Dynamics of Decoherence: Universal scaling of decoherence factors

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We study the time dependence of the decoherence factor (DF) of a qubit globally coupled to an environmental spin system (ESS) which is driven across the quantum critical point (QCP). In the limit of weak coupling we analyze the time evolution of the DF in the vicinity of the QCP (chosen to
be at t=0) and define three quantities, namely, the generalized fidelity susceptibility $\chi_F(\tau)$ (defined right at the QCP), and the decay constants $\alpha_1(\tau)$ and $\alpha_2(\tau)$ which dictate the decay of the DF at a small but finite t(>0). Using a dimensional analysis argument based on the Kibble-Zurek healing length, we show that $\chi_F(\tau)$ as well as $\alpha_1(\tau)$ and $\alpha_2(\tau)$ indeed satisfy universal power-law scaling relations with τ and the exponents are solely determined by the spatial dimensionality of the ESS and the
exponents associated with its QCP. Remarkably, using the numerical t-DMRG method, these scaling relations are shown to be valid in both the situations when the ESS is integrable and nonintegrable and also for both linear and nonlinear variation of the parameter.