Hidden quantum phase transition in $Mn_{1-x}Fe_xSi$

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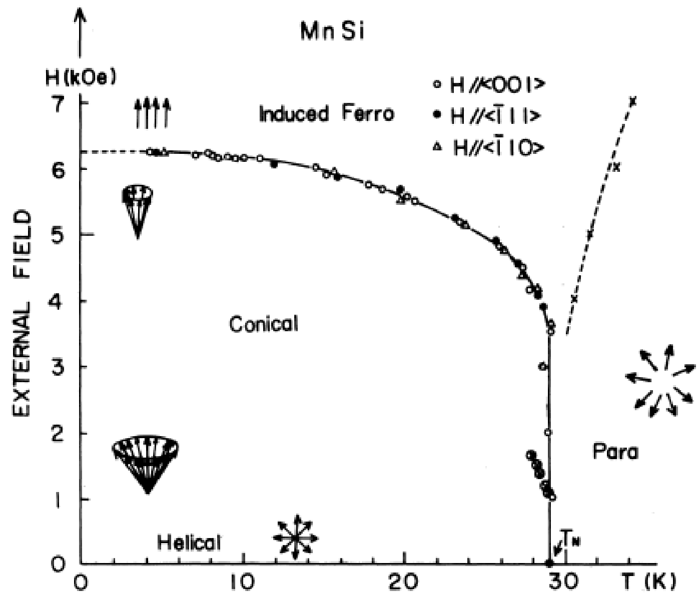
3) (x-T) phase diagram in $Mn_{1-y}Fe_ySi$

4) Hidden quantum phase transition in $Mn_{1-x}Fe_xSi$

5) The driving force of QPT in $Mn_{1-y}Fe_ySi$

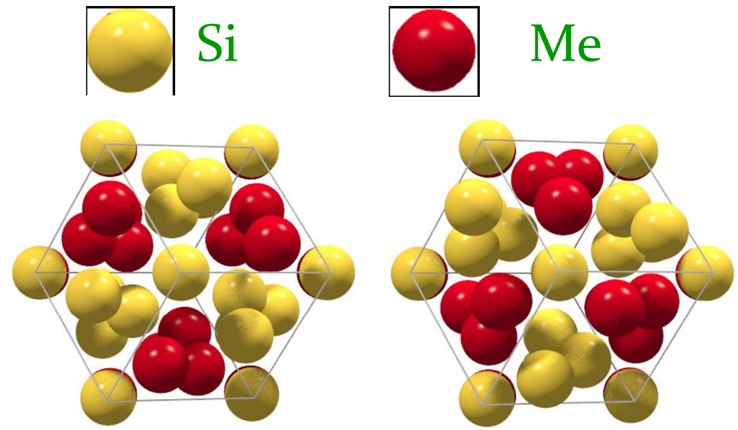
Magnetic order in MnSi



[1] Y. Ishikawa, G. Shirane, J.A. Tarvin, M. Kohgi, Phys.Rev.B **16** (1977) 4956.

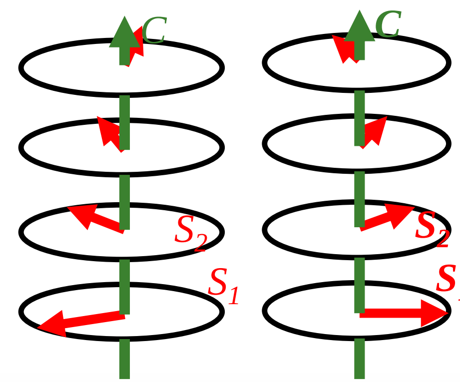
B20-type cubic structure
a = 4.55 Å

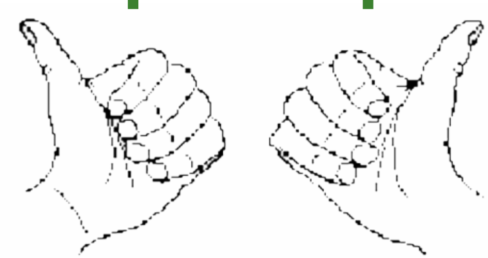
Space group $P2_13$



Left-handed helix **Right-handed helix**

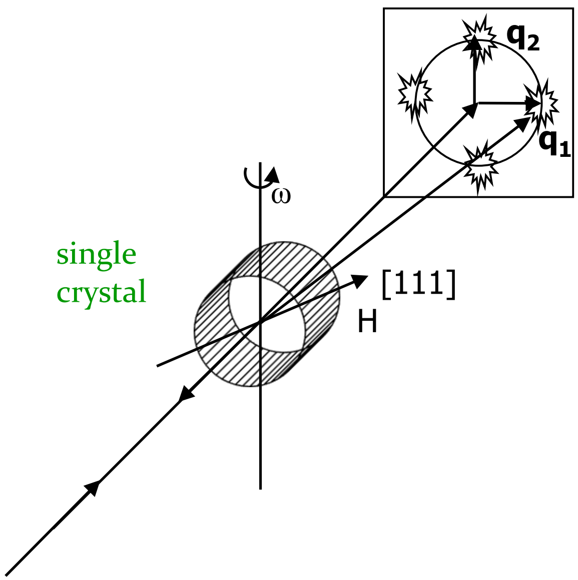
Spin spiral with period 18 nm and
μ_S (Me) = 0.40 μ_B





The thermal phase transition in MnSi

Small angle neutron diffraction experiment on MnSi single crystal

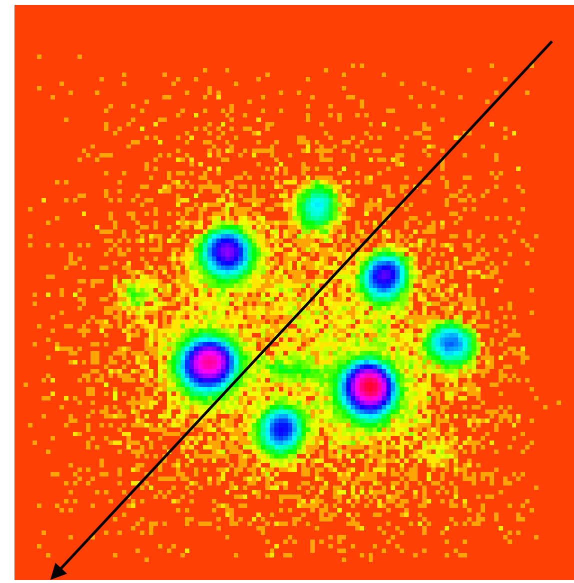


PHYSICAL REVIEW B **72**, 134420 (2005)

Critical fluctuations in MnSi near T_C: A polarized neutron scattering study

S. V. Grigoriev,[1,*] S. V. Maleyev,[1,†] A. I. Okorokov,[1] Yu. O. Chetverikov,[1] R. Georgii,[2,‡] P. Böni,[2] D. Lamago,[2] H. Eckerlebe,[3] and K. Pranzas[3]

T =10 K

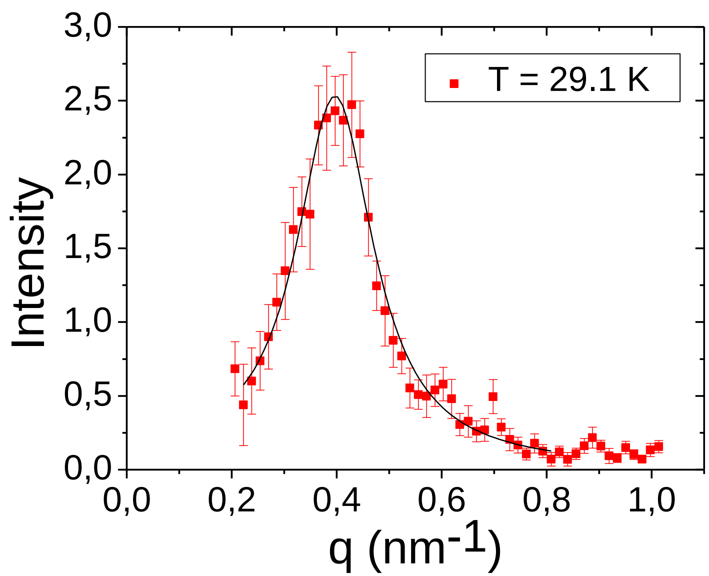


Screen shot of the neutron diffraction picture from MnSi

Data analysis: q-dependence

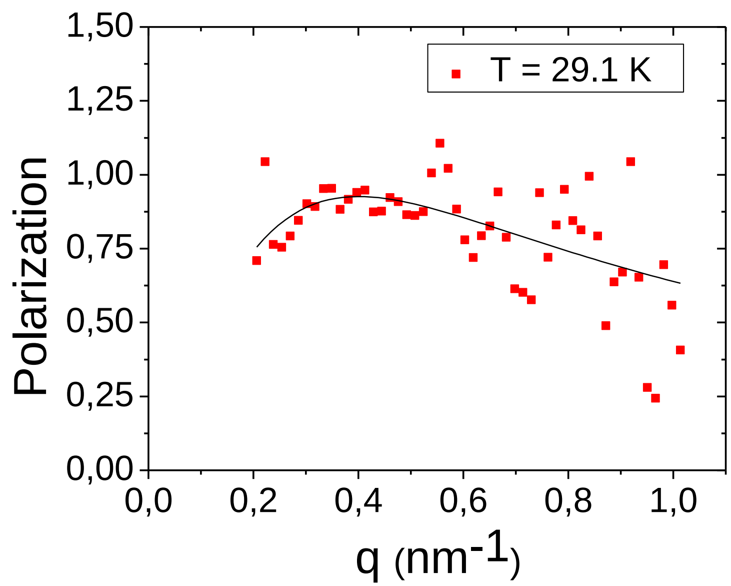
$$\frac{d\sigma}{d\Omega} = \frac{[rF(\mathbf{q})]^2 T}{[B(q+k)^2+\kappa^2]} \frac{k^2+q^2+\kappa^2-2k\mathbf{q}\mathbf{P}_0}{[(q-k)^2+\kappa^2+(|U|k^2/2)(\hat{q}^4-1/3)]}$$

$$P_s = \frac{\sigma(\mathbf{P}_0)-\sigma(-\mathbf{P}_0)}{\sigma(\mathbf{P}_0)+\sigma(-\mathbf{P}_0)} = -\frac{2kqP_0\cos\varphi}{q^2+k^2+\kappa^2}$$



Intensity of the scattering at **q** || **P**$_o$

I(q) = (I(q,P$_o$) + I(q,-P$_o$))



Polarization of the scattering at **q** || **P**$_o$ at T = T$_C$ + 0.3 K.

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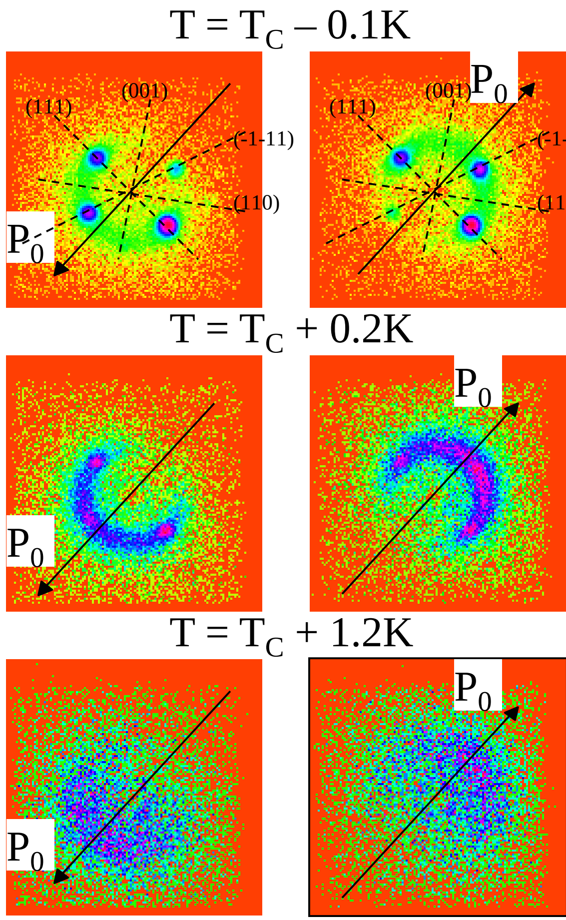
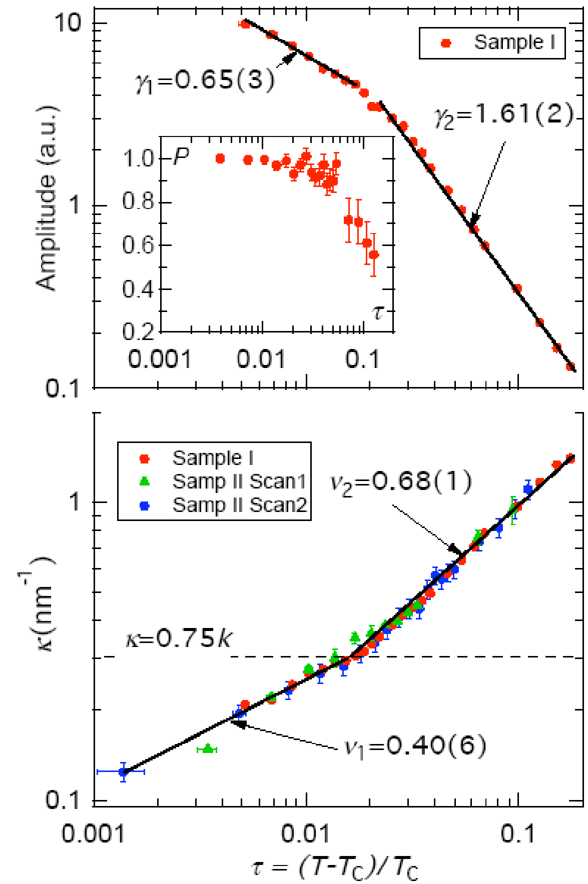
Data analysis: temperature dependence

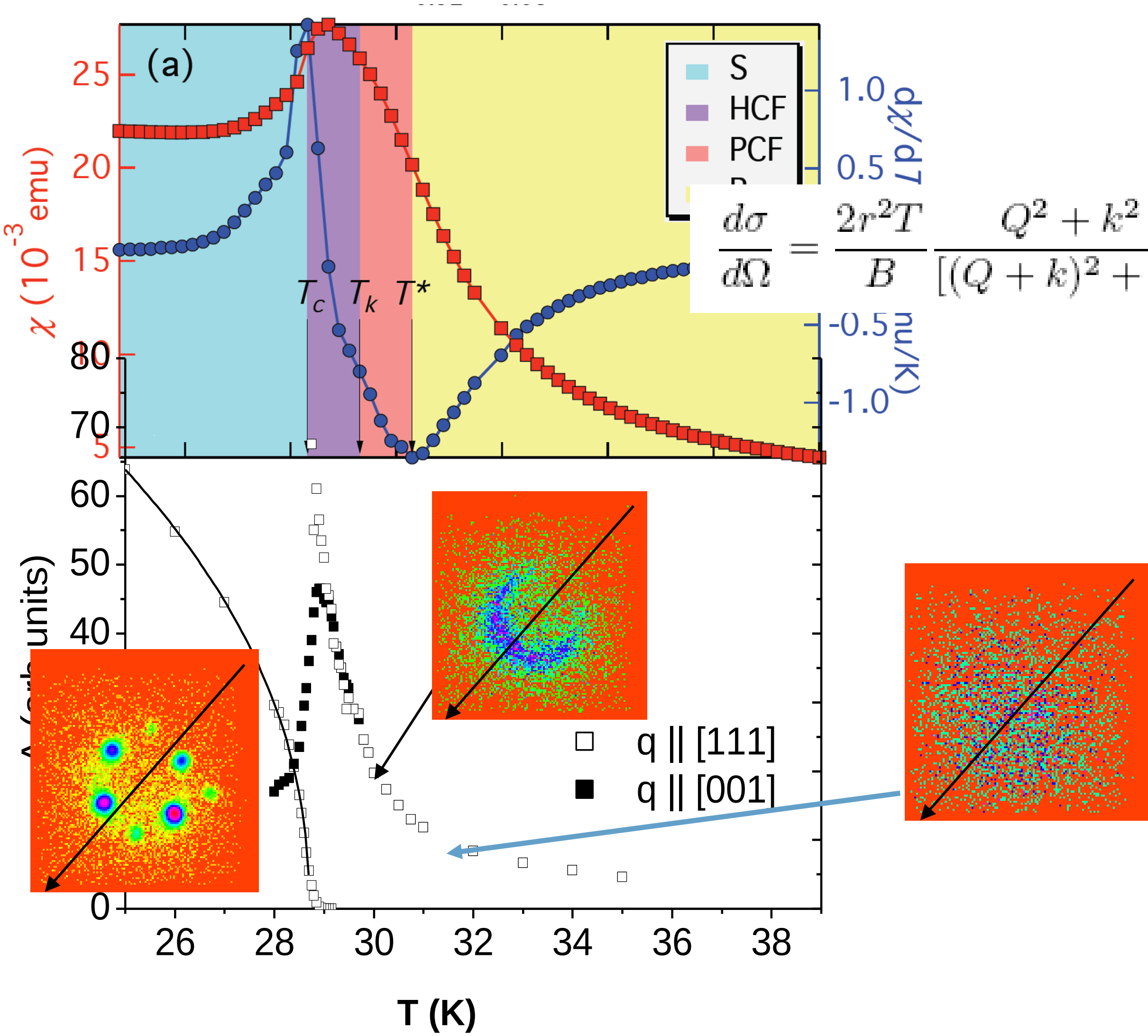




Polarized SANS maps

τ - dependence of (a) amplitude of scattering and (b) inverse correlation length.

Thermal phase transition in MnSi



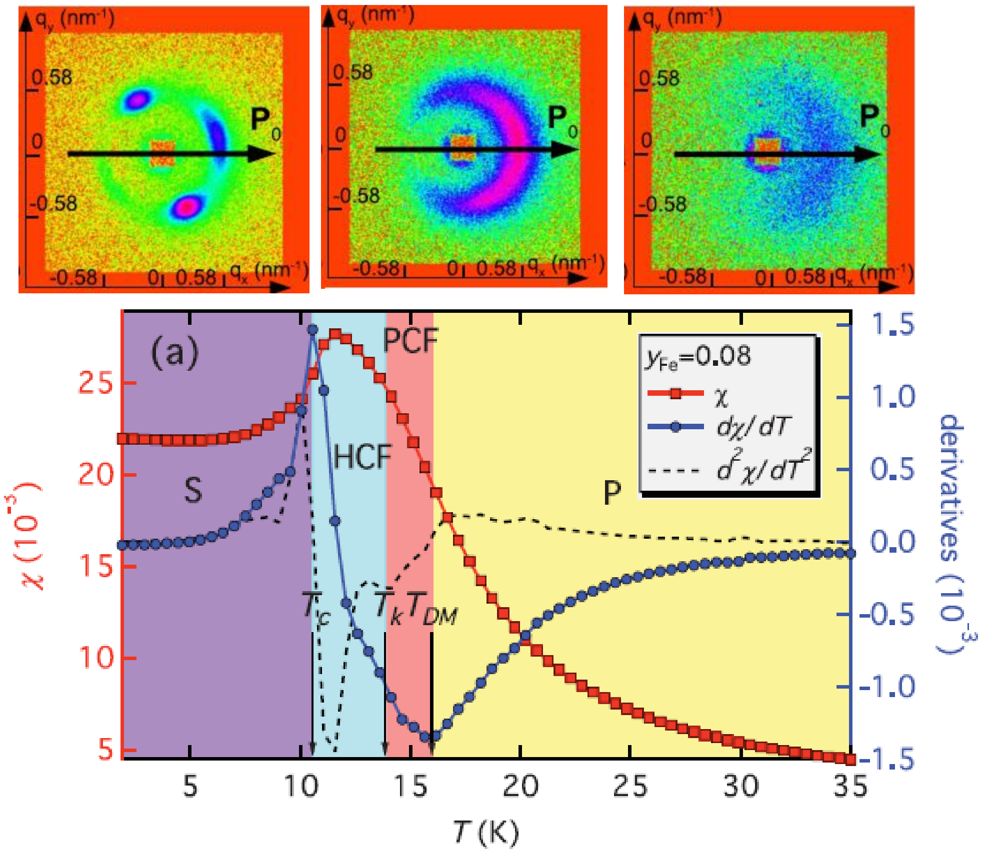
$$\frac{d\sigma}{d\Omega} = \frac{2r^2T}{B}\frac{Q^2 + k^2 + \kappa_1^2 + 2k(D/|D|)(\mathbf{Q}\cdot\mathbf{P}_0)}{[(Q+k)^2 + \kappa_1^2][(Q-k)^2 + \kappa_1^2] + k^2\kappa_A^2(\mathbf{Q})}$$

Thermal phase transition in $Mn_{1-y}Fe_ySi$

Long-range magnetic order (Chiral solid)

Short-range magnetic order (Chiral liquid)

Paramagnet (Chiral gas)



Correlation between magnetic susceptibility and polarized neutron scattering data is established in $Mn_{1-x}Fe_xSi$.

The extrema of the $\partial\chi/\partial T$ derivative may be used for identification of the magnetic phases with long-range and short-range magnetic order.

PHYSICAL REVIEW B **83**, 224411 (2011)

Chiral criticality in the doped helimagnets $Mn_{1-y}Fe_ySi$

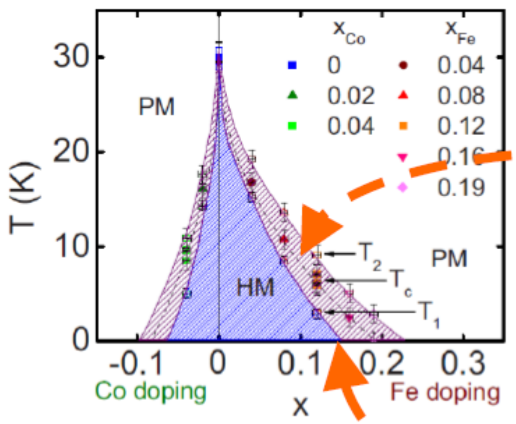
Sergey V. Grigoriev,[1] Evgeny V. Moskvin,[1] Vadim A. Dyadkin,[1] Daniel Lamago,[2,3] Thomas Wolf,[3] Helmut Eckerlebe,[4] and Sergey V. Maleyev[1]

Magnetic order in $Mn_{1-y}Fe_ySi$

PHYSICAL REVIEW B **82**, 064404 (2010)

Quantum phase transitions in single-crystal $Mn_{1-x}Fe_xSi$ and $Mn_{1-x}Co_xSi$: Crystal growth, magnetization, ac susceptibility, and specific heat

A. Bauer,[1] A. Neubauer,[1] C. Franz,[1] W. Münzer,[1] M. Garst,[2,3] and C. Pfleiderer[1,*]



Intermediate phase (Chiral spin liquid, CSL)

Underlying QCP

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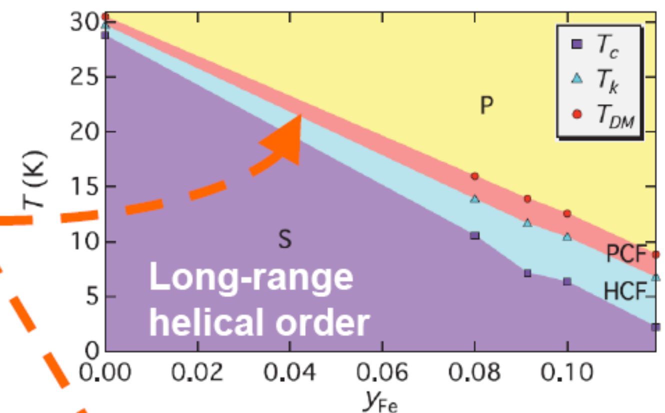
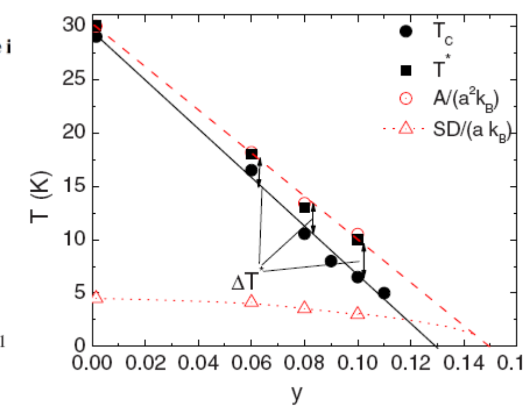


Phase diagram of the i ... rements

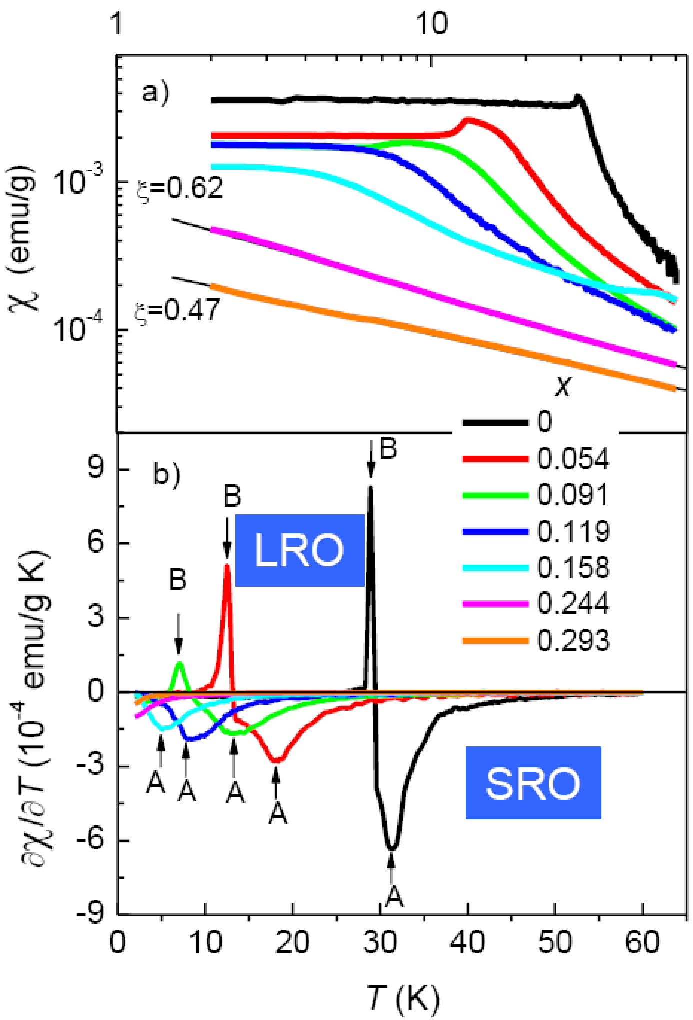


PHYSICAL REVIEW B **79**, 144417 (2009)

Helical spin structure of $Mn_{1-y}Fe_ySi$ under a magnetic field: Small angle neutron diffraction study

S. V. Grigoriev,[1] V. A. Dyadkin,[1] E. V. Moskvin,[1,2] D. Lamago,[3,4] Th. Wolf,[4] H. Eckerlebe,[5] and S. V. Maleyev[1]

Thermal phase transition in $Mn_{1-y}Fe_ySi$



Peak B is a marker of long-range magnetic order (LRO).

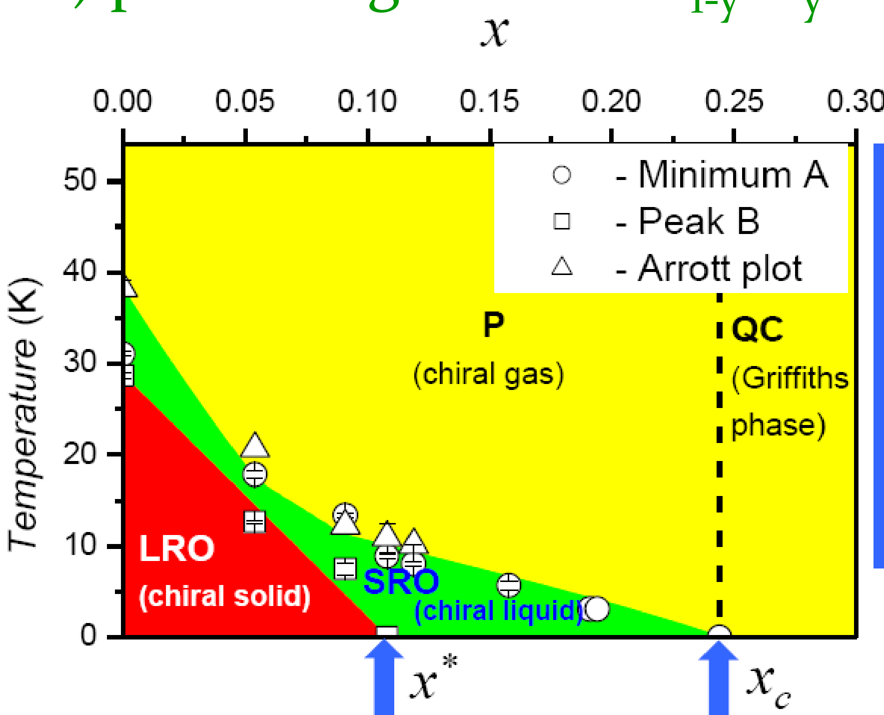
Minimum A is a marker of short-range magnetic order (SRO).

Pis'ma v ZhETF, vol. 98, iss. 12, pp. 933 – 937

Quantum bicriticality in $Mn_{1-x}Fe_xSi$ solid solutions: exchange and percolation effects

S. V. Demishev[+1)], *I. I. Lobanova*[+*], *V. V. Glushkov*[+*], *T. V. Ischenko*[+], *N. E. Sluchanko*[+], *V. A. Dyadkin*, *N. M. Potapova*, *S. V. Grigoriev*

(x-T) phase diagram in $Mn_{1-y}Fe_ySi$



Both susceptibility and Arrott analysis give characteristic temperatures above transition into the magnetic phase with spiral LRO. These temperatures corresponds to formation of the magnetic phase with SRO (chiral spin liquid).

There are two quantum critical points, x^* and x_c. The first QC point x^* ~ 0.11 corresponds to disappearance of LRO and is an underlying one, which is hidden inside the SRO phase. The second QC point x_c ~0.24 is a “true” one and marks suppression of the magnetic phase with SRO (chiral spin liquid).

Pis'ma v ZhETF, vol. 98, iss. 12, pp. 933 – 937

Quantum bicriticality in $Mn_{1-x}Fe_xSi$ solid solutions: exchange and percolation effects

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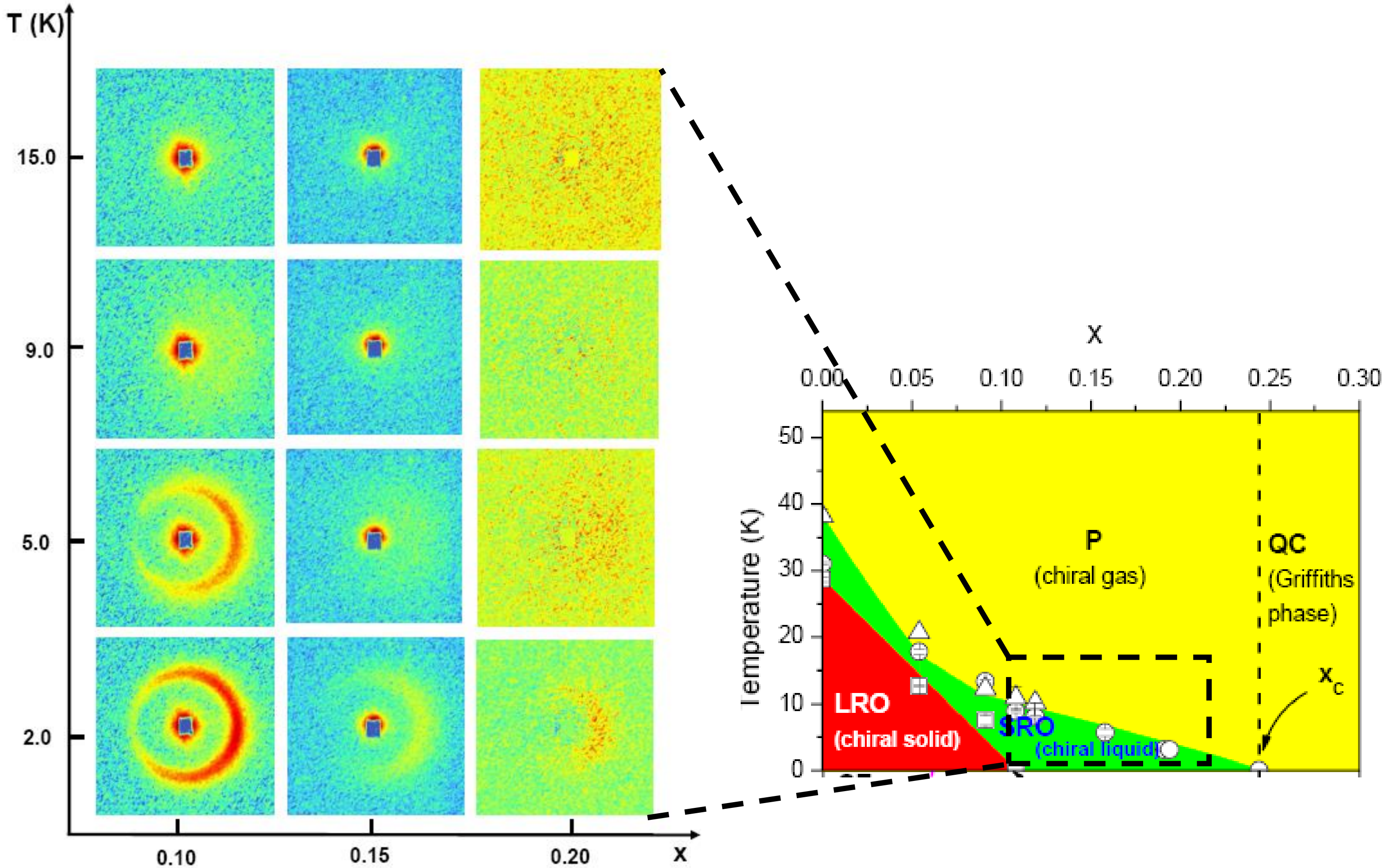
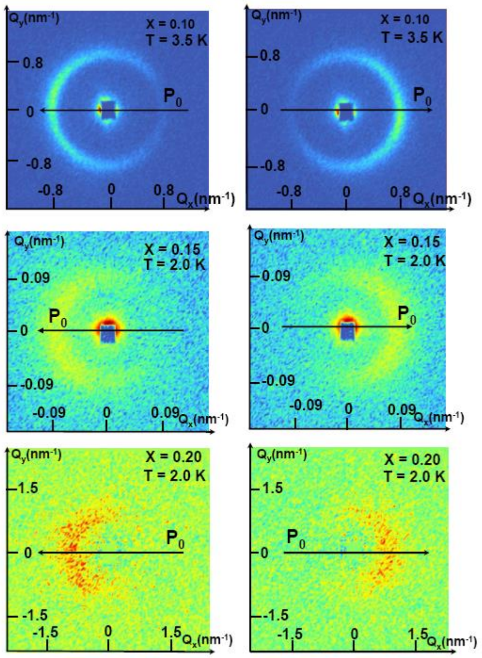
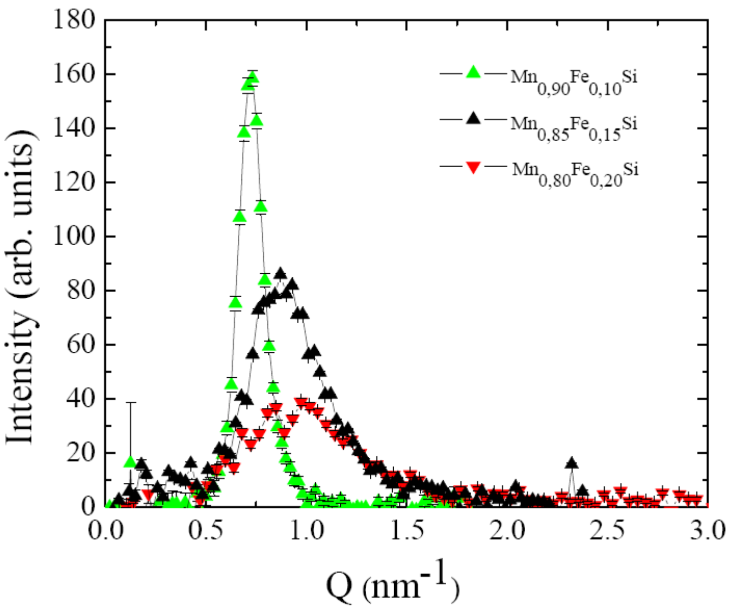
Short-range order beyond the QCP



Short-range order beyond the QCP

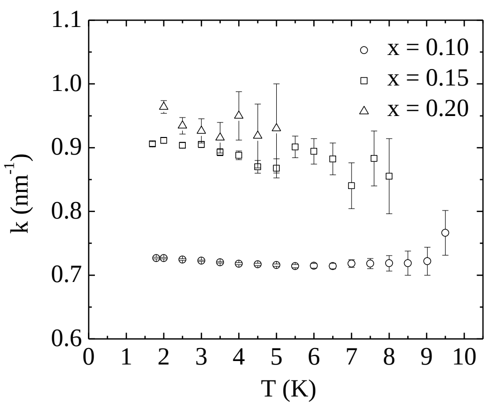
Analysis of the polarized SANS data gives
- **(i) the position of the peak ≡ helix wavevector k;**
- **(ii) the width of the peak ≡ the coherent length of the helix fluctuation;**
- **(iii) polarization of the peak ≡ the chirality of the fluctuation.**



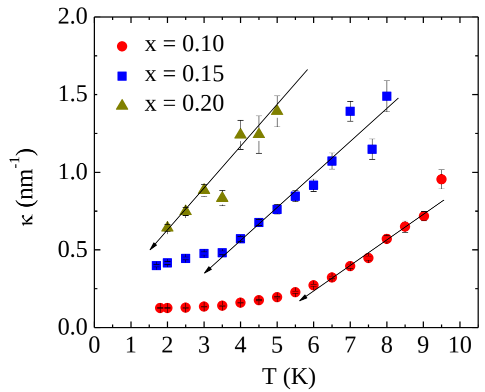


Short-range order beyond the QCP

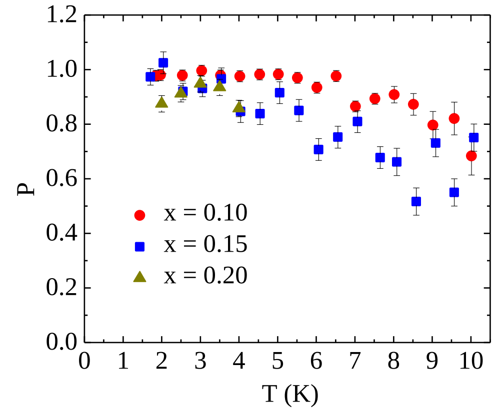
helix wavevector k = 2π/d



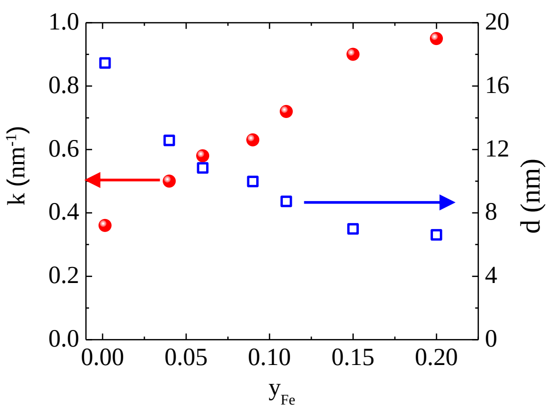
width of the peak



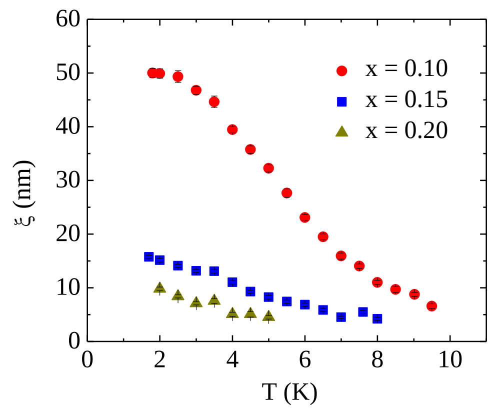
polarization ≡ the chirality



helix wavevector k = 2π/d



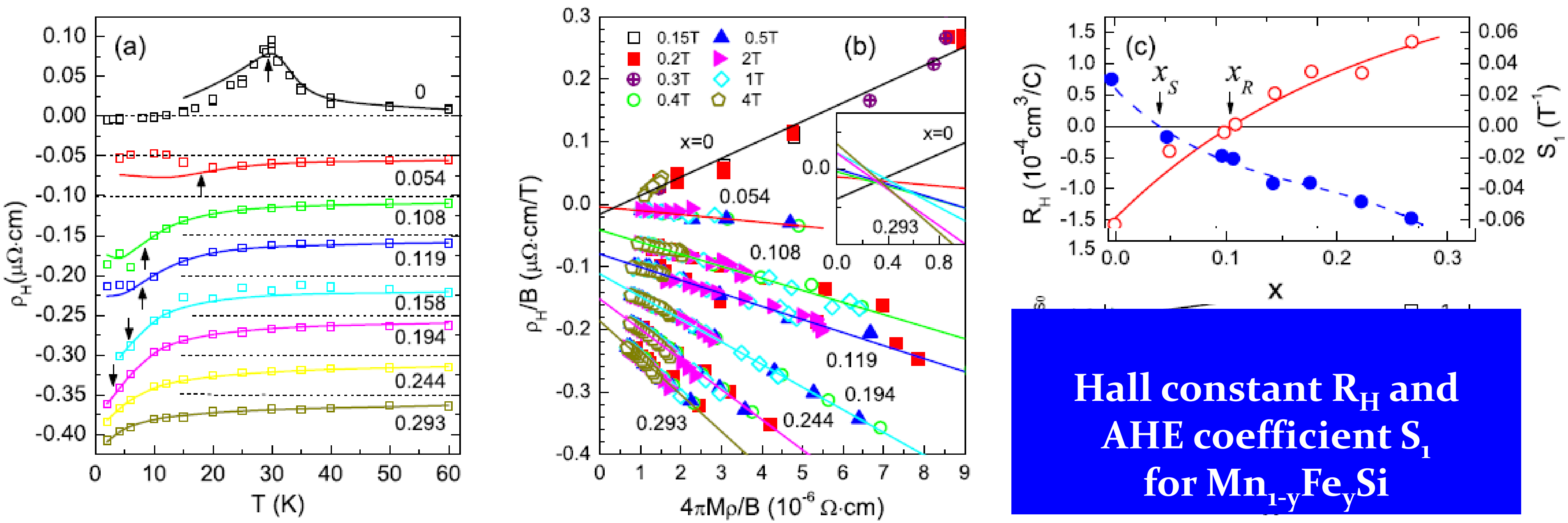
coherent fluctuation length



The driving force of QPT in $Mn_{1-y}Fe_ySi$

Hall resistivity $\rho_H(T,B)$ for pure MnSi and $Mn_{1-y}Fe_ySi$

$$\rho_H = R_H B_0 + \mu_0 S_1 \rho M$$



Hall constant R_H and AHE coefficient S_1 for $Mn_{1-y}Fe_ySi$

The important finding appears from the OHE sign inversion detected at Fe content $x_R \approx 0.115$. This fact points to the competing electron and hole contributions to charge transport in $Mn_{1-x}Fe_xSi$.

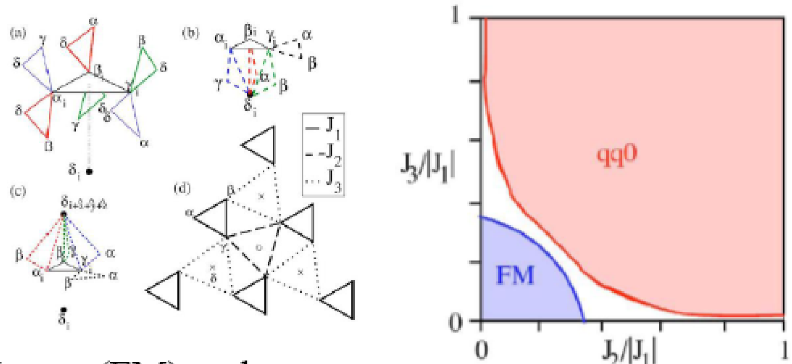
The driving force of QPT in $Mn_{1-y}Fe_ySi$

Why intermediate phase is formed? Why LRO phase is supressed?

PHYSICAL REVIEW B 75, 064430 (2007)

Microscopic model for spiral ordering along (110) on the MnSi lattice

John M. Hopkinson* and Hae-Young Kee†



J_1 – nn (FM) exchange

J_2 – next nn (AFM) exchange

J_3 – third nn (AFM) exchange

$J_2 \cong J_3$

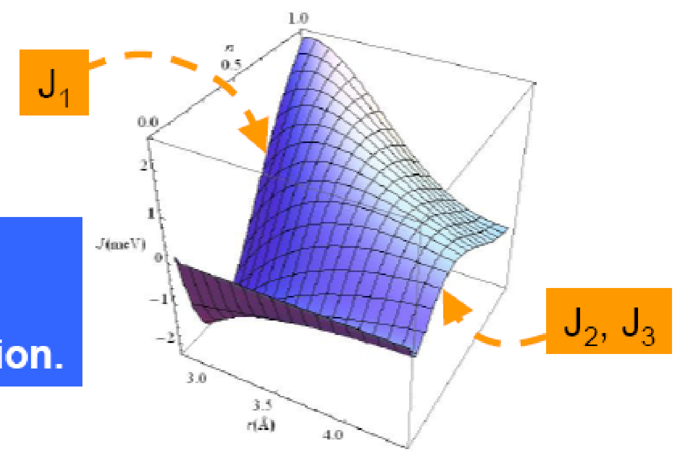
$|J_2 / J_1|_{cr} \sim 0.21 - 0.32$

Frustration try to align spirals along (110).

DM interaction try to align spirals along (111)

Competition between two interactions may lead to loosing of the long-range order and formation of the chiral liquid state.

In Heisenberg paradigm RKKY exchange defines J_1, J_2, J_3 parameters, which may be tuned by variation of the electron concentration.



Conclusion

(1) The experiments has revealed the relationship of the transport anomalies to the QC transition between LRO and SRO phases.

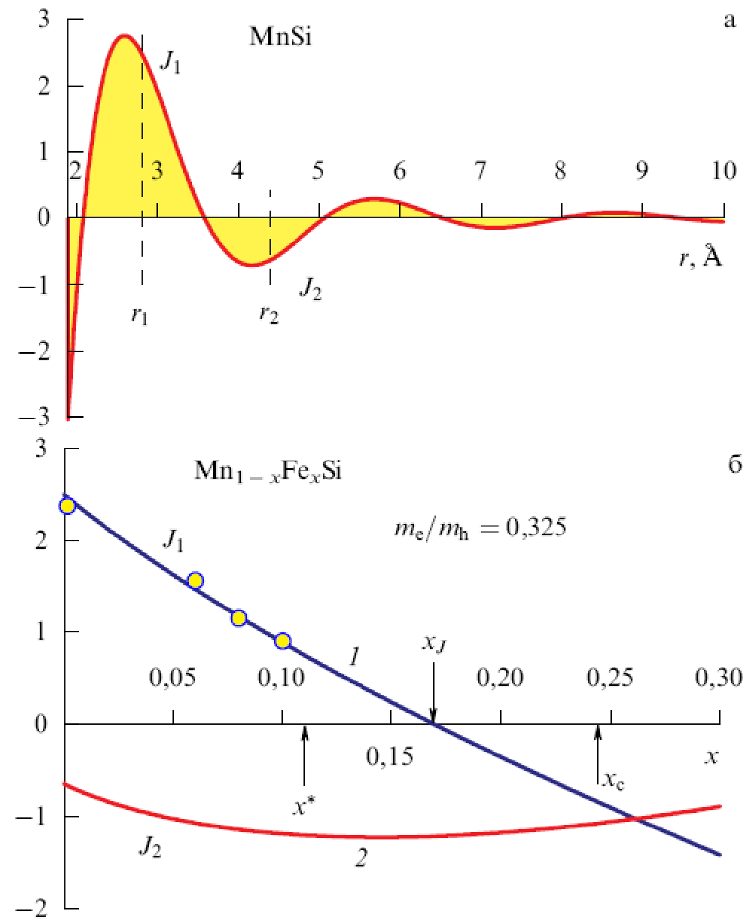
(2) As long as the exchange energies are tuned via the RKKY mechanism, the change of electron and hole concentrations may be considered as a microscopic driving force for QC in $Mn_{1-x}Fe_xSi$.

(3) In Heisenberg paradigm RKKY exchange defines J1, J2, J3 parameters, which may be tuned by variation of the electron concentration.

Июнь 2016 г. УСПЕХИ ФИЗИЧЕСКИХ НАУК *Том 186, № 6*

Квантовые фазовые переходы в спиральных магнетиках без центра инверсии

С.В. Демишев, В.В. Глушков, С.В. Григорьев, М.И. Гильманов, И.И. Лобанова, А.Н. Самарин, А.В. Семено, Н.Е. Случанко



Acknowledgements

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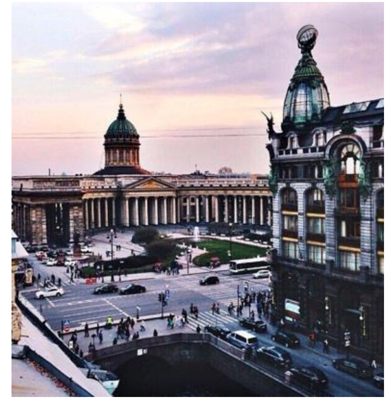
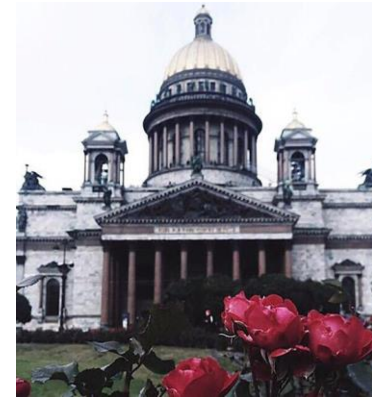
Many thanks you for attention!





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