Numerical study of the six-dimensional Ising spin glass on a field

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The study of spin glasses has been tackled from many different points of view. On the theoretical side, great efforts have been dedicated to studying and classifying the phase transition. Specifically, for the Sherrington-Kirkpatrick mean field model of a spin glass, Parisi's Replica Symmetry Breaking solution[1] provides an exact description of the system. For the finite-dimensional models, however, we have no exact solution and the standard way to study them is the Wilsonian Renormalization Group[2]. Systems with no external magnetic field have been widely studied, both by theory and by simulations, and we have a good understanding of the physics of their transition. The upper critical dimension D=6 has been identified and the critical exponents for the short-range finite-dimensional model have been computed[3,4]. Nevertheless, the scenario for systems with an external magnetic field is completely different. It is not clear if there is a phase transition to a spin glass phase at all. In the literature, some results can be found that support that there is no phase transition at any dimension. Different studies defend there is phase transition only above dimension D=6. A recent publication analyzes the system by using a loop expansion around the Bethe solution finding that the upper critical dimension corresponds to D=8[5,6,7]. From the computational point of view, numerical simulations suggest a phase transition occurs for D=4[8], while the results are not conclusive for D=3[9].

The results we present here, try to add some clarity to the debate around the value of the upper critical dimension by means of massive numerical simulations for the six-dimensional spin glasses in the presence of an external field. Because of the difficulties to simulate such a system, we use sophisticated algorithms and techniques such as the Parallel Tempering Method and the Multi Spin Coding with intensive use of computational resources. We simulate the Edwards-Anderson model and study the phase transition through different estimations of the magnetic susceptibility. We identify a continuous phase transition and we also estimate the critical temperature, significative smaller than the critical temperature of the model with no external magnetic field. We also computed the critical exponents η and ν. However, their estimations are not accurate enough to determine if they are compatible with the mean-field values.

References

[1] G. Parisi, Phys. Rev. Lett., 43(23), 1754 (1979).
[2] K. G. Wilson, J. Kogut, Phys. Rep., 12, 75 (1974).
[3] A. B. Harris, T. C. Lubensky, J.-H. Chen, Phys. Rev. Lett. 36, 415 (1976).
[4] Baity-Jesi et al. (Janus Collaboration), Phys. Rev. B 88, 224416 (2013).
[5] D. S. Fisher, D. A. Huse, Phys. Rev. Lett. 56, 1601 (1986).
[6] D. S. Fisher, D. A. Huse, Phys. Rev. B 38, 373 (1988).
[7] M. C. Angelini, C. Lucibello, G. Parisi, G. Perrupato, F. Ricci-Tersenghi, T. Rizzo, Phys. Rev. Lett. 128,
[8] R. A. Baños et al. (Janus Collaboration), Proc. Natl. Acad. Sci U.S.A 109, 6452 (2012).
[9] M. Baity-Jesi et al. (Janus Collaboration), J. Stat. Mech., P05014 (2014).