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Stability of solitons for ultracold gas mixtures

Abstract

Ultracold gases are formed by bosons, or fermions or mixtures. By the Mean Field Approximation, each species behaves as a single particle function, which solves a nonlinear Schr̈dinger equation, also called Gross-Pitaevskii. We wil consider the Bose-Fermi Mixtures

$$i\frac{\partial}{\partial t}\varphi_1 = \Big(-\frac{1}{2}\Delta + V_1(x) + g_1|\varphi_1|^2 + g_{12}|\varphi_2|^2\Big)\varphi_1, \tag{1}$$

$$i\frac{\partial}{\partial t}\varphi_2 = \Big(-\frac{1}{2}\Delta + V_2(x) + g_2|\varphi_2|^{\frac{4}{3}} + g_{12}|\varphi_1|^2\Big)\varphi_2, \tag{2}$$

where $g_2 > 0$, g_1, g_{12} can change sign, and

$$V_e(x,y,z) = \frac{C_e}{2}(\gamma_{xe}x^2 + \gamma_{ye}y^2 + \gamma_{ze}z^2), \quad e = 1,2$$

and the spin-orbit-coupled Fermi gas

$$i\frac{\partial}{\partial t}\varphi_1 = \Big(-\frac{1}{2}\Delta + |\varphi_1|^{\frac{4}{3}} - \gamma|\varphi_2|^2 + \epsilon\Big)\varphi_1 + \lambda\Big(\frac{\partial\varphi_2}{\partial x} - i\frac{\partial\varphi_2}{\partial y}\Big), \tag{3}$$

$$i\frac{\partial}{\partial t}\varphi_2 = \Big(-\frac{1}{2}\Delta + |\varphi_2|^{\frac{4}{3}} - \gamma|\varphi_1|^2 - \epsilon\Big)\varphi_2 + \lambda\Big(\frac{\partial\varphi_1}{\partial x} + i\frac{\partial\varphi_1}{\partial y}\Big), \tag{4}$$

where $\gamma > 0$ the effective self-repulsive Pauli nonlinearity, $\lambda > 0$ the Rashba type spin-orbit-coupling, and $\epsilon \geq 0$ the Zeeman splitting.

We study these two models of systems of nonlinear Schrödinger equations. using analytical framework to prove existence of ground states for the stationary system, and numerical approach to study the dynamics and the stability of the system.