Variational Monte-Carlo study of the effective mass of soliton excitations in a Bose gas

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Using a many-body approach, we calculate the excitation energy and the effective mass of a soliton in a three dimensional Bose gas of hard spheres. The ansatz for the many-body wave function presents a one-body term, which is constructed from the soliton solution of the Gross-Pitaevskii equation with positve scattering length, and a two-body Jastrow term which introduces explicitely the correlations arising among the atoms. We optimize the parameters in the many-body wave function via a Variational Monte Carlo procedure, calculating the energy of the system in a moving reference frame where the soliton is stationary.

Our many-body calculations show that, in a gas at high density, the excitation energy is larger than the mean-field prediction and that the soliton notch tends to fill up. The effective mass is extrapolated from the behavior of the excitation energy of the soliton as a function of its speed: we see that, as the density of the gas increases, the result obtained with our many-body approach becomes smaller than the one obtained with the mean-field theory, consistently with the decreasing of the number of depleted particles.