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The Dicke quantum phase transition with a superfluid gas in an optical cavity

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A phase transition describes the sudden change of state in a physical system, such as the transition between fluid and solid. Quantum gases provide the opportunity to establish a direct link between experiment and generic models which capture the underlying physics. A fundamental concept to describe the collective matter-light interaction is the Dicke model which has been predicted to show an intriguing quantum phase transition. We have realized the Dicke quantum phase transition in an open system formed by a Bose-Einstein condensate coupled to an optical cavity, and have observed the emergence of a self-organized supersolid phase. The phase transition is driven by infinitely long-ranged interactions between the condensed atoms, which are induced by two-photon processes involving the cavity mode and a pump field. We have shown that the phase transition is described by the Dicke Hamiltonian, including counter-rotating coupling terms, and that the supersolid phase is associated with a spontaneously broken spatial symmetry. The boundary of the phase transition is mapped out in quantitative agreement with the Dicke model.