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Free Energy Structure and Relaxation Characteristics Near the First-Order Phase transition Line

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Using the three-dimensional kinetic Ising model with Metropolis algorithm, we calculate the free energy in the whole phase boundary, particularly near the first phase transition line (1st-PTL). The results show that along the 1st-PTL, as the temperature decreases, the energy barrier between the two coexisting phases diverges. This results in more difficulty to reach the equilibrium, i.e., ultra-slow relaxation, which has been recently demonstrated [1]. Meanwhile, we exam the randomness of the equilibrium time. It is found that near the 1st-PTL the equilibrium time is self-diverging, in contrast to the non-self-averaging near the critical point.
[1]. Xiaobing Li, Ranran Guo, Mingmei Xu etl al., Phys. Rev. E 111, 064115 (2025).

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