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TITLE: MUON SPIN-RELAXATION MEASUREMENTS OF THE FLUCTUATION MODES IN SPIN-GLASS AgMn

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MUON SPIN RELAXATION MEASUREMENTS OF THE

FLUCTUATION MODES IN SPIN-GLASS AgMn

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Recently reported zero-field μSR measurements below the spin-glass transition temperature in AgMn (1.6 at.%) show a temperature dependent inhomogenous width. We discuss these data in terms of a model in which the local field undergoes limited-amplitude fluctuations. We find that both very slow (~0.3 μs^{-1}) and rapid (~3000 μs^{-1}) fluctuations are required.

In recently reported zero-field μSR experiments on the spin-glass AgMn (1.6 at. %), the positive muon (μ^+) inhomogenous line width, a(T), was found to increase monotonically as the temperature was lowered below the glass temperature T_g.[1] This effect was interpreted as evidence for rapid, small-amplitude fluctuations of the local fields, with the decreasing amplitude of these fluctuations producing the increasing a(T) as the temperature is lowered. The purpose of the present paper is to discuss these data in the context of a spin-glass model based on just such limited-amplitude fluctuations of the local fields. We will see that the data provide evidence for the existence of both slow- and fast-fluctuation modes.

Models for the depolarization of positive muons in spin glasses which assume complete reorientation of the local fields during fluctuations have been presented by Uemura et al.[2] and by Leon;[3] these models cannot plausibly produce a temperature-dependent a(T), however. A two-state model, one state of which has a fixed local field direction, has been discussed by Uemura.[4]

In the present "quasimagnon model" we assume that the local dipolar field (corresponding to a particular muon site) has both a static component H_0 which is Lorentzian-distributed with width a_L, and a fluctuating component which is Gaussian-distributed with width $\Delta(H_0)$. For this fluctuating component the "strong collision" assumption is made,[5] i.e., there is no correlation before and after the jump. Finding the evolution of the μ^+ polarization then amounts to solving the "Kubo-Toyabe" problem[6] for an arbitrarily oriented static external field H_0. Fortunately, this can be done in terms of the polarization functions $G_\parallel(t)$, $G_\perp(t)$ for the parallel and perpendicular H_0 configurations, using the relation

$$G(t) = \cos^2\theta_0\, G_\parallel(t) + \sin^2\theta_0\, G_\perp(t), \qquad (1)$$

Θ_o being the angle between H_o and $\hat{z}$ (the initial μ^+ polarization direction). Each G_i ($i = \parallel, \perp$) evolves independently of the other, and is determined from an integral equation involving the corresponding static (no-fluctuation) polarization function $G_i^o(t)$.[5,6]

These integral equations are solved numerically, for given H_o, Δ, and fluctuation rate ν, to give the $G_i(t) \equiv G_i(t;H_o,\Delta,\nu)$. We take $\Delta = \alpha H_o$, so that α represents the characteristic angle of fluctuation of the total field. Lastly, an integration over H_o (i.e., over the different muon sites) is performed to give the net polarization function $G(t;\nu)$.

Since we want the RMS value of the local field at each site to be independent of the amplitude of the fluctuations, we impose the constraint

$$a_L = \frac{a_L^o}{\sqrt{1 + 3\alpha^2}} \quad , \tag{2}$$

where $a_L^o = 19\ \mu s^{-1}$ is the frozen spin value.[7] In general, of course, the inhomogeneous width, a, will depend both on a_L and α.

Finally, since one can show that for very fast fluctuations ν_o of angular amplitude α_o,

$$G_i(t) = P(t)G_i^o(t;H_o,\Delta) \tag{3}$$

where

$$P(t) = \exp\{-2\left[\frac{\alpha_o H_o}{\nu_o}\right]^2 (e^{-\nu_o t} - 1 + \nu_o t)\}, \tag{4}$$

we can combine these very fast fluctuations with slower ones in an approximate way by simply substituting these $G_i(t)$ for $G_i^o(t)$ in the integral equations. In this case Eq. (2) is replaced by

$$a_L = \frac{a_L^o}{\sqrt{1 + 3\alpha^2 + 3\alpha_o^2}} \quad . \tag{5}$$

The data at $T = 0.3\ T_g$ and $T = 0.8\ T_g$ were first fitted assuming a single, fast fluctuation mode of limited amplitude, applying the constraint of Eq. (2). Excellent fits to the first 0.5 μs of data were obtained for the fluctuation rate of $10^4\ \mu s^{-1}$. As can be seen from the dotted curves in Fig. 1, however, both the long- and short-time behavior of the relaxation function cannot simultaneously be well fitted with this model. Next both fast (ν_o) and slow (ν) fluctuation modes were included. This provides a better fit to the data as shown in Fig. 1. The fit parameters are summarized in Table I; for convenience we have taken $\alpha = \alpha_o$. It must be emphasized that these parameters are certainly not unique.

In conclusion, we have presented a model for muon spin relaxation in a spin-glass system which incorporates limited-amplitude fluctuations of the local field and accounts for the observed temperature dependence of the inhomogeneous line width in a physically plausible way. Our model assumes the same two fluctuation rates and angular amplitudes at each muon site. An equally plausible picture in which different sites have different (single) fluctuation rates and amplitudes may also be consistent with our data. In reality, we expect the spin glass to possess a continuum of fluctuation modes, as has been observed with the neutron spin-echo technique;[8] however, whether a single site experiences this continuum or is dominated by a single mode is not known. Finally, we note that the existence of spin-glass modes at frequencies much lower than that found in numerical simulations of harmonic quasimagnon excitations,[10] as previously reported,[1] persists in this new analysis; this provides evidence that small amplitude barrier modes may be important in the relaxing of the muon spin.

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TABLE I. Parameters Used to Generate Fits to the AgMn (1.6 %) data.[1]

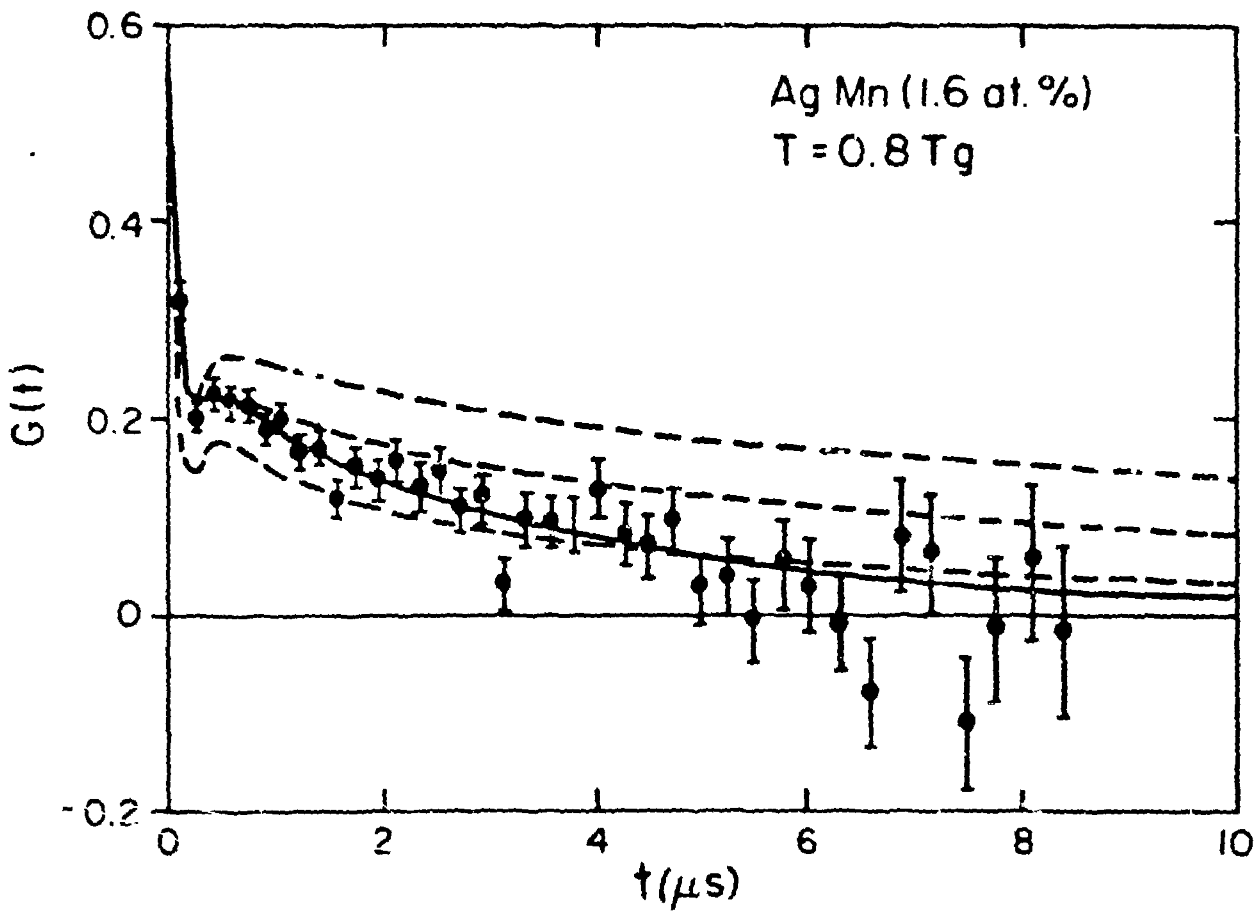
T/T_g	a_L/a_L^o	α	$\nu(\mu s^{-1})$	α_o	$\nu_o(\mu s^{-1})$	χ^2/N
.30	.92	0	0	.24	3000	6.0
.30	.86	.24	.3	.24	3000	2.8
.80	.60	0	0	.76	3000	3.6
.80	.47	.76	.3	.76	3000	1.4

$T_g = 7.5$ K

$a_L^o = 19\ \mu s^{-1}$

FIGURE CAPTION

Fig. 1. Zero-field muon spin relaxation function for spin-glass AgMn (1.6%) at $T = 0.8\ T_g$. The dotted curves from bottom to top were calculated from the quasimagnon model using a single fluctuation rate of 1000, 3000, and 9000 μs^{-1}, respectively. The solid curve was generated using rates 0.3 μs^{-1} and 3000 μs^{-1}. Table I gives other relevant parameters.


Ag Mn (1.6 at.%)
T = 0.8 Tg
G(t)
t(μs)
0.6
0.4
0.2
0
-0.2
0
2
4
6
8
10