing a wealth of novel phenomena (see, e.g., Refs. [1-4] and references therein). Contrary to expectation, it was observed that, quenching a Bose condensate even straight into the unitary strong interacting regime, where the two-body scattering length diverges, the gas lives long enough to permit the momentum distribution to evolve to a quasisteady-state, consistent with universality, while the gas remains degenerate [2]. Further, it has been shown that, following an interaction quench, three-body correlations develop slower than two-body ones and are consistent with zero up to a characteristic time scale [3].

Given the success of these recent experiments, the proposed project concerns the spreading of density-density correlations in a Bose-Einstein condensate following a deep interaction quench in the strongly interacting regime. The scope of this work is to explore the spatiotemporal properties of the correlation function in the strongly interacting regime in order to determine the nature of the underlying quasi-particle spectrum. It has been already shown for a weakly interacting gas [5] that correlations spread diffusively at short distances and ballistically at large distances, with a characteristic speed given by the condensate speed of sound. However, it is far from clear how the quasiparticle spectrum evolves in the strongly interacting case and already dramatic deviations from the Bogoliubov theory have been observed [4].

Already a time-dependent variational method, similar to the time-dependent Hartree-Fock-Bogoliubov formulation, has been used in our group in order to describe the early time evolution of the system. This method takes into account correlations between condensed and non-condensed atoms, as well as between the non-condensed atoms, to all orders. We plan to extract the properties of the quasiparticle spectrum from the evolution of the density-density correlation function and the structure factor, such as the correlation propagation speed. The goal of this work is to compare our results with the new higher-resolution imaging techniques probing spatial correlation functions, which might lead to a deeper understanding of this strongly correlated regime.

References

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