**Single spin- and chiral-glass transition in vector spin glasses in three-dimensions**

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**Recommended and a Commentary by David Huse, Princeton University**

The spin-glass problem is one where a lot of effort is expended and many papers are written, but real progress in our understanding is nevertheless rare. This paper by Lee and Young strikes me as one that does indeed seem to finally resolve (in the affirmative) one of the basic open questions about spin glasses, namely: Does the Heisenberg spin-glass model (in 3D with only short-range interactions) have a spin-glass phase transition at nonzero temperature?

The spin-glass transition, like any magnetic ordering, may be viewed as a spontaneous breaking of the system's symmetry under rotations in spin space. For vector spins this symmetry includes both proper and improper rotations. Villain (in 1975) suggested the possibility of a phase where only the symmetry under improper rotations is broken. In this so-called "chiral glass" the simplest local order parameter for 3-component vector spins is constructed out of three spins that define a local "handedness" or chirality in spin-space. Over the years it has been debated whether or not chiral-glass and spin-glass ordering appear at nonzero temperature in the 3D Heisenberg spin glass, and whether or not a phase exists with chiral-glass order but no spin-glass order. Kawamura has been the strongest advocate of the presence of the chiral-glass phase, and had suggested that the spin-glass transition in certain real experimental spin glasses may be primarily driven by chiral ordering.

There are no analytic techniques that come even close to systematically addressing these questions, so computer studies, mostly Monte Carlo simulations, are the way these questions have been seriously attacked. We are asking about the equilibrium behavior, and a large sample of spin glass just can not be equilibrated (either numerically or experimentally) at temperatures below the spin-glass phase transition. So the numerical studies typically study many finite-sized samples that are small enough to equilibrate at the temperatures of interest, and do some sort of finite-size-scaling analysis of their properties. The traditional quantity used in finite-size-scaling studies of spin-glass transitions is the Binder ratio of moments of the order parameter probability distribution: (4th moment)/(2nd moment)^2. The Binder ratio is a measure of the shape of the probability distribution of the order parameter, and only looks at spatial averages (thus zero "momentum") so does not directly address the distance dependence of the correlation functions. It has been found to not be very reliable in finding phase transitions near the lower critical dimension, where the quantitative difference between the Binder ratios of the critical point and of the ordered phase are rather small. The innovation that Lee and Young have adopted was introduced and demonstrated for Ising spin glasses by Ballesteros, et al. This is simply to use a direct measure of the correlation length, instead of the Binder ratio, to do the finite-size scaling. This of course more directly addresses the question of long-range order, and was shown to work very well for the Ising spin glass. (See the papers for more details.)

Using this finite-size scaling approach of Ballesteros et al., and the "parallel tempering" simulation algorithm, Lee and Young have done analyses of the spin-glass and chiral-glass correlations, obtaining quite nice evidence for phase transitions at nonzero temperature in both quantities, with the transition temperatures the same within the uncertainties. This supports the simple scenario of a standard spin-glass transition at nonzero temperature in the three-dimensional Heisenberg spin glass model, with no novel chiral-glass phase being present. The transition temperature is quite low, about a factor of five smaller than the mean-field estimate. The requirement to obtain equilibirium data at such low temperatures was one of the major factors in preventing an earlier resolution of this question.