Homogeneous kinetic relaxation in YIG in the dipole region

I. D. Luzyanin and V. P. Khavronin

B. P. Konstantinov Institute of Nuclear Physics, USSR Academy of Sciences
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Investigation of homogeneous magnetic relaxation in YIG has revealed a strong singularity of the kinetic coefficient Γ_0/χ_{st} in the dipole region of the second-order phase transition.

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When homogeneous magnetic relaxation in the paramagnetic phase of a second order transition is investigated by radio-frequency methods, it is necessary to take into account the fact that the characteristic energy of the critical fluctuations, described within the framework of the dynamic similarity hypothesis by means of the characteristic energy Γ_0, tends to zero as the transition

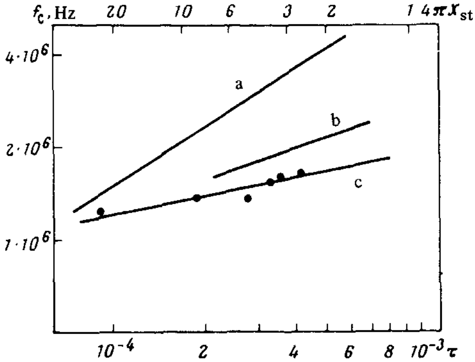


FIG. 1. Plot of $f_c(\tau)$ (c). The dashed lines corre spond to the theoretical plot of $\Gamma_0 \sim \tau^{2/3}$ (a)[1] an $\Gamma_0 \sim \tau^{1/3}$ (b)[3].

point is approached and can become comparable in magnitude with the alternating-magnetic-fiel frequency at which the investigation is carried out. It is obvious that for this reason the validity c the relation between the dynamic susceptibility $\chi(\omega)$ and the characteristic energy Γ_0 [1]

$$\chi(\omega) = \chi_{st} \frac{1/\Gamma_0}{-i\omega + 1/\Gamma_0} \qquad ($$

(real at) $\omega << \Gamma_0$

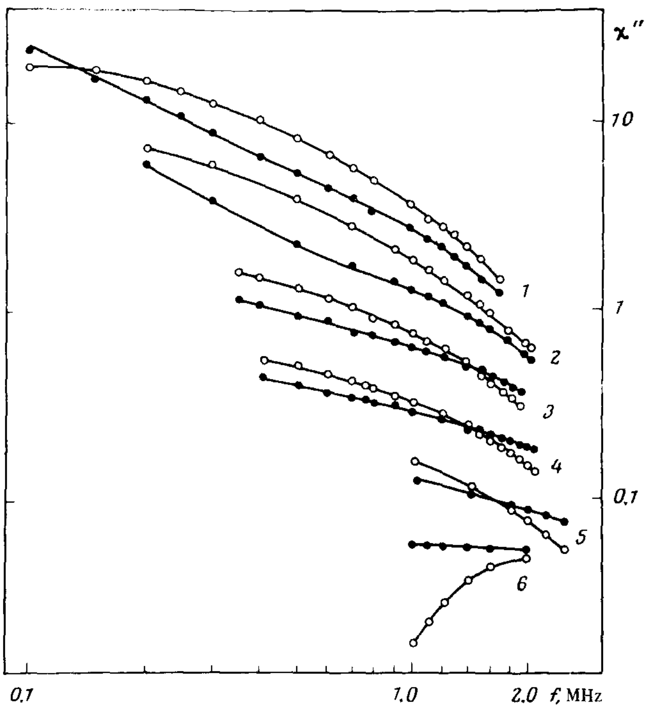
is particularly easy to violate in the immediate vicinity of T_c. It therefore becomes impossible to obtain in the dipole region ($4\pi\chi_{st} \gg 1$) information on the character of the dependence of Γ_0 (the relative temperature τ [$\tau = (T - T_c)/T$] with the aid of expression (1). In this case one c propose another method for the determination of the temperature dependence of Γ_0, a dependen of considerable interest for the understanding of the physics of phase transitions. In fact, wh $\omega = 2\pi f$ is of the order of Γ_0, a situation is possible wherein at a certain frequency f_c the real and t imaginary parts of the susceptibility become equal in magnitude. On the other hand, according the dynamic-similarity hypothesis, the dynamic susceptibility is a homogeneous function of or the characteristic energy Γ_0:

$$\chi(\omega) = \chi'(\omega) - i\chi''(\omega) = F(\omega/\Gamma_0) \equiv F'(\omega/\Gamma_0) - iF''(\omega/\Gamma_0).$$

Therefore, if $\chi'(f_c) = \chi''(f_e)$, then the equality $F'(f_c/\Gamma_0) = F''(f_c/\Gamma_0)$. should hold. Thus, by determi ing from the functions $\chi'(\omega)$ and $\chi''(\omega)$ at different distances from T_c the frequency at whi $\chi' = \chi''$, we can obtain information on the character of the $\Gamma_0(\tau)$ dependence.

In previous investigations of the homogeneous relaxation in yttrium-iron garnet (YIG),[2] t frequency range was insufficient to determine the $\Gamma_0(\tau)$ from the values of f_c in the dipole regi (according to [2], the value $4\pi\chi_{st} = 1$ corresponds to $\tau \approx 1 \times 10^{-3}$). At the same time, on the basis the frequency dependence of the values of Γ calculated from (1) at $\tau < 1 \times 10^{-3}$, it was conclud that the homogeneous relaxation is likely not to have a Lorentz shape in the dipole region. F these reasons, the temperature dependence of the characteristic energy in the dipole region co not be determined in[2].

In the present communication we present the results of an investigation of homogenec relaxation in the dipole region, using the same toroidal single crystal as in[2]. The frequency ran



G. 2. Frequency dependences of χ' and χ'' for different relative temperatures: 1—$\tau = -8\times10^{-5}$; -$\tau = \sim +6\times10^{-5}$; 3—$\tau = +1.9\times10^{-4}$; 4—$\tau = +2.8\times10^{-4}$; 5—$\tau = +4.2\times10^{-4}$; 6—$\tau = +1\times10^{-3}$. ɔr comparison, all plots of $\chi'(f)$ and $\chi''(f)$ with the exception of curve 1 are shifted relative to one ɔther in the vertical direction.)

1–2.5 MHz) was chosen on the basis of estimates made in[1] and[2] of the value of Γ_0 in the dipole ion. The closeness of the approach to the Curie point was restricted by the accuracy $\tau \approx (2\text{–}3)\times10^{-3}$] at which the temperature was maintained. The values of f_c at different ıperatures were determined from the intersection of the plots of $\chi'(\omega)$ and $\chi''(\omega)$. The plot of f_c .inst τ obtained in this manner is shown in a logarithmic scale in Fig. 1. To determine the order nagnitude of $4\pi\chi_{st}$, the values of χ_{st} obtained in[2] in the temperature region $\tau > 1\times10^{-3}$ were rapolated to the dipole region in accordance with the law $\chi_{st}\sim\tau^{-4/3}$. The extrapolated values of χ_{st} are marked on the upper scale of Fig. 1. Notice must be taken first of the power-law behavior $f_c(\tau)$, which attests to the applicability of the dynamic-similarity hypothesis in the investigated ıperature interval. The exponent in this relation, however, differs substantially from the predicı $\Gamma_0\sim\tau^{2/3}$ given in[1] for the case of uniform relaxation. On the other hand, the experimental ıes of the critical exponent turned out to be (0.2 ± 0.05). The shapes of the plots of $\chi'(f)$ and $f)$ (Fig. 2) for different temperatures of the dipole region (curves 3,4,5) point to a patently ı-Lorentzian character of the uniform relaxation. At the same time, it must be emphasized that relations obtained at $\tau = 1\times10^{-3}$ (curve 6) in the paramagnetic phase and in the ferromagnetic ıon (curve 1) are at any rate close to Lorentzian.

Thus, the results given above reveal a stronger singularity in the kinetic coefficient Γ_0/χ_{st} than dicted by the similarity hypothesis for the dipole region of a second-order phase transition. A sible explanation is given in[3], according to which the dynamics of the ferromagnetic fluctuations (precisely those for which $\Gamma_0 \sim \tau^{2/3}$) in a ferrimagnet that has two or more sublattices can b determined by the field of the antiferromagnetic fluctuations, and the exponent of the temperatu dependence of the characteristic energy of the ferromagnetic fluctuations can accordingly b changed. From among the results, notice should also be taken of the non-Lorentzian character of the relaxation at $4\pi\chi_{st} > 1$.

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