Influence of Initial States and Structure Defects on Non-equilibrium Critical Behavior of 3D and 2D Ising Models

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

Dostoevsky Omsk State University, Omsk, Russia

One of the peculiarities arisen in describing the critical behavior of systems is the critical slowing down effect. It is associated with an anomalous increase in the system relaxation time $t_{\rm rel}$ when approaching the second-order phase transition temperature T_c. As a result, the system being at the critical point appears in no condition to reach equilibrium throughout the entire relaxation process. Therefore, at times $t << t_{\rm rel}$, extraordinary non-equilibrium phenomena characteristic of systems with slow dynamics, such as aging, fluctuation–dissipation theorem (FDT) violation, and the effect of various initial non-equilibrium system states arise in the behavior of systems [1].

We present results of Monte Carlo description of features of non-equilibrium critical behavior in three- and two-dimensional Ising models conditioned by presence of structural quenched disorder. It was shown that limiting fluctuation–dissipation ratio (FDR) values characterizing the degree of system departure from equilibrium and FDT violation satisfy inequality $X^{\infty} < 1$ and depend on the universality class of non-equilibrium critical behavior to which they belong: one of these classes corresponds to the high-temperature, and the other to the low-temperature initial state of the system. The concept of threshold initial magnetization m_0^{th} separating these two universality classes is introduced.

It was revealed that the increase in the concentration of defects is accompanied by the strengthening of the aging effects manifested as the slowing down of correlation and relaxation processes in structurally disordered systems as compared to the pure system. Non-equilibrium initial states begin to increasingly more strongly influence peculiar features and characteristics of the system's evolution. For example, in the case of evolution from a high-temperature initial state with magnetization $m_0 << 1$, the influence of defects is manifested in quantitative changes to universal characteristics of non-equilibrium critical behavior and the limiting FDR X^{∞}. Values of these non-equilibrium characteristics in 3D Ising model demonstrate belonging to universality classes of critical behavior of weakly and strongly diluted systems [2], but non-equilibrium characteristics in 2D Ising model depend continuously on concentration of defects owing to the crossover effects in the percolation behavior [3].

For case with evolution from a low-temperature initial state with $m_0 = 1$, the autocorrelation function decreases in the long-time regime as a power-law of critical magnetization relaxation due to domain wall pinning on structural defects, while limiting FDR values determined by the domain dynamics become equal to zero. It was shown that the two-time scaling dependence of the autocorrelation function obeys relations of the ”superaging” theory suggesting enhanced influence of the system's ”age” (the time of onset of t_w measurement) determined by the power-law dependence $(t_w)^{\mu}$ with exponent $\mu > 1$ [2,4]. Values of ”superaging” exponent μ are calculated for systems with different defect concentrations.

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. The simulations were supported in through computational resources provided by the Shared Facility Center “Data Center of FEB RAS” (Khabarovsk), by the Supercomputing Center of Lomonosov Moscow State University, by Moscow Joint Supercomputer Center and by St. Petersburg Supercomputer Center of the Russian Academy of Sciences.

1. *V.V. Prudnikov, P.V. Prudnikov, and M.V.ºMamonova*, Phys. Usp., **60**, 762 (2017).
2. *V.V. Prudnikov, P.V. Prudnikov, and P.N. Malyarenko*, JETP, **125**, 1102 (2017).
3. *V.V. Prudnikov* and *O.N. Markov*, Europhys. Lett., **29**, 245 (1995).
4. *V.V. Prudnikov, P.V. Prudnikov, E.A. Pospelov, and P.N. Malyarenko*, JETP Lett., **107**, 569 (2018).