Slow dynamics in Heisenberg spin glasses and spontaneous restoration of the spin configuration existing before

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Spin-glass has been one of the most-studied glassy systems; however, little is known regarding their nature. One of the reasons is that non-equilibrium relaxations continue throughout experiments over a period of weeks whereas various intriguing equilibrium states have been theoretically proposed till now. In this study, we carefully reexamine the features of the slow relaxations themselves, in order to clarify the nature by a detailed comparison with the energy landscapes predicted by the theories.

Samples are materials regarded as a kind of Heisenberg spin glass: a dilute magnetic alloy $Cu_{97}Mn_3$ [1], a dilute magnetic semiconductor $Cd_{55}Mn_{45}Te$ [2], and a geometrically frustrated magnet $ZnFe_2O_4$ [3]. In our typical experiments, each sample was initially subjected to a magnetic field for a significant duration (aging.) Then the field was cut off and decay of thermoremanent magnetization was recorded on various thermal histories. Consequently, we found that the decay was extremely accelerated when the sample was temporarily heated/cooled midway through the isothermal relaxation. In contrast, in the cases that the sample was sufficiently aged in the magnetic field, the thermoremanent magnetization surprisingly increased despite absence of magnetic field when the temperature returned to the original after the temporary heating/cooling. In other words, the memory in the aging period returns despite once being rejuvenated. These phenomena were commonly observed in the three samples.

Because the magnetization mirrors evolution of the spin configuration, these acceleration and reversion of the decay indicate that the configuration is destabilized when the temperature changes and it is spontaneously restored when the temperature is returned to the original. Whereas such destabilization and restoration do not occur if the spin glass is simply frozen, it is possible in an energy landscape with a temperature- sensitive funnel-like structure in the explored region**.** This explanation agrees well with the ghost domain scenario of the droplet picture but not in the other cogent models proposed over the last few decades [1-3]. This finding has thus provided fresh insight into the stereotype of glassy systems: a disordered configuration frozen in numerous meta-stable states.

References

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