Quantum Entangled States of a Classically Radiating Macroscopic Spin

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Entanglement constitutes a main feature that distinguishes quantum from classical physics and is a key resource of quantum technologies. Here we show, however, that entanglement may also serve as the essential ingredient for the emergence of classical behavior in a composite nonlinear radiating system.

We consider the radiation from a macroscopic spin emitter, such as the collective radiation from an atomic ensemble. We introduce a new class of macroscopic spin states, the coherently radiating spin states (CRSS), defined as the asymptotic eigenstates of the SU(2) lowering operator. We find that a spin emitter in a CRSS radiates classical-like coherent light, although the CRSS itself is a quantum entangled state exhibiting spin squeezing. We further show that CRSS are naturally produced in Dicke superradiance and underlie the dissipative Dicke phase transition. Our CRSS theory thus provides new concepts for studying the quantum physics of radiation, with applications in current platforms involving collections of atoms or spins, their consideration in quantum technologies such as metrology and lasing, and the many-body theory of spin systems.