Cold atoms with point-interactions: Supersingular rank four perturbations

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We study the formation of cold molecules by considering Rashba spin-orbit coupled cold atoms with Dirac delta potential. Given an unperturbed two-particle Hamiltonian H, we provide a rigorous meaning to its singular rank four perturbation

$$H_C = H + \sum_{i,j=1}^{4} C_{ij}\langle\varphi_j, \cdot\rangle\varphi_i$$

for some complex-valued matrix $C = (C_{ij})$. An element φ_i represents a normalized in a certain sense Dirac distribution, and the perturbation describes the spin-dependent point-interaction between the two atoms. Thus the perturbation is of rank four because the Kronecker product of two half spins reduces to the sum of singlet and triplet states. Let $(\mathfrak{H}_n)_{n\in\mathbb{Z}}$ be the standard scale of Hilbert spaces [1, 2, 3] associated with a self-adjoint operator H. Our main result is that an element φ_i is of class $\mathfrak{H}_{-4} \setminus \mathfrak{H}_{-3}$ for a nonzero spin-orbit-coupling strength, since in this case the two-particle Hamiltonian is non-separable in the center-of-mass coordinate system [4]. One concludes that there are no nontrivial self-adjoint realizations of H_C in a Hilbert space.

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