The Last Survivor: a Spin Glass Phase in an External Magnetic Field.

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Spin glasses are a longstanding model for the sluggish dynamics that appears at the glass transition. However, spin glasses differ from structural glasses for a crucial feature: they enjoy a time reversal symmetry. This symmetry can be broken by applying an external magnetic field, but embarrassingly little is known about the critical behavior of a spin glass in a field. In this context, the space dimension is crucial.

Whether spin glasses in a magnetic field undergo a phase transition has been a long-debated and still open question. In the mean-field approximation, which is valid for dimensions greater than the upper critical dimension ($d_{\rm u} = 6$), the de Almeida-Thouless line separates the high-temperature paramagnetic phase from the glassy phase. However, the droplet model predicts no phase transition at all. Finally, experimental studies are still controversial. In this abstract we will present results on four and three dimensions (both dimensions below the upper critical dimension).

We have obtained conclusive evidence for the presence of a phase transition in a four-dimensional spin glass in a field[1] using the Janus special-purpose computer[2] and employing a novel finite size study. In a complementary approach, based in the study of the one dimensional Ising spin glass model with decaying algebraic coupling (whose exponent allows us to connect with finite dimensional short range spin glasses), similar conclusions were reached[3].

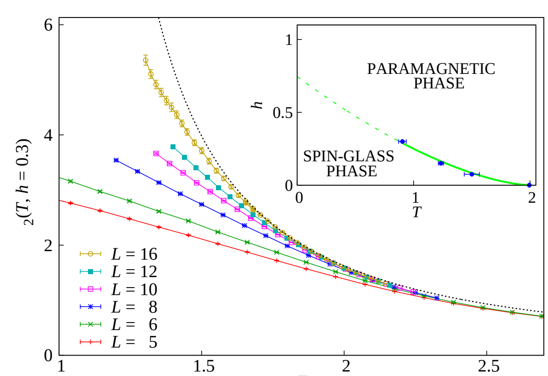

FIG. 1. Plot of the correlation length ξ_2 against temperature in an external field $h = 0.3$ in four dimensions. The dotted black line is a fit to a critical divergence as $\xi_2^\infty \propto [T - T_{{\rm c}(h)}]^{-\nu}$. The inset is a sketch of the phase diagram (the de Almeida-Thouless line), including a fit to the Fisher-Sompolinsky scaling $h_{\rm c}^2(T) \simeq A|T - T_{\rm c}^{(0)}|^{\beta^{(0)}+\gamma^{(0)}}$. The quantities with a superindex (0) are the values for the $h = 0$ critical point, so the only free parameter is the amplitude A.

In Fig. 1 we show the behavior of the finite computed correlation length, ξ_2 (avoiding the zero mode of the system in its definition) as a function of the temperature, behavior which marks the presence of a phase transition.

The situation in three dimensions, is still not clear. To address this problem we have changed the (static) equilibrium approach, we have used in four dimensions, for a dynamical, on and off equilibrium, study[4]. We have used again the Janus special-purpose computer and we have been able to reach times equivalent to 0.01 seconds in experiments. We have studied the system relaxation both for high and for low temperatures, clearly identifying a dynamical transition point. This dynamical temperature is strictly positive and depends on the external applied magnetic field (see Fig. 2). However, it is not clear whether this dynamical phase transition corresponds or not with a thermodynamical one.

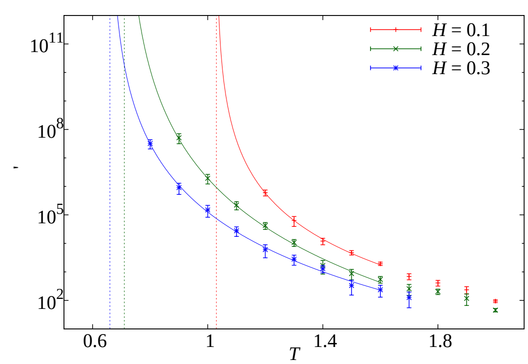

FIG. 2. Three dimensional spin glass. Behavior of the relaxation time τ' as a function of the temperature for the three magnetic fields simulated. We also plot our fits to a power-law divergence of τ' for a finite temperature: $\tau' \propto (T - T_d(h))^{-\nu z}$. z is the dynamical critical exponent.

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