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SPIN DEPENDENCE OF THE SUSCEPTIBILITY AND CURIE TEMPERATURE OF AMORPHOUS FERROMAGNETS

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Several experimental investigations of amorphous ferromagnets [1 - 4] have established that their magnetizations and the Curie temperatures are lower than those in the crystalline state. The results of theoretical investigations depend essentially on the chosen approximation. As a result of fluctuations of the exchange integrals, both a decrease [5 - 8] and an increase [9] of the Curie temperature and of the susceptibility were obtained. It was noted in [6, 8] that the fluctuations in the account of the short-range magnetic order always lead to a decrease of these quantities.

In this paper, using a high-temperature expansion (HTE), we consider the effect of fluctuations of the exchange integrals on χ and T_c for the Heisenberg and Ising models, as functions of the spin S and of the number of nearest neighbors. A somewhat unexpected "spin anomaly" (change of the influence of the fluctuations on χ and T_c) was established for the Ising model. In analogy with [7], we calculate the first four coefficients in the HTE of the susceptibility

$$\bar{\chi} = 3kT\chi/\mu_B^2 g^2 NS(S+1) = \sum_{n=0}^{\infty} a_n \theta^n; \quad \theta = \langle I \rangle / kT \tag{1}$$

for the Heisenberg and Ising models at different values of the spin. The structure disorder is taken into account within the framework of the lattice model (see [7]) with the aid of stochastically fluctuating exchange integrals. If the coefficients a_n from (1) are represented in the form

$$a_n = a_n^\circ (1 + A_n \Delta^2); \quad \Delta^2/2 = \langle \Delta I_{12}^2 \rangle / \langle I \rangle^2, \tag{2}$$

then calculation yields for n = 1, ..., 4:

	Heisenberg model	Ising model
$S = 1/2$	$A_n \le 0$	$A_n \le 0$
$S \ge 1$ (up to $S = \infty$)	$A_n \le 0$	$A_n \ge 0$

The first coefficients of the HTE (1) determine uniquely the behavior of the susceptibility at $T \gg T_c$. Thus, in the Heisenberg model at high temperatures, we have $\Delta\chi_H = \chi_H - \chi_H^0 \le 0$ for all S (i.e., a decrease of χ as a result of the fluctuation[1]). The modulus of A_n then decreases with increasing spin S, but remains finite up to $S = \infty$.

In the Ising model, to the contrary, a reversal of the sign of $\Delta\chi_I$ is observed with increasing spin. $\Delta\chi_I < 0$ when $S = 0$, and then $|\Delta\chi_I|$ is much smaller than $|\Delta\chi|_H$. It turned out unexpectedly that $\Delta\chi_I > 0$ when $S \geq 1$. These results show that the influence of the fluctuations depends very strongly on the concrete form of the spin interaction. Thus, for example, during the course of the calculations it is seen that in the Heisenberg model it is precisely the x and y components of the spin operators which make the decisive contribution to A_n.

In order to explain the cause of this spin anomaly more lucidly, let us consider briefly the influence of the short-range magnetic order on the magnetization as a function of the spin for a crystalline ferromagnet. It is well known that T_c and the paramagnetic Curie temperature T_p come closer together with increasing spin. This can be interpreted also as meaning that when S increases the description of the interaction by means of an effective internal Weiss field becomes more and more realistic; in other words, the influence of magnetic short-range order on the thermodynamic quantities decreases.

This property is more strongly pronounced in the Ising model than in the Heisenberg model, i.e., $(T_p - T_c)_I$ is smaller than $(T_p - T_c)_H$ for all values of the spin.

Using the results of [9], where an increase of the Curie temperature and of the susceptibility, as a result of the fluctuation, was obtained in the Weiss molecular field approximation, we can understand the qualitative role played by the value of the spin.

The increase of $\Delta\chi$ is due to the increasing influence of the molecular field, by which the present interaction is approximated better the larger the spin S. In addition, at the same value of S, this approximation is much better for the Ising model than for the Heisenberg model.

This leads us to the conclusion that the influence of the fluctuations of the exchange integrals in amorphous ferromagnets is determined essentially by the role of the short-range magnetic order.

These fluctuations decrease the susceptibility and the Curie temperature only in the case when χ and T_c for the crystal decrease sufficiently strongly under the influence of the short-range magnetic order. The number of nearest neighbors Z, unlike S, plays a lesser role. For all the aforementioned A_n we found that $|A_n|$ and accordingly $|\Delta\chi|$ decrease with increasing Z. This is perfectly understandable, for at large values of Z the mean fluctuations decrease. It follows, in particular, that all $A_n = 0$ at $Z = \infty$. However, the sign of $\Delta\chi$ cannot reverse when Z changes. In addition to determining $\chi(T)$, the HTE makes it possible to determine also T_c at high temperatures, by extrapolation (see [7]).

It turns out that the spin anomaly of the susceptibility extends also to the Curie temperature T_c, i.e., for the Heisenberg model the extrapolated T_c decreases because of the fluctuations of the exchange integrals at all values

[1]) All the quantities in which no account is taken of the fluctuations are marked by the superscript "0."

of the spin S, whereas for the Ising model we have a decrease of the Curie temperature at $S = 1/2$, and an increase at $S \geq 1$.

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ANOMALOUS PLASMA RESISTANCE DUE TO INSTABILITY AT CYCLOTRON HARMONICS

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The appearance of a high anomalous plasma resistance in a large number of experiments (particularly in collisionless shock waves [1]) is attributed to the appearance of ion-acoustic instability [2]. The ion-acoustic instability can arise, however, only in the case of sufficiently strong anisothermy, $T_e \gg T_i$. Yet an anomalous resistance is observed also when this condition is not satisfied [1, 3].

Recently, in connection with the problem of anomalous resistance, the instability at electron cyclotron oscillations (Bernstein modes) has been under discussion [4 - 9]. The Bernstein modes are oscillations with a wave vector that is strictly or almost strictly perpendicular to the magnetic fields, and have frequencies on the order of $n\omega_{He}$. If current flows through the plasma, then the oscillation frequency turns out to be, owing to the Doppler effect, in the laboratory frame where the ions are at rest, $\omega' = n\omega_{He} - \vec{k}\cdot\vec{v}_d$, where $\vec{v}_d$ is the drift velocity. At sufficiently large k and v_d it is possible to decrease strongly the frequency in the ion reference frame, to make these oscillations interact with the ions at $\omega' \sim kv_T$. An effect such as wave instability with negative energy sets in. These oscillations have a rather large growth increment, $\gamma \sim \omega_{He}(v_d/v_{Te})$. Unlike in ion sound, the instability sets in also at $T_i \gtrsim T_e$.

The purpose of the present article is to derive an expression for the anomalous resistance that results from the buildup of Bernstein modes. The main question is the explanation of the nonlinear mechanism that leads to saturation of the oscillation growth. For ion-acoustic instability, such a mechanism would be induced scattering of waves by ions (nonlinear Landau damping by ions) [2]. For the Bernstein modes, the principal role is played by electronic nonlinearity. We use, just as in the theory of strong turbulence [10], the fact