Levy flight spreading of contact process in open quantum system

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We investigate the non-equilibrium absorbing transition in a quantum spin system dissipatively and coherently driven, using the quantum Langevin equation and the semi-classical field theory. In the previous works, it has been revealed that a system of cold gases such as the Rydberg atoms with strong dephasing noise may realize a ordinary directed percolation (DP) universality. In this work, we extend the dissipatively driven Rydberg atoms with the long-range interaction to the quantum spin system manifesting the contact process, where coherent and incoherent interactions are comprised. We derive the Heisenberg equations from the total Hamiltonian consisting of the system, bathes and their interaction. Then taking the semi-classical approach we build the Martin-Siggia-Rose-Janssen-de Dominicis (MSRJD) action. By the saddle-point approximation, the mean field phase diagram is obtained, where the second-order transition belonging to the DP universality is found in weak quantum regime while in strong quantum regime, the absorbing transition turns out to be the first-order type. The upper critical dimension and critical exponents are also discussed in terms of the exponent of the long-range interaction.