Spin squeezing in quantum simulators

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Abstract

Spin squeezing of the collective spin is a fundamental property of correlated quantum states, both as a resource for quantum metrology and as a witness of entanglement. The paradigmatic way to generate squeezing is the dynamics induced by the one-axis-twisting collective-spin dynamics (as realized e.g. with spinor Bose-Einstein condensates). Here we propose two alternative strategies, suitable to a broad range of modern quantum-simulation platforms.

(1) Several platforms realize spin-1/2 models with slowly-decaying spin-spin couplings - e.g. Rydberg atoms with dipolar couplings, or trapped ions. For these systems, a quench protocol initialized in a coherent spin state generates spin squeezing at short time, where the dynamics remains close to the sector with maximal total spin. For couplings that are sufficiently long-range, the optimal squeezing value (obtained at finite time) has the same scaling properties as for the one-axis-twisting model - a consequence of the large overlap of the initial state with the so-called Anderson tower of states.

(2) For platform that realize short-range spin-1/2 models (like bosonic/fermionic Mott insulators in optical lattices, or superconducting circuits), we propose an alternative protocol for scalable spin squeezing. This consists in preparing a fully polarized ground state by means of a strong magnetic field, and then slowly reducing the field in the presence of spin-spin couplings. As the ground state tends to develop long-range order, transverse-spin fluctuations are reduced and the squeezing diverges (in the thermodynamic limit) as the fields tends to zero.

References:

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