Peculiarities of Non-equilibrium Critical Behavior of Site-diluted 2D Ising Model

P.N. Malyarenko, V.V. Prudnikov, P.V. Prudnikov

Dostoevsky Omsk State University, Omsk, Russia

The collective behavior of statistical systems close to critical points is characterized by an extremely slow dynamics with anomalously long relaxation times which diverges as $t_{rel} \sim |T-T_c|^{-z\nu}$ for $T \to T_c$. Therefore, systems do not achieve equilibrium at the critical point in the course of the whole relaxation process. During this out-of-equilibrium stage aging phenomena occurs with two-time dependence of correlation $C(t,t_w)$ and response $R(t, t_w)$ functions characterized by two times: waiting time t_w and observation time $(t - t_w)$ with $t > t_w$ and $t, t_w << t_{rel}$. Non-equilibrium dynamic shows the violation of the fluctuation-dissipation theorem (FDT). It connects the correlation $C(t,t_w)$ and response $R(t, t_w)$ functions by relation: $TR(t,t_w) = X(t,t_w)\partial C(t,t_w)/\partial t_w$. The asymptotic limit $X^{\infty} = \lim_{t_w \to \infty} \lim_{t \to \infty} X(t,t_w)$, which called fluctuation-dissipation ratio (FDR) is an important characteristic of the non-equilibrium stage [1-3].

In analysis of the effect of the initial states of the system on the characteristics of the non-equilibrium critical behavior, we distinguish the high-temperature initial states formed at $T_0 > T_c$ and characterized by initial magnetization $m_0 = 0$ and the low-temperature initial states with $T_0 < T_c$ and $m_0 \neq 0$. Initial states with magnetization $m_0 \neq 0$ leads to a new time scale $t_m \sim m_0^{-k}$ with the exponent $k > 0$, which substantially affects the temporal behavior of the autocorrelation and response functions. Thus, the strong differences in the nonequilibrium critical behavior of systems relaxing from the different initial states necessitate a more detailed description of the effect of the initial value of magnetization [2, 4].

We report the results of Monte Carlo study the influence of different initial states and structural defects on the non-equilibrium critical behavior of the 2D Ising model relaxing from different initial states. The results revealed an important role of different initial values of the magnetization m_0 on the non-equilibrium critical behavior of the 2D Ising model. It has been shown that two universality subclasses corresponding to the evolution of the system from the high-temperature (with $m_0 = 0$) and low-temperature (with $m_0 = 1$) initial states with the values of the asymptotic fluctuation-dissipation ratio typical of these states can be singled out.

We also study the effect of structural defects on the non-equilibrium critical dynamics of the 2D Ising model. It has been revealed that the aging effects increase with the growth of the density of defects. In the structurally disordered systems relaxing from low-temperature initial state we obtain significant slowing down (as compared to pure systems) of correlation effects, which is associated with pinning of domain walls at structural defects. In this case superaging effect occur in the scaling behavior of the autocorrelation function. At the same time, the asymptotic values of the FDR determined by the domain dynamics in the long-term regime equals zero [5]. In the case of relaxing from high-temperature initial state, we obtain that the non-equilibrium critical behavior of weakly disordered systems with spin concentrations $p \geq 0.9$ is described by characteristics of the pure system, whereas for strongly disordered systems non-equilibrium critical characteristics are appreciably dependent on the concentration of defects owing to the crossover effects in the percolation behavior [6].

The reported study was funded by RFBR according to the research projects № 17-02-00279, 18-42-550003 and grant MD-6868.2018.2 of the President of the Russia. For our calculations, we used the resources provided by the Shared Facility Data Center (Khabarovsk), Far East Branch, Russian Academy of Sciences.

1. *P. Calabrese and A. Gambassi*, J. Phys. A. **38**, R133 (2005).
2. *V.V. Prudnikov, P.V. Prudnikov, and M.V. Mamonova,* Phys. Usp., **60**, 762 (2017).
3. *V.V. Prudnikov, P.V. Prudnikov, and E.A. Pospelov,* J. Stat. Mech., **2016**, 043303 (2016).
4. *P.V. Prudnikov, V.V. Prudnikov, E.A. Pospelov, and P.N. Malyarenko,* PTEP, **2015**, 053A01 (2015).
5. *V. V. Prudnikov, P. V. Prudnikov, E. A. Pospelov and P. N. Malyarenko,* JETP Lett. **107**: 569 (2018).
6. *V. V. Prudnikov and O. N. Markov*, Europhys. Lett. **29**, 245 (1995)