

The Phase Transitions in a p spin Glass Model: A Numerical Study

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We investigate the balanced $M = 4$, $p = 4$ spin-glass model for a one-dimensional long-range proxy for the finite dimensional short-range p -spin glass model to examine the nature of the glass transition beyond mean-field theory. We perform large-scale Monte Carlo equilibrated simulations for both fully connected and power-law diluted versions of the model. The critical temperatures extracted from the finite-size scaling (FSS) analysis of spin-glass susceptibility are in good agreement with theoretical predictions for $\sigma = 0, 0.25$, and 0.55 . For these values of the long-range exponent σ (which is the power of the decrease of the interactions between the spins with their separation), one might have expected that mean-field theory would provide a good description of the system. However, the spin-overlap distribution and the value of the λ -parameter do not provide numerical evidence for a one-step replica symmetry breaking (1RSB) phase transition. Instead, our results indicate a direct transition from the paramagnetic state to a full replica symmetry broken phase, with a renormalized value of $\lambda \equiv \omega_2/\omega_1 < 1$ suggesting a continuous FRSB transition, despite this ratio being equal to 2 at mean-field level. A value of $\lambda > 1$ is required for the discontinuous 1RSB transition. We argue that strong finite-size effects and closely spaced transition temperatures remove the expected 1RSB transition for the system sizes which we can study. For values of the exponent $\sigma = 0.85$ which roughly corresponds to a three dimensional system, we find that the renormalized value of λ is again less than 1, with no signs of either the 1RSB transition or the continuous FRSB transition, suggesting that the Kauzmann temperature T_K in three dimensions might be zero, and the complete absence of phase transitions in structural glasses.