Prohibition of discontinuous transitions in non-equilibrium disordered systems ($d \leq 2$)

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The effect of quenched disorder on both, the statics and the dynamics of many-particle systems, is drastic. An interesting example is the great influence it has on the order of phase transitions in low dimensional systems ($d \leq 2$). It is known that, in equilibrium systems, spontaneously broken symmetries cannot exist after the introduction of disorder. Indeed, discontinuos phase transitions are rounded by this disorder and become a continuous transition[2] that would probably exhibit critical exponents consistent with those of the corresponding pure model as it has been suggested by Kardar et al[3]. This effects has been verified in countless examples, both experimentally and numerically and has been discussed in many works. A time-honored argument by Imry and Ma[4] explains the first case based on the analysis of the energetics of the system. They conclude that there will always exist a large enough region of linear size L, with a majority of random fields opposing the broken-symmetry state, for which it will become energetically favorable to the system to align to the random field and thus preventing symmetries from being spontaneously broken and continuous phase transitions from existing. An extension of this argument explains the effect on discontinuos case.

Above studies have been done in equilibrium systems, but what happens in non-equilibrium cases? A recent work by Barghathi and Vojta[5] shows that, in a one-dimensional non-equilibrium system with spontaneously broken symmetry between two absorbing states, the continuous transition persist in spite of the introduction of quenched disorder. Therefore, *the Imry-Ma argument does not apply to these non-equilibrium systems owing to the presence of absorbing states.* Regarding these results, the question arises as to whether this shattering of a fundamental cornerstone of equilibrium Statistical Mechanics would happen in the case of discontinuous transitions too (see figure 1 for a synthetic summary).

Aimed at shedding some light on this issue, we study one of the simplest non-equilibrium model exhibiting a first-order/discontinuous transition, the quadratic contact process, in which two particles are needed to generate an offspring while isolated particles can spontaneously disappear. We employ a model which was numerically studied in two-dimensions and verified to exhibit a first-order phase transition separating an active from an absorbing phase[6]. As a first step, we study the behaviour of the pure version and verify that it exhibits first-order. Then we introduce disorder in the form of a site-dependent transition rates and investigate whether the discontinuous character of the transition survives.

In the disordered case we have found results as those reported for the standard contact process with quenched disorder[7], i.e. a second order phase transition with a Griffiths phase and an activated type of scaling fully compatible with the standard strong-disorder fixed point of the corresponding universality class (quenched directed percolation). In conclusion, we conjecture that the Imry-Ma-Aizenman-Wehr-Berker argument for equilibrium systems can be extended to non-equilibrium situations including absorbing states, i.e first-order phase transitions cannot appear in these low-dimensional disordered systems. The underlying reason for this is that, even if the absorbing phase is fluctuation-less and hence is free from the destabilizing effects the Imry-Ma argument relies on, the other phase is active and subject to fluctuation effects. Therefore, intrinsic fluctuations destabilize it as predicted by the Imry-Ma-Aizenman-Wehr-Berker argument, precluding phase coexistence.

System with Random Fields $d \leq 2$	2nd order (spontaneous sym. breaking)	1st order (phase coexistence)
Equilibrium	NO [3]	NO [1,2]
Non-equilibrium (abs. states)	YES [4]	NO

FIG. 1. **Summary of the effects of quenched random fields** on the existence of second and first order phase transitions in $d \leq 2$ systems. Both, the equilibrium and non-equilibrium cases are considered, the latter including the possibility of one or more absorbing states.

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