Comment on "Stripe Glasses: Self-Generated Randomness in a Uniformly Frustrated System"

In a recent Letter, Schmalian and Wolynes [1] have studied a uniformly frustrated system whose Hamiltonian is given by

$$\mathcal{H} = \frac{1}{2}\int d^3x \left\{ r_0\phi(\mathbf{x})^2 + [\nabla\phi(\mathbf{x})]^2 + \frac{u}{2}\phi(\mathbf{x})^4 \right\} + \frac{Q}{2}\int d^3x \int d^3x' \, \frac{\phi(\mathbf{x})\phi(\mathbf{x}')}{|\mathbf{x}-\mathbf{x}'|}. \quad (1)$$

Using the replica formalism and the self-consistent screening approximation, they show that the competition of interactions on different length scales leads, below a crossover temperature T_A, to the emergence of an exponentially large number of metastable states and, at a lower temperature T_k, to a phase transition to a glassy state. Moreover, from entropic droplet arguments they predict that slow activated dynamics should occur at temperatures between T_A and T_K, with the relaxation time τ obeying a Vogel-Fulcher law, $\tau \propto \exp(\frac{DT_k}{T-T_k})$, and the fragility parameter D being proportional to $(\frac{\partial S_c}{\partial T}|_{T_k})^{-1}$, where $S_c(T)$, the configurational entropy, is the logarithm of the number of metastable states. Since they find that $\frac{\partial S_c}{\partial T}$ decreases when the frustration parameter Q decreases, the system should become less fragile (i.e., with a larger D) when Q decreases. Such a conclusion is strikingly at odds with the prediction made for similar systems by the frustration-limited domain theory of the glass transition [2].

We comment here on the connection made by Schmalian and Wolynes [1] between the configurational entropy and the relaxational behavior of the frustrated system and on the relation between the fragility of a glass-forming system and the frustration. We have carried out computer simulations of the "hard-spin" lattice version of the field-theoretical action in Eq. (1), namely,

$$H = -\sum_{\langle i,j\rangle} S_i S_j + \frac{Q}{2}\sum_{i\neq j}\frac{S_i S_j}{r_{ij}}, \quad (2)$$

where the spins, $S_i = \pm 1$, are placed on a cubic lattice [3]. By using the Metropolis algorithm with the constraint of zero total magnetization, we have computed the (equilibrium) spin-spin correlation function, $C(t) = \frac{1}{N}\sum_i \langle S_i(0)S_i(t)\rangle$, as a function of temperature for a range of frustration parameter Q that covers the values studied in Ref. [1]. The relaxation time τ has been obtained from the simulation in a standard way [4] as the time at which $C(t) = 0.1$. The results are reported in Fig. 1.

Although other formulas can be used as well [2], we have fitted our simulation data to the Vogel-Fulcher law discussed in Ref. [1], and, as seen from Fig. 1, the fits are very good for all values of Q. In the inset, we display the fragility parameter D versus Q on a ln-ln plot: D roughly increases as $\sqrt{Q}$. Clearly, the uniformly frustrated system

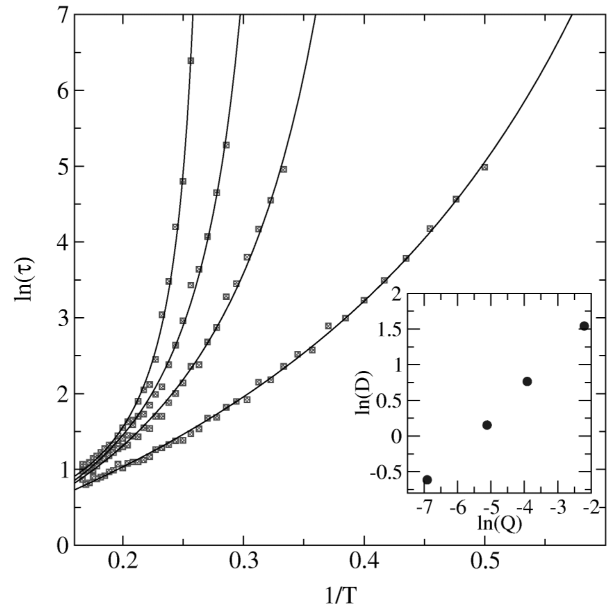

FIG. 1. $\ln(\tau)$ versus $1/T$ for $Q = 0.001, 0.006, 0.02, 0.11$ (from left to right). Solid lines: fits to the Vogel-Fulcher law. The higher T values [down to $\ln(\tau) \sim 0$] are used in the fit, but are not shown here. Inset: $\ln(D)$ versus $\ln(Q)$.

becomes less fragile when the frustration Q increases, as can also be seen from the curvature of the various $\ln(\tau)$ curves in Fig. 1. This result, that fragility decreases as frustration increases, disagrees with the analysis presented in Ref. [1] but supports the prediction of the frustration-limited domain theory [2].

The above discussion seems to suggest that, contrary to the commonly held view, the relaxation time of a system that possesses a complex, rugged free-energy landscape (which, as shown in [1], is the case of the uniformly frustrated system) is not solely, nor primarily, determined by the number of available metastable states, i.e., by the configurational entropy. Other ingredients (preferred paths, free-energy barriers, connectivity of the minima) may be necessary as well.

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Received 6 November 2000
DOI: 10.1103/PhysRevLett.86.3455
PACS numbers: 75.10.Nr, 61.43.Gt, 74.25.–q

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