Effect of static impurities on the critical dynamics of ferromagnets above T_c. Critical dynamics of ferrites

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The scattering of critical fluctuations by impurities makes the critical-fluctuation energy, as $T \to T_c$, proportional to $\kappa^{1/2}$ rather than to κ (κ is the reciprocal correlation radius). The role of impurities in ferrites can be assumed by long-lived fluctuations of the antiferromagnetic order of the sublattices.

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Two variants of critical dynamics of cubic ferromagnets in the dipole region ($4\pi\chi \gg 1$) abc T_c are discussed in the literature: 1) normal $\Omega \sim \chi^{-1} \sim \kappa^2$ [1,2] and 2) anomalous $\Omega \sim \chi^{1/2} \sim \kappa$ [3] (is the characteristic energy of the critical fluctuations, $\chi \sim \kappa^{-2}$ is the susceptibility, κ is the recipı cal correlation radius). In experiments on homogeneous magnetic relaxation in yttrium ir garnets it has been observed, however, that $\Omega \sim \tau^{(0.2 \pm 0.05)} \sim \kappa^{(0.3 \pm 0.08)}$ (the approximation $\kappa \sim \tau$ $\tau = (T - T_c)T_c^{-1}$ is used on the right-hand side). In this communication an attempt is made explain this phenomenon. We recall first the main idea of[3]. According to Kubo's formulas, Ω expressed in terms of the retarded commutator of the operators $d\mathbf{S}_k/dt$ ($\mathbf{S}_k$ is the Fourier tra form of the spin density). In the dipole region, at $k < q_0 = (\omega_0/T_c)^{1/2}a^{-1}$ [$\omega_0 = 4\pi(g\mu)^2 v_0^{-1}$ is t dipole energy and a is a length of the order of the interatomic distance] we have:

$$\frac{d\mathbf{S}_k}{dt} \approx - N^{-1/2} \omega_0 \sum_{\mathbf{q}} q^{-2} [\mathbf{S}_{\mathbf{q}+\mathbf{k}}, q](\mathbf{q}, \mathbf{S}_{\mathbf{q}})$$

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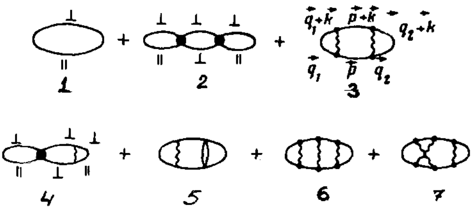

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ıerefore two critical fluctuations are emitted in the bare vertices of the diagram series for Ω (Fig. . one of which is polarized parallel to the momentum. As $\tau\to 0$ and $q\to 0$, however, this ctuation is finite and only the fluctuations perpendicular to the momentum increase without ıit. Therefore the first diagram makes a normal contribution to Ω. The anomalous contribution due to rescattering into an intermediate state with two perpendicular fluctuations (second ıgram). It is obvious that any perturbation makes an additional contribution to such rescatterȝs and can alter the dependence of Ω on κ.

1. Static impurities (diagrams 3–7 of Fig. 1).

We consider first the third diagram. In the corresponding expression, owing to the suppresɔn of the longitudinal fluctuations, we have $q_{1,2}\sim q_0$ and at the same time $p\sim\kappa$, $k\ll q_0$. Therefore $_2\gg p$ in the total amplitudes $\Gamma(\mathbf{q}_{1,2},\mathbf{p})$ of the interaction of the critical fluctuations with the ıpurities; from dimensionality considerations, $\Gamma\sim\partial G^{-1}/\partial\tau$ and, as shown in[5], $\Gamma=Aq_{1,2}^{2-1/\nu-\eta}$ at $_2\gg p$. As a result, the integral with respect to $\mathbf{p}$ takes the same form as in the absence of ıormalization of the interaction with the impurities. If account is taken of only the third ıgram, we obtain by the method of[3]:

$$\Omega_{\mathrm{imp}}= T_c(q_0 a)^2(\kappa a)^{\frac{1}{2}(1+\eta)} g = \omega_0 g(\kappa a)^{\frac{1}{2}(1+\eta)} \approx \omega_0 g\tau^{\frac{1}{3}}, \qquad (2)$$

ıere $g\sim cU_0^2/T_c^2$ (c is the impurity concentration and U_0 is the energy of their interaction with the ctuations). According to[3] we have in the dipole region $\Omega_d\approx T_c(q_0a)^{3/2}\kappa a$; the condition $_{\mathrm{np}}>\Omega_d$ coincides with the condition that the interference diagrams (the fourth and fifth) are all, and take the form $\kappa\ll g_0$ and $g^2\equiv q_1$. It is easy to verify that more complicated impurity ıgrams (six, seven, etc.) must be taken into account if $(\kappa a)^{-\alpha/\nu}=\tau^{-\alpha}>g$, where $\alpha=2-3\nu$ is heat-capacity exponent; this inequality coincides with the well known condition that point-like purities have an influence on the phase transition. Most likely $\alpha<0$.[6] In this case the region of plicability of (2) is bounded from below by the condition $\tau>0$. The dependence of Ω_{imp} on κ d on q_0 is based on two facts—the suppression of the longitudinal fluctuations and the existence a singular intermediate state. Therefore, formula (2) with $g\sim 1$ should hold at $\alpha<0$ also at lues of c that are not small, and even for amorphous ferromagnets. At $\alpha>0$, in the case of not) small g, the region of applicability of (2) can be bounded from below by very small τ, owing to smallness of α. At nonzero momenta, the dynamics is determined by the impurities and Ω_{imp} $)=\omega_0 g(ka)^{1/2}$ if $\kappa<k<q_1$. In the exchange region $(4\pi\chi<1)$ the value of dS_k/dt is determined by exchange interaction, bare vector vertices appear, and rescattering by the impurities does not er the critical dynamics: $\Omega_e=T_c(\kappa a)^{5/2}$.

2. We now attempt to explain the results of[4]. At the Curie point, a spontaneous moment ses in ferrites and a sublattice magnetic structure is produced. The number of sublattices is material to us, and we assume it to be two. It is obvious that the fluctuations of both the ıgnetization and of the antiferromagnetism vector are critical. In the exchange region $(4\pi\chi<1)$ se two fields form a coupled system in which the usual critical slowing down of the relaxation

takes place with two characteristic energies, $\Omega_F = T_c \gamma_F (\kappa a)^{z_F}$ and $\Omega_{AF} = T_c \gamma_{AF} (\kappa a)^{z_{AF}}$ ($\gamma_F \sim \gamma_{AF} \sim$ 1 κ is the reciprocal dimension of the ferromagnetic fluctuations). In the dipole region, the onset c the ferromagnetic fluctuation leads to a large increase of the system energy because of the syster magnetic field, and accordingly to a decrease of the time of its decay, i.e., to a decrease of z_F. Th dipole forces act on the antiferromagnetic fluctuations indirectly, via the magnetization fluctu ations, so that the change of z_{AF} should be weaker. It may turn out here that $z_{AF} > z_F$, i.e., th antiferromagnetic fluctuations have a much longer lifetime than the ferromagnetic ones, and fror the point of view of the latter, constitutes so to speak an external random static field. In this case to determine z_F we can use the arguments of the preceding section, and the characteristic energy c the ferromagnetic fluctuations will be described by the formula (2) with $g \sim 1$.

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