Short-range interactions generating massive multipartite entanglement for metrology

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Multipartite entanglement is the key resource to push quantum metrology beyond the standard quantum limit imposed on systems of uncorrelated particles; and to explore the ultimate limits of measurement precision. Multipartite entanglement can be very effectively generated by infinite-range interactions among particles — yet the latter are literally realized only by coupling atoms (real or artificial) to a cavity mode; otherwise they can be effectively realized with contact interactions, but only in small atomic ensembles trapped in one or few spatial modes. Identifying entangling mechanisms beyond the infinite-range interactions is therefore of greatest interest, in order to use the native interactions in any quantum device as a resource

Here we focus on time-independent many-body Hamiltonians for qubits and qudits; and we theoretically show that massively entangled states possessing scalable spin squeezing, can be generated by power-law interactions, as well as by genuinely short-range ones. This is achieved either via quantum quenches [1-3], or by driving the system with an external field [4]. Scalable squeezing rests upon an effective dynamical decoupling between collective spin degrees of freedom and spin-wave ones [3], giving rise to a dynamics analog to that of the infinite-range models; or it can rely on spontaneous breaking of a continuous symmetry, which allows a driving field to achieve scalable squeezing even when pushed to very small values [4]. These protocols open the route to achieve scalable squeezing in a vast range of quantum devices, including Rydberg-atom and trapped-ion arrays, superconducting-qubit arrays, or optical-attice atomic clocks.

References

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Figures

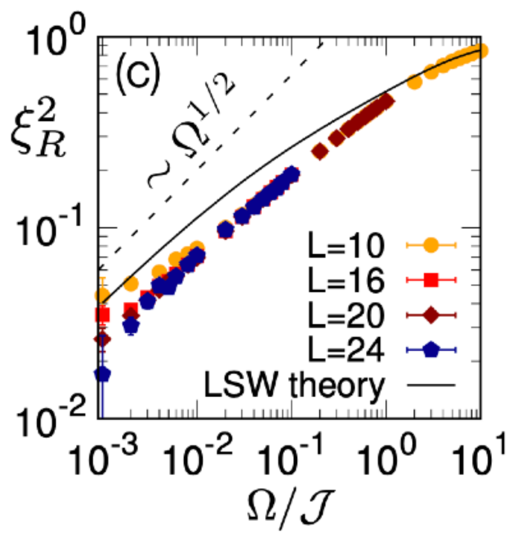

Figure 1: Scalable squeezing (y axis) obtained from driving adiabatically with a Rabi field (x axis) a system of neutral atoms in an optical lattice, realizing the two-dimensional Heisenberg model. Figure taken from Ref. [4].