Dark solitons revealed in Lieb–Liniger eigenstates

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Solitons are certain types of solutions of nonlinear integrable differential equations that maintain their shapes throughout the time evolution. For instance, one-dimensional Bose gas with either repulsive or attractive contact interaction is governed by the nonlinear Schrödinger equation (i.e. Gross–Pitaevskii (GP) equation) with respective dark or bright solitonic solutions. On the other hand, the same system can be described using the Lieb-Liniger model [1]. In this case two branches of low-lying excitation spectra are obtained. One of them corresponds to the lower type-II excitations, so-called yrast states – many-body eigenstates that minimize the energy for a fixed total momentum. In the weak coupling regime, they are identified as the dark solitons arising in the GP approach [2].

Recently, several groups have investigated the correspondence between dark solitons and yrast states [3, 4]. J. Sato *et al.* showed that dark solitons can be extracted directly from superpositions of yrast states for which the reduced single-particle probability densities resemble a solitonic shape. Whereas A. Syrwid *et al.* focused on a single yrast state, and showed that dark solitons emerge in the measurement process.

Here we investigate the unobvious correspondence between the dark solitons originating from GP equation and the lowest excitations of the Lieb–Liniger model. We unify these different approaches by employing a simple Ansatz for the yrast state in the weak coupling regime. The results obtained with this method are compared to many-body calculations performed in the Bogoliubov approximation, which is exploited further to analyse dynamics of the system.

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