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MAGNETIC FIELD DEPENDENCE OF STATIC CORRELATIONS AND SPIN DYNAMICS OF REENTRANT SPIN GLASSES STUDIED BY NEUTRON SCATTERING

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MAGNETIC FIELD DEPENDENCE OF STATIC CORRELATIONS AND SPIN DYNAMICS OF REENTRANT SPIN GLASSES STUDIED BY NEUTRON SCATTERING

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ABSTRACT :We report small angle (SANS) and inelastic neutron scattering in zero and applied field for a-FeMn, NiMn and AuFe at composition where both ferromagnetic and frustration characters occur. We discuss the field evolution of the transverse correlations which arise below T_c. A study of the field sensivity of the spin wave anomalies in a-FeMn is reported.

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INTRODUCTION

The term reentrant spin glass (RSG) has been attributed to a class of systems which show both ferromagnetic character and frustration effects. The a-c susceptibility χ_{ac} first exhibits a sharp increase at T_c ascribed to a ferromagnetic transition, then reaches a plateau value usually limited by demagnetizing effects [1]. It finally decreases at lower temperature below which spin glass like properties are observed. This behavior was ascribed to a transition from ferromagnetism to a spin glass state, hence the name of these systems. This situation occurs in many $A_x B_{1-x}$ disordered alloys with competing ferromagnetic and antiferromagnetic exchange interactions but dominant ferromagnetism. By varying the composition x, an evolution from the RSG behavior towards a true spin glass behavior, characterized by a cusp of χ_{ac}, is observed at a given composition x_c. The interest in these systems has been renewed by the development of theoretical models [2]. In the mean field theory for Heisenberg spins, two distinct transitions are predicted below T_c [3]. A colinear ferromagnetic state sets up at T_c. Spin transverse components freeze at a lower temperature. Finally, at a still lower temperature T_G, another transition, reminiscent of the de Almeida-Thouless one in true spin glass, occurs. In this model the long range ferromagnetic order persists at all temperature via the longitudinal spin component. The existence of a freezing process is also found by a local mean field approach using Monte Carlo simulations for XY spins on a square lattice [4]. In this latter model only particular spins are frozen. A decrease of the magnetization is predicted since the frozen spins tip progressively the non frustrated ones over. These two models provide two possible pictures of RSG. The first one emphasizes the possibility of cooperative effects while the second one considers mostly local effects. In spite of a great deal of experimental activity in the recent past, the situation in real systems is still far from being clear. We present and discuss here results obtained by neutron scattering techniques. We have studied three different systems, a-$Fe_{1-x}Mn_x$ with $x=0.22, 0.235, 0.247$ ($T_c=300, 250, 220$ K), $Ni_{1-x}Mn_x$ with $x=0.216, 0.22$ ($T_c=330, 250$ K), $Au_{0.81}Fe_{0.19}$ ($T_c=160$ K). The T_G values, determined from the inflexion point of χ_{ac}, lie between 10 K and 30 K. We first review small angle neutron scattering (SANS) studies in zero and applied field. For one sample we could compare the SANS data with Mössbauer experiments. In a second part we discuss the dynamical anomalies in zero and applied field.

STATIC CORRELATIONS

The RSG have been extensively studied by SANS [5-7] techniques but the physical pictures proposed have often appeared controversial. Here we want to emphasize that several q-scales can be defined in the SANS.

1. Zero field experiments

In a-$Fe_{1-x}Mn_x$ or $Au_{1-x}Fe_x$ for instance, for which the scattered intensity I(q) has been measured in a large q-range ($10^{-3} < q < 10^{-1}$ Å^{-1}), two distinct dependences with temperature are observed depending on the q-scale.

At very small q ($q < 10^{-2}$ Å^{-1}) no critical scattering peak is observed and the intensity exhibits thermal irreversibilities. At a given q the I(T) curve shows a broad maximum which goes to higher temperature as q decreases (fig. 1). The q-dependence at constant T can be analysed with a phenomenological law $A/(\kappa^2 + q^2)^\alpha$ [6]. Good fits are obtained for $T < 0.5\ T_c$ (fig. 1b) with α strongly decreasing with T at low temperature [8]. In absence of any precise model no physical meaning is attributed to the parameter κ^{-1}. This small q-scattering reveals the presence of large magnetic inhomogeneities which evolve continuously with temperature. More precise descriptions, assuming changes in a cluster distribution or fractal clusters, have been attempted in some cases [9].

By contrast, in the $10^{-2} < q < 10^{-1}$ Å^{-1} (inset fig. 1), an anomalous elastic scattering appears at a temperature well below T_c (90 K for instance in a-$Fe_{0.765}Mn_{0.235}$ where T_c=250 K). This scattering increases continuously down to low T. At low temperature it can be fitted by a Lorentzian squared law as outlined by many authors [6-9].

These two typical behaviours are observed clearly in weakly frustrated RSG like the samples discussed above. As the frustration increases the two behavior occur in closer q ranges and we expect that they overlap for $x \simeq x_c$ where a complex temperature behavior is observed [6]. This explains partly the difficulties to define any typical behavior from SANS in zero field. Depending on the concentration and the q range of the observation, various authors have emphasized either a continuous change of the magnetic state with temperature [5] or the onset of new correlations at a characteristic temperature smaller than T_c [10].Controversial interpretations were proposed involving either a break up of the ferromagnetic order or its persistence down to T = 0. The first hypothesis was based on the observation of a Lorentzian squared scattering which could be understood invoking random field effects [6]. SANS studied alone cannot settle this debate. An interesting clarification came recently with the direct observation by electron microscopy [11], in zero field, of micron size ferromagnetic domains in several weakly frustrated RSG. Very interestingly the domain size does not evolve with temperature. This result corroborates polarisation analysis measurements which have shown a depolarisation of the transmitted neutron beam at all temperature below T_c [12]. We must conclude that in these systems no collapse of the ferromagnetism occurs and that the large inhomogeneities detected in SANS are imbedded in still larger ferromagnetic domains. A different picture is expected for $x \simeq x_c$ as seen in a-FeNi [Erwin, private communication] and in FeAl [13].

2. Field effects

In RSG the magnetisation curves show, after a steep increase in low field, a marked knee between 0.8 and 1.5 kOe [14,15]. This behavior, not observed in spin glasses, rather looks like that of usual ferromagnets where the sharp increase of M corresponds to the removal of Bloch walls. However in RSG when H increases further, M(H) shows a residual slope, even when T goes to zero, and complete saturation is only achieved at very high field (about 300 kOe)[16].

When $q < 10^{-2}$ Å^{-1}, the magnetic scattering is suppressed by a small field of about 100 Oe. For $10^{-2} < q < 10^{-1}$ Å^{-1} the anomalous elastic scattering strongly decreases with the field but remains visible in all the studied field range (0-10 kOe) and seems to persist in higher fields. In this q range, like the zero field intensity, the intensity measured at constant field decreases when T increases from 10 K. Within the experimental accuracy it disappears at the same temperature in zero field as in applied field (see fig. 3). Moreover very peculiar features are observed for $H > 1.5$ kOe, namely a maximum of the I(q) curve for $q = q_{max}$, which has been reported in many systems [10,15]. This maximum is observed for all the direction (q,H) but its intensity is enhanced for $q /\!/ H$ $[I_{q/\!/H}/I_{q\perp H} \sim 1.7]$ which shows that the involved spin components are mainly transverse, i.e. perpendicular to the field [10]. At low temperature, q_{max} varies approximately like $\sqrt{H/D}$ where D is the stiffness constant [15].

Since it is observed near $q=0$, this "structure" corresponds to ferromagnetic correlations between the transverse components. The precise origin of the maximum is not straightforward. We have suggested previously to relate q_{max} to a typical size of some characteristic defects, in which the transverse spins would perform a 2π rotation. Although expected in 2d XY spin glasses [18] such defects seem hard to define in 3 dimensions. Another posssibility is to relate the q_{max} value to some cut off length. When aligning the spins the applied field would suppress only the correlations with length higher than a cut off value, determined by the competition between Zeeman and exchange energies, yielding the observed $\sqrt{H/D}$ law. When increasing the temperature from 10 K at constant field, we also observe a small variation of q_{max}, but the main effect remains the strong decrease of the intensity (fig. 3) which can only be explained by a decrease of the transverse spin length.

In conclusion the onset of elastic scattering below T_c is associated to a freezing of transverse spin components which occurs at a temperature roughly independent on the field in the 0-10 kOe range.

3. Comparison between Mössbauer and SANS experiments

Unlike the neutron scattering experiments, sensitive to correlations between spins, the Mössbauer technique is a local probe. Mössbauer studies have been extensively performed in RSG. A remarkable anomaly is found in the temperature dependence of the mean hyperfine field $\bar{h}$ [19] which is usually considered to reflect the length of the mean thermal value of the spin. We report here Mössbauer experiments performed on the a-$Fe_{0.765}Mn_{0.235}$ sample previously used in neutron experiments. As usually found in other RSG, the distribution of hyperfine fields, P(h) exhibits two broad maxima (inset fig. 4). P(h) varies continuously with temperature so that $\bar{h}$ is not sufficient to characterize the system. When analysing P(h) as the sum of two field distributions we can define two mean hyperfine fields h_1

and h_2. Both h_1 and h_2, as well as $\bar{h}$, exhibit a step-like increase around 45 K (fig. 4) which shows that the anomaly on $\bar{h}$ is not an artefact. This abnormal increase has been usually related to the onset of frozen transverse spins. However, it appears here well below the onset of transverse correlations (90 K) determined by SANS on the same sample. The difference between the two temperatures seems to large to be explained only by the different time windows of experiments. As already noticed, at 90 K the $\bar{h}(T)$ curve departs from the magnetization M(T) curve measured at technical saturation ($0.8 < H < 3.4$ kOe), which could be related to the occurrence of the frozen transverse spins [12]. Thus the comparison between the Mossbauer and the SANS data suggest the existence of two characteristic temperatures below T_c . Since the first one at 90 K has been attributed to the freezing of transverse spins, one can wonder about the significance of the second one. This point will be discussed below when considering the spin waves behaviour.

To be fully consistent, we should also discuss results obtained by Mössbauer experiments in applied field, where the onset of non colinearity between the spins is revealed by additional lines in the hyperfine spectrum. From the above discussion, we expect that this onset occurs above the $\bar{h}$ anomaly. In AuFe, Murani [20] pointed out that they could be present from T_c . However for FeCr [21], the different characteristic temperatures nearly coincide. Clearly, the difficulty of analysis prevent to draw definite conclusions from this kind of experiments.

DYNAMICAL ANOMALIES

Propagating spin waves give rise in a constant q scan to two peaks corresponding to the absorption or the creation of a spin wave. The scattered intensity can be analysed in the usual form

$I(q,\omega) \propto k_B T \chi^t(q) F(q,\omega)$ in the $k_B T \gg \hbar\omega$ limit. $\chi^t(q)$ is the static transverse susceptibility. In a standard ferromagnet $\chi^t(q) \propto q^{-2}$ is temperature and energy independent and therefore obtained from the energy integration of $I(q,\omega)$. The spectral weight function $F(q,\omega)$ describes the dynamics of the spin system. For a ferromagnet it contains the dispersion law of the spin waves ($\omega(q) = \Delta + Dq^2$, where D is the stiffness constant and Δ an eventual energy gap) and their damping $\Gamma(q)$. A theoretical formulation of $F(q,\omega)$ implies the knowledge of the mechanism giving rise to the damping. In spite of some quantitative differences, related to the choice of the spectral function, damped harmonic oscillator (DHO) or double Lorentzian (DL), various authors agree with the spin wave behavior in RSG except at very low temperature. When T decreases below T_c, D displays the usual increase but then goes through a maximum and starts to decrease. Concomitantly Γ and χ^t increase anomalously. The final evolution in the low temperature range appears still now rather unclear. In most cases there is a considerable difficulty to get unambigous results because of the simultaneous observation of a huge elastic scattering (see sect.I) and of heavily damped spin waves with low energy. This technical difficulty has been illustrated in the study of FeCr. The first neutron measurements on this alloy (T_c=178 K), which were the first ones of this kind in RSG [22], lead to the conclusion that propagative spin waves did not longer exist below 25 K suggesting the break up of long range ferromagnetic order. We have shown on the same sample [23], by improving the resolution, that the spin waves can be clearly observed down to 10 K where experimental limitations prevent unambiguous observations. Other studies on a-FeMn, a-FeCr and a-FeNiZr [24] indicated a decrease of D with an apparent levelling off at low temperature where the damping is large. However in NiMn and a-$Fe_{0.765}Mn_{0.235}$ [25], the spin waves could be observed down to the lowest temperature. Very surprisingly the stiffness constant goes through a minimum before increasing again in the lowest temperature range. Simultaneously the damping exhibits a maximum and then decreases again. It must be noticed that these features appear on raw data, regardless of the model used for the data analysis. This observation was easier in NiMn because of the higher value of D. From a study in $Fe_{1-x}Mn_x$ at zero field, we show that this low temperature behavior can only be observed in an extremely reduced concentration range. For x = 0.22 we observe only a levelling off of D below 30K while for x = 0.247(T_c = 220 K) , D is so small that spin waves cannot be observed at all temperature [16].

We want to emphasize here the interest of applying a magnetic field. In usual ferromagnets the field induces an energy gap ($g\mu_B H$) and modifies the scattered intensity by changing the domain distribution and the static susceptibility (no more divergence at q=0). In RSG another important effect is to reduce considerably the elastic scattering (see sect.I). The overall result, from an experimental point of view, is to provide quite clear data. At a given temperature the field dependence of the spin wave parameters Γ,D,χ^t(q)provides a check of the sensitivity of the system to the applied field. On figure 5, we have compared Δ, Γ and D obtained in zero and applied field on a-$Fe_{0.753}Mn_{0.247}$. Around T_c the field strongly affects the dynamical properties. Similarly to the FeCr case [22] spin waves are observed 10 degrees above T_c in a field as low as 3.4 kOe. Thus long distance ferromagnetic correlations seem to be restored above T_c by applying a small field. This could be related to the persistence, in zero field, of correlated spins above T_c. On the contrary, below 150 K, the dynamical parameters are rather unsensitive to the applied field. Only a slight decrease of Γ is detected as the field increases. Like in zero field experiment we observe an increase of D and a decrease of Γ at low temperature. Since they are observed on the raw data [23], these effects cannot be an artefact of the analysis. Concomitantly, we observe an abnormal increase of the gap above its expected value ($g\mu_B H$), indicating the increase of some intrinsic anisotropy in the system.

In conclusion of this part, the study of the dynamics reveals two changes at different temperatures. The decrease of the stiffness constant accompanied by the increase of the damping and of the transverse susceptibility, occurs significantly above the onset of transverse spin correlations (elastic scattering). This suggests to consider this dynamical anomaly as a precursor effect. Very qualitatively one can understand that the onset of transverse components, introducing some disorder and non colinearity produces a decrease of the stiffness constant. The increase of D at lower temperature is more intricate. In the study of the a-FeMn system we noticed that the temperature of the D minimum, although not sharply defined, increases with frustration. Thus the increase of D cannot be interpreted as resulting from an enhancement of the ferromagnetic character. Very interestingly in a-$Fe_{0.765}Mn_{0.235}$ D reaches its minimum at about the same temperature as the hyperfine field shows its step like behavior (45K). We have already noticed the stricking similarities between the low temperature magnon anomalies observed in RSG and the phonon anomalies observed in molecular glasses [26]. In the latter case a theory [27] has been developed which relates the increase of the elastic constants and the decrease of the damping to some blocking transition of the molecules with orientational disorder. Although an analogy with a magnetic problem is not straightforward, the present dynamical anomalies could reveal a similar blocking of the spins resulting in an abnormal increase of the total spin length, thus of the hyperfine field and an increase of the stiffness constant. Preliminary experiments in applied field show this also exist in AuFe and therefore is likely general in RSG.

CONCLUSION

The overall results show in the weakly frustrated RSG studied here. the existence of two scales. At low q-values, we observe large inhomogeneities and no characteristic temperature can be defined below T_c. We suggest to relate this continuous temperature evolution and the observed irreversibilities to the increase of coercivity, which also yields to the decrease of the susceptibility and of the low field magnetization [1]. The observed inhomogeneities coexist with micron size ferromagnetic domains as shown by electron microscopy and neutron depolarisation. In AuFe, the continuous increase of the magnetic Bragg intensity shows that there is no breakdown of ferromagnetism [5]. The situation could be different near $x \simeq x_c$ where T_c is low, in EuSrS [28] and in FeAl [13] for which the origin of the difference is obscure.

At a larger q-scale ($q \simeq 10^{-2}$ Å^{-1}), the possibility of defining some characteristic temperatures can be seriously discussed. We observe the critical scattering around T_c, then below a lower temperature, an anomalous elastic intensity related to the freezing of transverse spin components. Although cluster models [5,6] have been invoked to explain this latter feature, our neutron experiments in applied field show that the elastic SANS depends on the stiffness constant, characteristic of the mean medium [15]. At this q-scale, neutron observations could then reflect mean field predictions. However, as argued previously [29], since the frozen spins are ferromagnetically correlated, there is no symetry change in zero field and therefore no real transition. Moreover, SANS measurements cannot prove that all the spins are colinear above this freezing temperature. In NiMn neutron diffuse scattering shows local order between transverse spin well above this temperature [30], which shows again the limit of the mean field theory.

When the temperature decreases further, we observe in NiMn and a-FeMn in the same q-range, a very peculiar spin wave behavior, namely a second extremum in the damping and the stiffness constant variations below the first one usually observed. We have suggested to relate it to the anomaly of the mean hyperfine field which occurs roughly at the same temperature. Interestingly in AuFe [5], below a first anomaly ascribed to the freezing process, the Bragg peak intensity shows a second one which has been related to the hyperfine field anomaly. This second anomaly, which affects the spin dynamics much more than the spin correlations, could correspond to a cooperative effect like a complete blocking of the spins. To have a fully coherent picture, it would be important to relate these neutron observations to the ESR anomalies and to low frequency measurements like out of phase susceptibility. Clearly, a deeper understanding of this second anomaly needs further theoretical and experimental work.

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REFERENCES

[1] COLES, B.R., SARKISSIAN, B.V.B., TAYLOR, R.H, Philos. Mag. B37 (1978) 489.

[2] SHERRINGTON, D., KIRKPATRICK, S., Phys. Rev. Lett. 35 (1975) 1792.

[3] GABAY, M., TOULOUSE, G., Phys. Rev. Lett. 47 (1981) 201.

[4] SASLOW, W.M., PARKER, G., Phys. Rev. Lett. 56 (1987) 1074.

[5] MURANI A.P. Solid State Comm. 34 (1980) 705.

[6] AEPPLI, G., SHAPIRO, S.M., BIRGENEAU, R.J., CHEN, H.S., Phys. Rev. B28 (1983) 5160.

[7] BURKE, S.K., RAINFORD, B.D., J. Phys. F 13 (1983) 441. BOUMAZOUZA, D., TETE, C., DURAND, J., MANGIN, P., SOUBEYROUX, J.L., J. Mag. Mag. Mat. 54-57 (1986) 95.

[8] MIREBEAU, I., LEQUIEN, S., HENNION, M., HIPPERT, F., MURANI, A.P., Procceedings of the International Conference on Neutron Scattering, Grenoble July 12-15, 1988.

[9] SALAMON, M.B., MURANI, A.P., THOLENCE, J.L., WALKER, J.L., Phys. Rev. B33 (1986) 7837.

[10] HENNION, M., MIREBEAU, I., HENNION, B., LEQUIEN, S., HIPPERT, F., Europhys. Lett. 2 (1986) 393 ; LEQUIEN, S., MIREBEAU, I., HENNION, M., HENNION, B., MURANI, A.P., Phys. Rev. B35 (1987) 7279.

[11] SENOUSSI, S., HADJOUDJ, S., JOURET, P., BILOTTE, J., FOURMEAUX, R., J. Appl. Phys. 63 (1988) 4086.

[12] MIREBEAU, I., JEHANNO, G., CAMPBELL, I.A., HIPPERT, F., HENNION, B., HENNION, M., J. Mag. Mag. Mat. 54-57 (1986) 99.

[13] MITSUDA, S., ENDOH, Y., KENS Report VI, 1985-1986, p. 178.

[14] ABDUL-RAZZAQ, W., KOUVEL, J.S., J. Appl. Phys. 55 (1984) 1623.

[15] HENNION, M., HENNION, B., MIREBEAU, I., LEQUIEN, S., HIPPERT, F., J. Appl. Phys. 63 (1988) 4071.

[16] RAKOTO, H., OUSSET, J.C., SENOUSSI, S., CAMPBELL, I.A., J. Mag. Mag. Mat. 46 (1984) 212

[17] BONI, P., SHAPIRO, S.M., MOTOYA, K., Solid State Comm. 60 (1986) 881

[18] KAWAMURA, H., TANEMURA, M., J. Phys. Soc. Japan 55 (1986) 1802.

[19] LAUER, J., KEUNE, W., Phys. Rev. Lett. 48 (1982) 1850; VARRET, F., HAMZIC, A., CAMPBELL, I.A., Phys. Rev. B26 (1982) 5195.

[20] MURANI, A.P., to be published in Mat. Science Forum Trans. Tech., Publications Neutron Scattering Symposium, Sydney (1987).

[21] DUBIEL, S.M., SAUER, Ch., ZINN, W., Phys. Rev. B31 (1985) 1643.

[22] SHAPIRO, S.M., FINCHER, C.R., PALUMBO, A.C., PARKS, R.D., Phys. Rev. B24 (1981) 6661.

[23] LEQUIEN, S., HENNION, B., SHAPIRO, S.M., to appear in Phys. Rev. B 38 (1988) volume 3.

[24] AEPPLI, G., SHAPIRO, S.M., BIRGENEAU, R.J., CHEN, H.S., Phys. Rev. B29 (1984) 2589; ERWIN, R.W., LYNN, J.W, RHYNE, J.J., CHEN, H.S.,J. Appl. Phys. 57 (1985) 3473; FERNANDEZ-BACA, J.A.,LYNN J.W., RHYNE, J.J., FISH, G.E., J. Appl. Phys. 63 (1988) 3749.

[25] HENNION, B., HENNION, M., HIPPERT, F., MURANI, A.P., J. Phys. F 14 (1984) 489; HENNION, B., HENNION, M., MIREBEAU, I., HIPPERT, F., Physica 136B (1986) 49.

[26] ROWE, M., RUSH, J.J., CHESSER, N.J., HINKS, D.L., SUSSMAN, S., J. Chem. Phys. 68 (1978) 4320.

[27] MICHEL, K.H., Phys. Rev. B35 (1987) 1414.

[28] MALETTA, H., AEPPLI, G., SHAPIRO, S.M., Phys. Rev. Lett. 48 (1982) 1490.

[29] SASLOW, W.M., PARKER, G., preprint.

[30] CABLE, J.W., NICKLOW, R.M., TSUNODA, Y., Phys. Rev. B36 (1987) 5311.

FIGURE CAPTIONS

Fig. 1. SANS intensity I(q) versus T in the 10^{-3} Å^{-1} range. Inset: plots at higher q showing critical scattering and an anomalous increase well below T_c.

Fig. 2. Plots of $I^{-1/\alpha}$ versus q^2 showing the decrease of α at low T.

Fig. 3. Raw intensities I(q) at 4.2 kOe and at several temperatures: + 10 K; ○ 19 K; △ 40 K; × 60 K; □ 80 K; • 120 K; ▽ 200 K. The nuclear background is located at about 90 K since no evolution of I(q) with T is observed between 90 K and the critical region. Inset: $I_q(T)$ in zero field. Unlike the data of fig. 1, intensities are elastic i.e. obtained with energy analysis.

Fig. 4. Mean hyperfine fields versus T determined from the hyperfine field distribution P(h) (see text). $\bar{h}(T)$ has been scaled with the magnetization m(T) measured at 0.875 kOe.

Fig. 5a and 5b. Dynamical parameters Δ, D, C versus T in zero and 3.4 kOe obtained with DHO and DL analysis. C is related to the damping Γ using a $\Gamma = Cq^2$ law. Details will be published elsewhere.

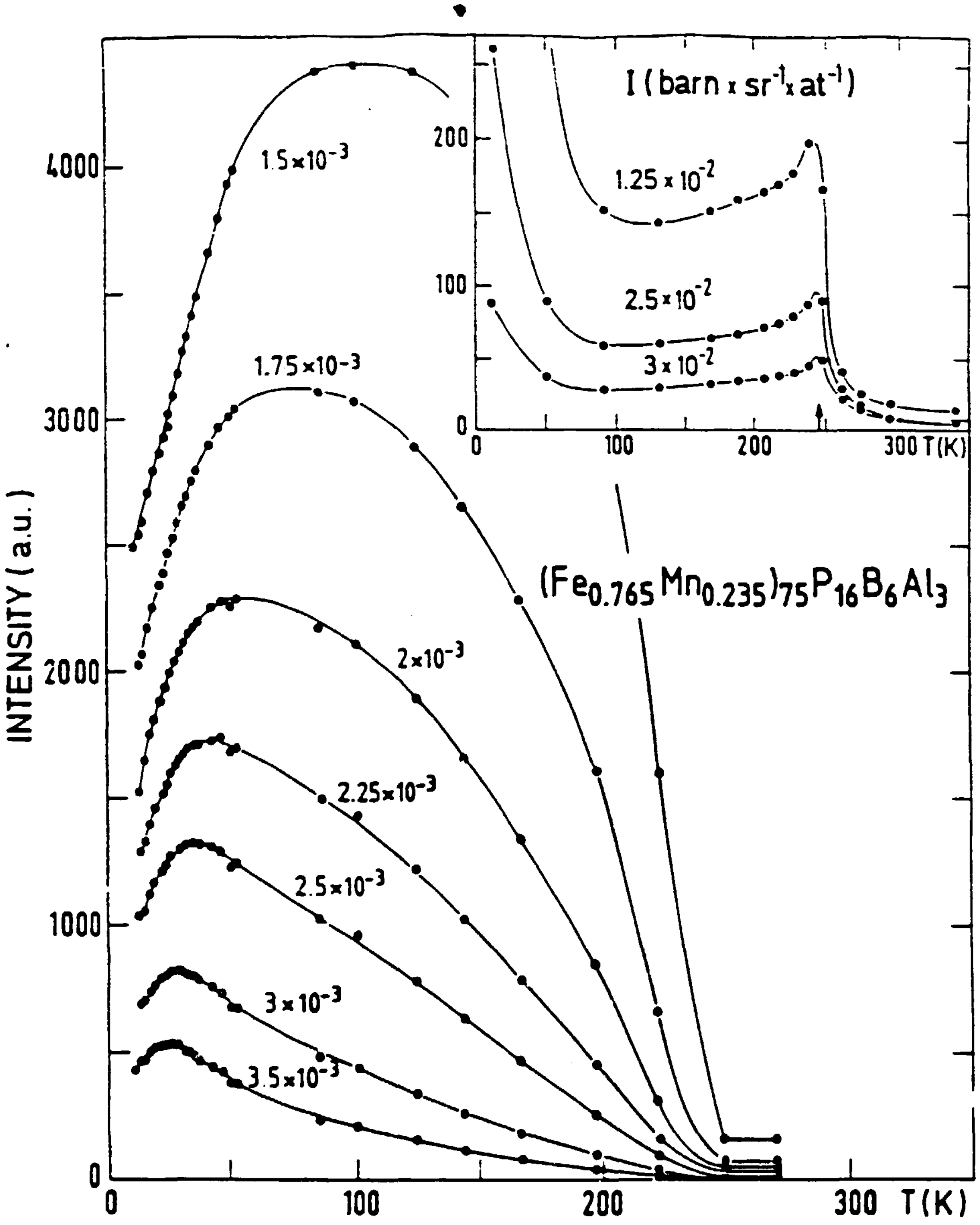

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fig. 1

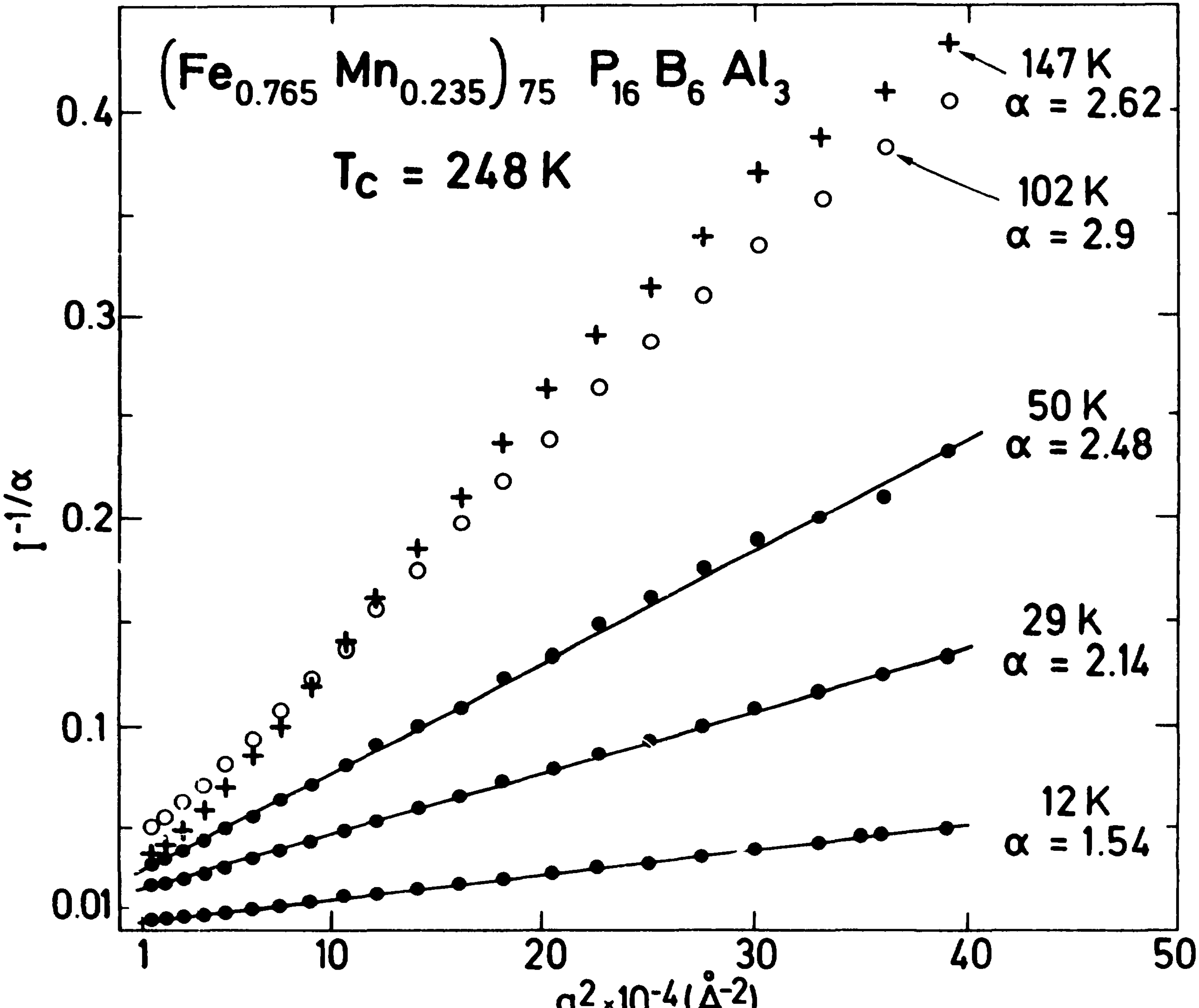

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fig 2

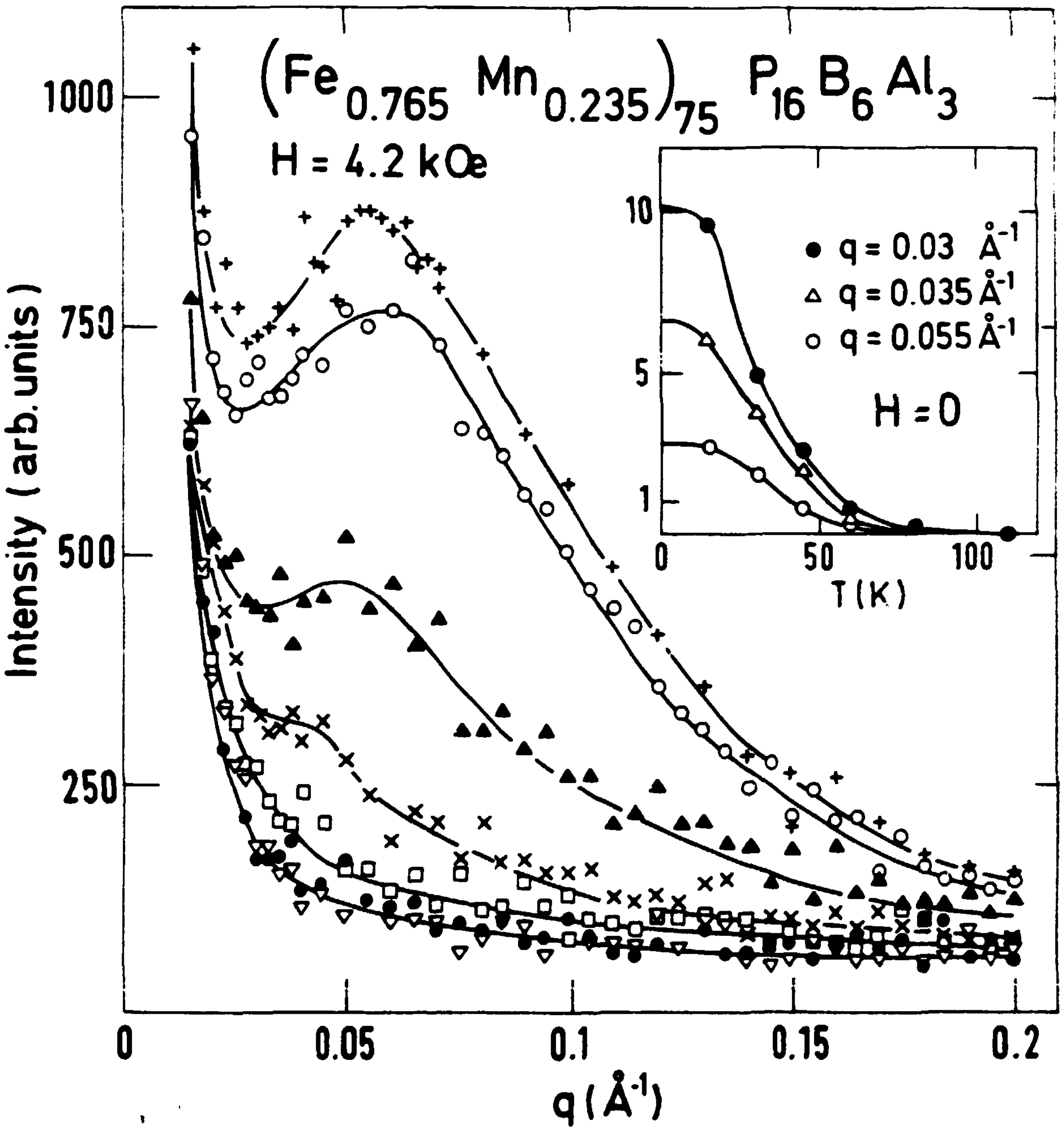

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fig. 3

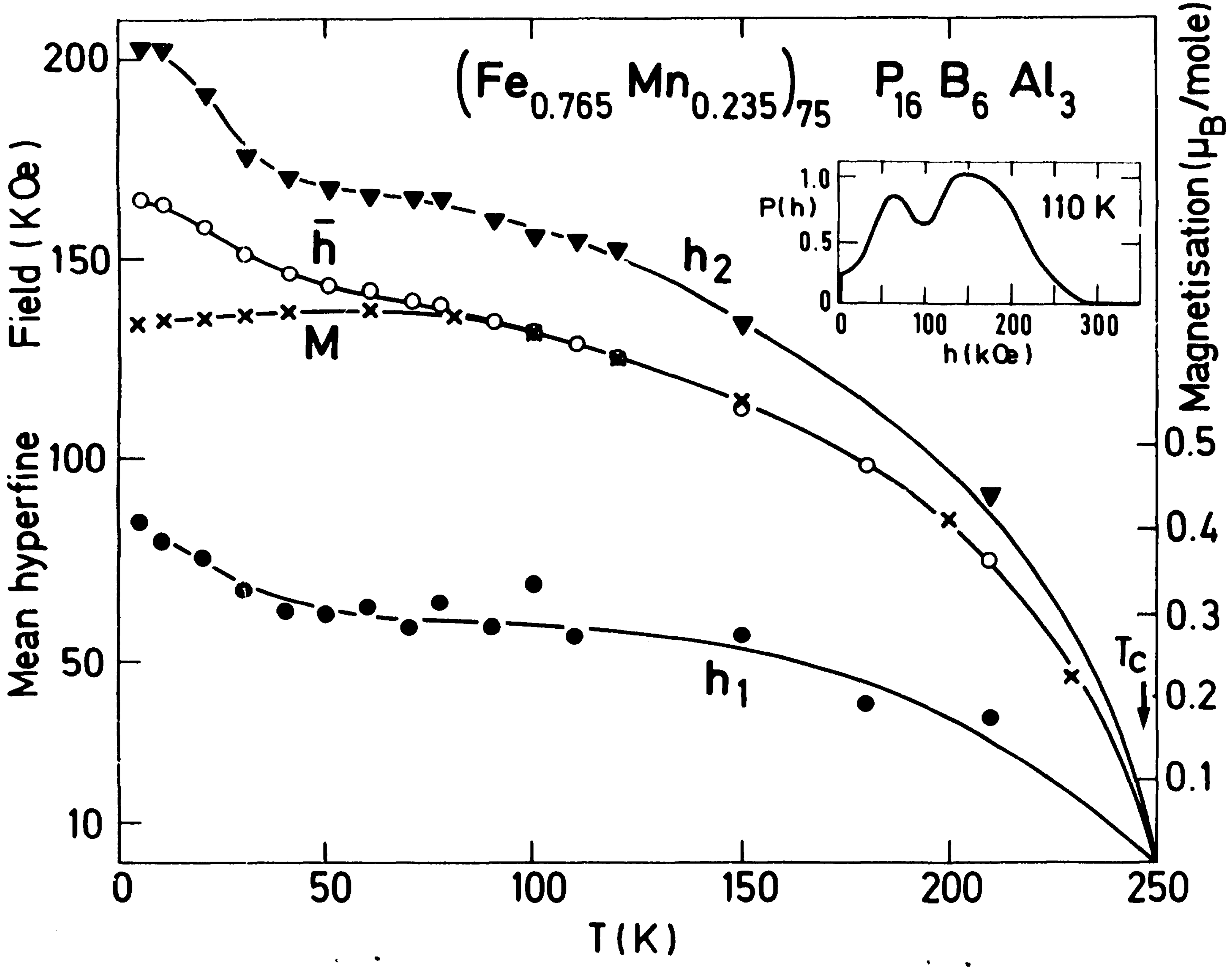

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fig 4

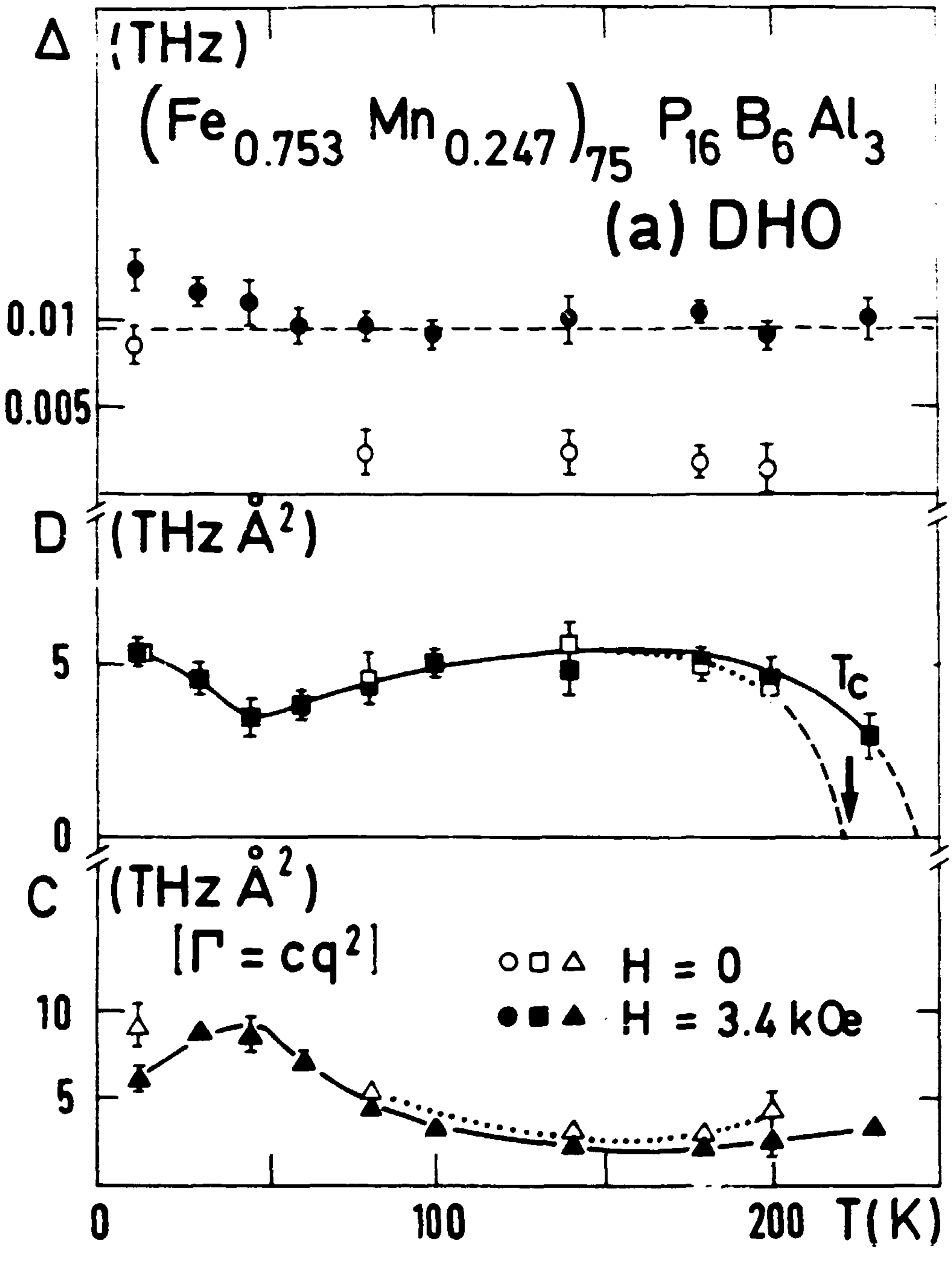

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fig. 5a)

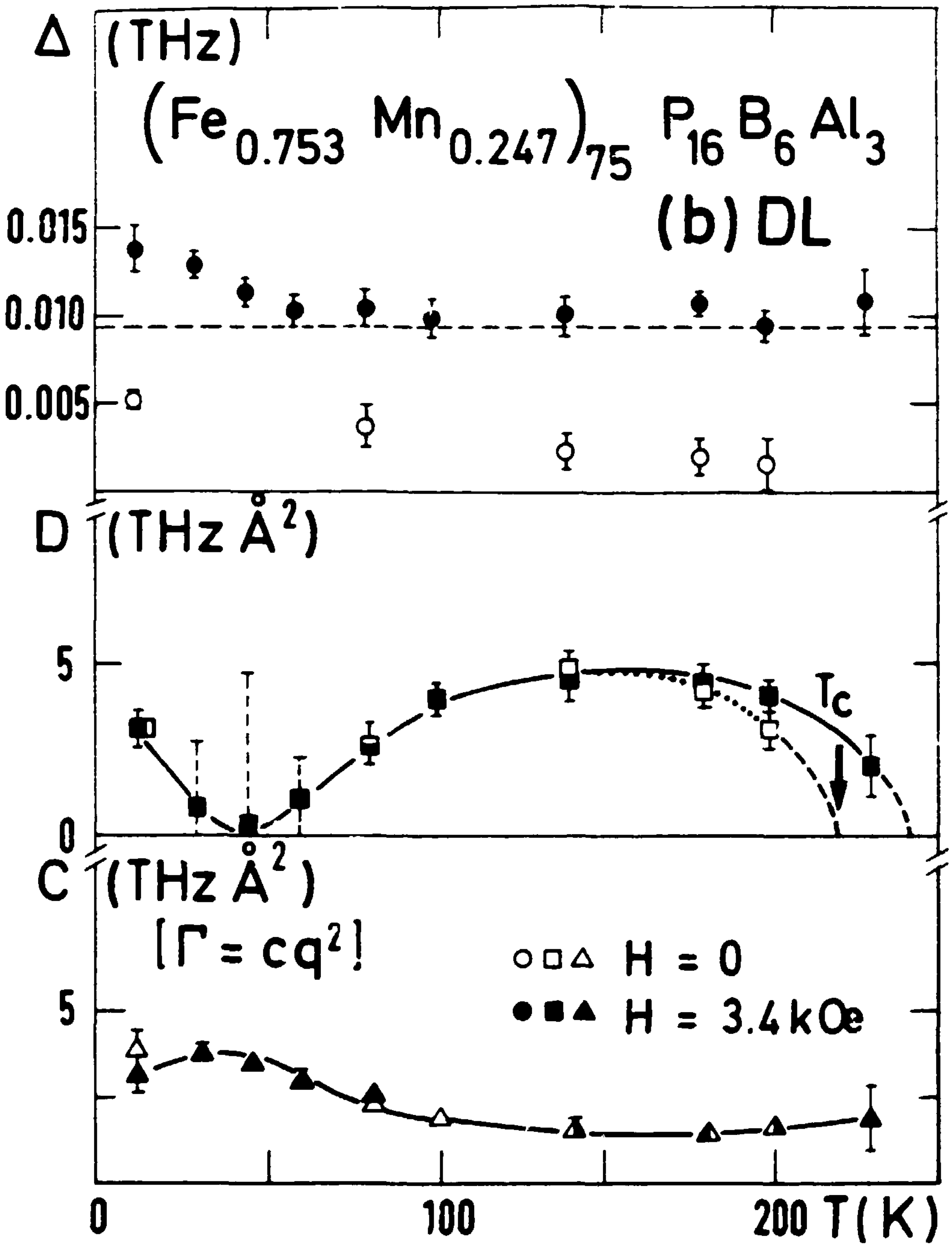

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fig. 5 b).