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On the phase transition of light in cavity QED lattices MARCO SCHIRO, Princeton Center for Theoretical Science and Department of Physics, Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544, USA, MYKOLA BORDYUH, BARIS OZTOP, HAKAN TURECI, Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA — Systems of strongly interacting atoms and photons, that can be realized wiring up individual cavity QED systems into lattices, are perceived as a new platform for quantum simulation. While sharing important properties with other systems of interacting quantum particles here we argue that the nature of light-matter interaction gives rise to unique features with no analogs in condensed matter or atomic physics setups. By discussing the physics of a lattice model of delocalized photons coupled locally with two-level systems through the elementary light-matter interaction described by the Rabi model, we argue that the inclusion of counter rotating terms, so far neglected, is crucial to stabilize finite-density quantum phases of correlated photons out of the vacuum, with no need for an artificially engineered chemical potential. We show that the competition between photon delocalization and Rabi non-linearity drives the system across a novel Z_2 parity symmetry-breaking quantum criticality between two gapped phases which shares similarities with the Dicke transition of quantum optics and the Ising critical point of quantum magnetism. We discuss the phase diagram as well as the low-energy excitation spectrum and present analytic estimates for critical quantities.

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