Comment on "Symmetrical Temperature-Chaos Effect with Positive and Negative Temperature Shifts in a Spin Glass"

In a very interesting Letter, Jönsson *et al.* [1] have shown that the effect of small temperature shifts on the aging behavior of a Heisenberg-like spin glass could be interpreted quantitatively using the ideas of temperature chaos and overlap length. In this Comment, we show that the same analysis can be performed in a case where temperature chaos is known to be irrelevant, weakening the main conclusion of Ref. [1].

As is now well established, aging at low temperatures T in spin glasses is associated with the slow growth with time t of a coherence length, $\ell_T(t)$. This length can be measured in simulations, but can also be inferred from experimental data leading to a rather consistent determination of $\ell_T(t)$. "Cumulative aging" [1] means that the same coherence length grows at different temperatures, although at different rates. In this case, the value of $\ell_{T_i}(t_w)$ after staying a time t_w at a temperature T_i serves as the "initial condition" for the growth of ℓ after a temperature shift.

Rejuvenation effects, on the other hand, demonstrate that cumulative aging cannot be the only story in spin glasses. The temperature chaos scenario postulates that typical equilibrium configurations in a spin glass at two temperatures differing by ΔT are strongly correlated only up to the overlap length, $\ell_{\Delta T}$, beyond which these correlations rapidly decay to zero. From scaling arguments, one expects $\ell_{\Delta T} \sim \Delta T^{-1/\zeta}$, with $\zeta \approx 1$ for the Ising spin glass. If this scenario holds, the initial condition for the growth of ℓ after a temperature shift, as encoded by an effective length ℓ_{eff}, will obey

$$\frac{\ell_{\text{eff}}}{\ell_{\Delta T}} = F\left(\frac{\ell_{T_i}(t_w)}{\ell_{\Delta T}}\right), \tag{1}$$

with $F(x \ll 1) = x$ (cumulative aging) and $F(x \gg 1) = 1$ (chaos). Rejuvenation, i.e., deviations from cumulative aging, is thus accounted for by temperature chaos. The verification of Eq. (1) using experimentally determined values of ℓ_{T_i} and ℓ_{eff} for different ΔT and t_w is the central result of Ref. [1], thereby providing support for the chaos scenario and the numerical value $1/\zeta \approx 2.6$ for the AgMn spin glass. In the above argument, one *assumes* that rejuvenation is induced by temperature chaos, and finds self-consistent results only.

However, other scenarios have been proposed to explain rejuvenation effects, such as the progressive freezing of smaller and smaller length scale modes [2,3]. In this respect, we recently demonstrated in a numerical simulation of the 4D Ising spin glass that a temperature change $\Delta T/T_c \sim 0.5$ induces *strong* rejuvenation effects, whereas the direct observation of the overlap between configurations reveals *no sign of chaos* on the dynamically relevant length scales [2].

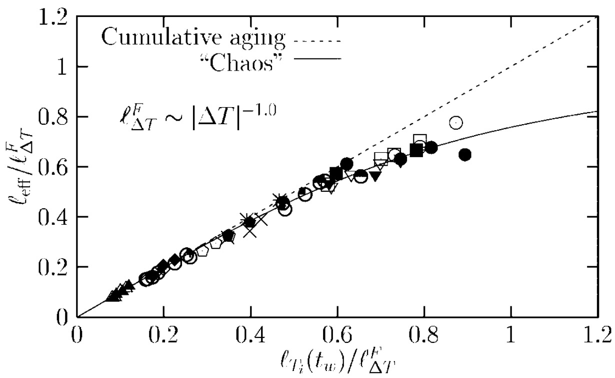

FIG. 1. Test of Eq. (1) for a series of "twin experiments" performed in the 4D Gaussian Ising spin glass strictly following protocols and analysis of Ref. [1]. A total of 56 shift experiments are represented with $T_i/T_c \in [0.4, 0.9]$, $\Delta T/T_c = 0.05, 0.1, 0.2, 0.3, 0.4$, $t_w \in [80, 57797]$. System size is $L = 25 \gg \ell_T(t)$. ℓ_{eff} was defined from the maximum of $\partial_t C(t + t_w, t_w)$, where C is the spin autocorrelation function (instead of TRM) and growth laws $\ell_T(t)$ taken from Ref. [2]. The fictitious overlap length $\ell^F_{\Delta T}$ is chosen to obtain the best scaling of all our data.

To understand these contradictory results [1,2], we have reproduced the protocol of Ref. [1] in an extensive series of new simulations, and followed the same steps to determine the length scales $\ell_{T_i}(t_w)$ and ℓ_{eff}. Although we know, from the direct analysis of the configurations, that the putative overlap length is much larger than all dynamic length scales in our simulations, we tried to rescale all our data using Eq. (1). As shown in Fig. 1, this works very well with the expected value $\zeta \approx 1$. Therefore, the very fact of plotting the data as suggested by Eq. (1) results in the appearance of a *fictitious* overlap length, $\ell^F_{\Delta T}$. This shows that although suggestive, the analysis of Ref. [1] cannot be viewed as definitive evidence for temperature chaos.

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