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Chaotic dynamical phase induced by non-equilibrium quantum fluctuations

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In recent years, the dynamical consequences of spontaneous symmetry breaking have been investigated: What is the fate of the order parameter when the system is driven away from equilibrium?

Mean-field analyses suggest that dynamical criticality sistematically appears. However, they rigorously describe unrealistic infinite-range of infinite-dimensional limits, where few collective macroscopic variables play a role and all the microscopic degrees of freedom, associated with spatial fluctuations, are frozen.

It is a matter of principle to understand whether such dynamical criticality is robust to the inclusion of fluctuations (that are present even at zero temperature in quantum systems): will they be able to drive the system to thermal equilibrium, and hence trivialize the dynamical critical phenomenon into a standard equilibrium transition? If so, the above dynamical criticality would just be a mean-field artifact.

We address this problem by studying an infinite-range Ising model in a transverse field with an additional short-range interaction. I will show a viable systematic approach to deal with the out-of-equilibrium dynamics that goes beyond mean-field.

The results are rather surprising: the spatial fluctuation modes turn out to have a deep impact to the dynamical critical point, giving rise to a whole new region with chaotic features, characterized by an "unpredictable" asymptotic order for long times. The latter non-trivial phenomenon, confirmed by numerical simulations of the exact quantum dynamics, is completely absent at mean-field level.

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