On the superposition principle and non-linear response in spin glasses

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The extended principle of superposition has been a touchstone of spin glass dynamics for almost thirty years. The Uppsala group has demonstrated its validity for the metallic spin glass, CuMn, for magnetic fields H up to 10 Oe at the reduced temperature Tr=T/Tg = 0.95, where Tg is the spin glass condensation temperature. For H > 10 Oe, they observe a departure from linear response which they ascribe to the development of non-linear dynamics. The thrust of this paper is to develop a microscopic origin for this behavior by focusing on the time development of the spin glass correlation length, $\xi(t, tw; H)$. Here, t is the time after H changes, and tw is the time from the quench for T>Tg to the working temperature T until H changes. We connect the growth of $\xi(t, tw; H)$ to the barrier heights Δ(tw) that set the dynamics. The effect of H on the magnitude of Δ(tw) is responsible for affecting differently the two dynamical protocols associated with turning H off (TRM) or on (ZFC). This difference is a consequence of non-linearity based on the effect of H on Δ(tw).

In this paper, we display the difference between the zero-field cooled $\xi_{ZFC}(t, tw; H)$ and the thermoremanent magnetization $\xi_{TRM}(t, tw; H)$ correlation lengths as H increases, both experimentally and through numerical simulations, corresponding to the violation of the extended principle of superposition in line with the finding of the Uppsala Group.