Emergent quantum criticality in driven-dissipative cavity arrays

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The possibility of realizing strongly correlated states in photonic cavity arrays has stimulated an intense research on open quantum many-body systems, establishing a fascinating interface between condensed matter physics and quantum optics. Among the phenomena emerging in these systems, dissipative phase transitions are nowadays receiving increasing attention. Due to the competition between the coherent and incoherent dynamics, a continuous tuning of the external parameters can lead to a criticality in the non-equilibrium steady state of the open system.

Here, I will present a theoretical study of the driven-dissipative Bose-Hubbard model in the presence of two-photon driving and losses, a model that is within reach of current experimental techniques based on circuit-QED resonators [1]. The mean-field analysis of the steady state of this system reveals the occurrence of a second-order phase transition, characterized by the spontaneous breaking of the Z2 symmetry of the model [2]. The critical exponents associated to the transition are computed using a fully many-body approach, based on the corner-space renormalization method. These show that the phase transition belongs to the universality class of the quantum transverse Ising model, revealing thus the important role of quantum fluctuations and long-range entanglement at the critical point [3].

Quadratically driven-dissipative photonic arrays are feasible both on a circuit-QED platform and using microcavity polaritons, as in both cases the coherent two-photon driving process has been experimentally demonstrated. Such systems would then be suitable for the simulation of a wide range of collective phenomena, among which the emergence of the spin liquid phase in frustrated magnets [4].

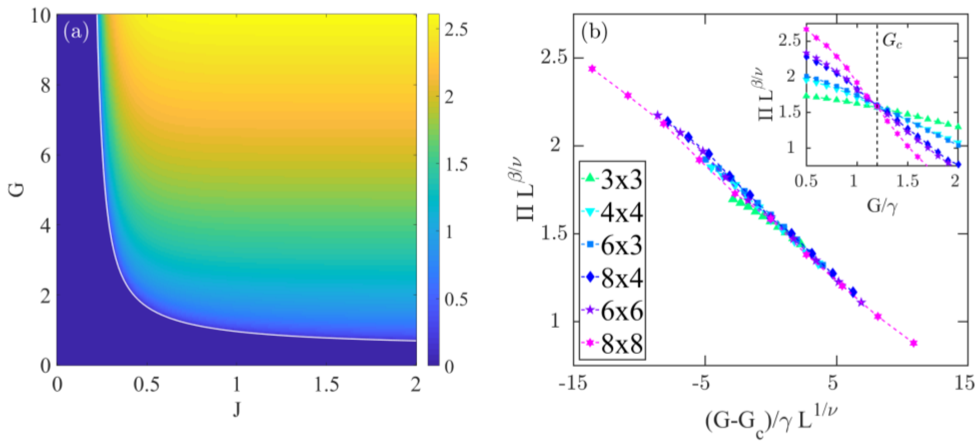

Fig. 1. Figure (a) Mean-field phase diagram of the quadratically driven-dissipative Bose-Hubbard model, as a function of the two-photon driving amplitude G and of the hopping strength J: the color plot indicates the value of the order parameter, i.e. the expectation value of the coherence. (b) Finite size scaling of the parity in a 2D lattice, using the critical exponents of the quantum 2D transverse Ising model.

References

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