

Ground state separability and entanglement transitions in spin systems under non-uniform fields

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Ground state of strongly interacting systems are normally entangled. However, exceptional points and curves in the space of parameters characterizing the system may exist for which the ground state becomes exactly and completely separable. These separability curves correspond to ground state entanglement transitions and can be also associated to special quantum critical points when the separable ground state is degenerate and breaks a basic symmetry of the Hamiltonian. Along these curves exact analytic expressions for the ground state and related observables may become feasible in systems with no exact solution away from separability. Here we will discuss the existence of completely separable ground states in general finite spin- s systems with anisotropic XYZ couplings under a non-uniform magnetic field. The general conditions for their existence are determined and analytic expressions for the separability curve in field space and for the ensuing factorized ground state and energy are derived, valid for any spin and size. It is shown that such curve corresponds to a fundamental ground state transition present for any spin, in agreement with the breaking of spin parity symmetry by the factorized ground state. It is also shown that non-uniform fields may induce separability in systems which do not exhibit this phenomenon under uniform fields, giving rise to two different types of ground state phase diagrams. The role of factorization in the magnetization and entanglement of these systems is also analyzed, and exact analytic expressions at the border of the separability curves for associated observables are derived. Illustrative examples for spin pairs as well as finite spin chains and lattices are discussed. Finally, the exceptional critical properties of the separability phenomenon in the XXZ limit are considered. These results also show the significantly increased control of strongly interacting systems that can be achieved through non-uniform fields.