Mathematical Physics

Asymptotic properties of excited states in the Thomas--Fermi limit

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Excited states are stationary localized solutions of the Gross--Pitaevskii equation with a harmonic potential and a repulsive nonlinear term that have zeros on a real axis. Existence and asymptotic properties of excited states are considered in the semi-classical (Thomas-Fermi) limit. Using the method of Lyapunov--Schmidt reductions and the known properties of the ground state in the Thomas--Fermi limit, we show that excited states can be approximated by a product of dark solitons (localized waves of the defocusing nonlinear Schr\"{o}dinger equation with nonzero boundary conditions) and the ground state. The dark solitons are centered at the equilibrium points where a balance between the actions of the harmonic potential and the tail-to-tail interaction potential is achieved.

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