A-PHASE ORIGIN IN CUBIC HELIMAGNETS (MnSi etc)

S.V.Maleyev

Petersburg Nuclear Physics Institute

Russia

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SPIN HELICES IN CUBIC NON-CENTROSYMMETRIC HELIMAGNETS(MnSi etc.)

Helical structure is a result of competition between

Ferromagnetic exchange

Dzyaloshinskii-Moriya interaction

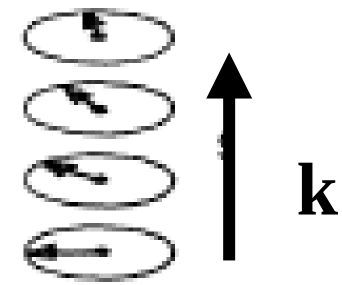
$$H = \sum \{ -J_{\mathbf{q}} (\mathbf{S}_{\mathbf{q}} \cdot \mathbf{S}_{-\mathbf{q}})/2 + iD_{\mathbf{q}} (\mathbf{q} \cdot [\mathbf{S}_{\mathbf{q}} \times \mathbf{S}_{-\mathbf{q}}])$$

P.Bak M.Jensen (1980)

MAGNETIC FIELD; MEAN FIELD

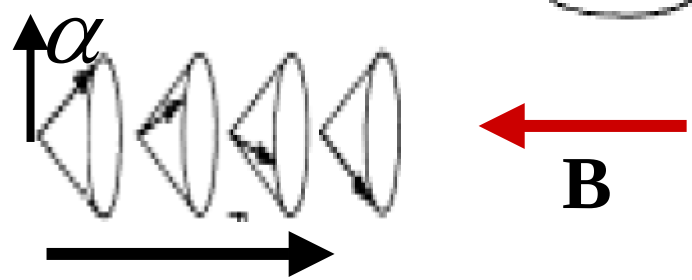
Zero field: **B=0,** Low T- Planar helix

Helix vector **k** along the anisotropy axis (111).



B greater than anisotropy E_{An}:

Conical helix, **k** along the field



$$\sin\alpha = -B/B_C$$

B_C is the field for ferromagnetic transition.

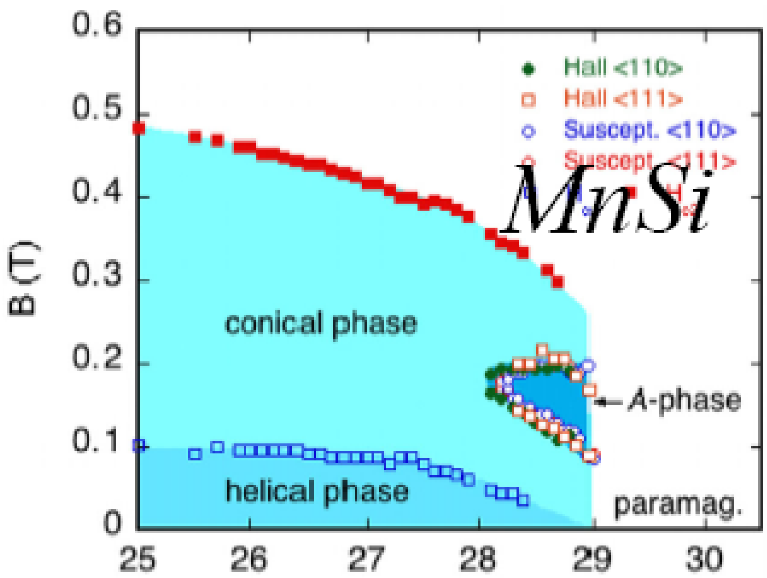
Mean-field energy: $E_{MF} = -\dfrac{B_{\parallel}^2}{2B_C} - \dfrac{B_{\perp}^2}{4B_C}$

$\parallel(\perp)$ **k** along (perpendicular to) the field.

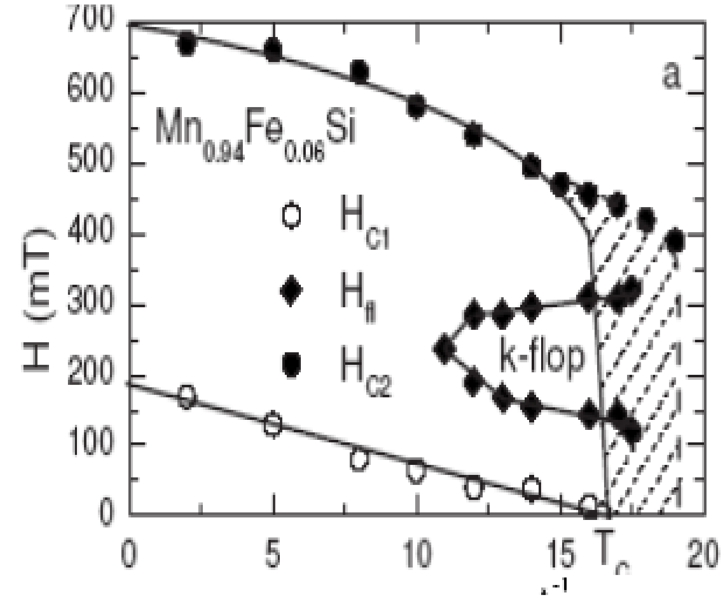
$1/4 = <\cos^2\varphi>/2;$ φ is an angle between spin and **B.**

Freely rotating **k** $(B > E_{An})$ always along the field!

EXPERIMENT



S.Mühlbauer at al.(2009)



S.Grigoriev et al. (2009)

Small pockets just below T_C where $\mathbf{k} \perp \mathbf{B}$

A-phase discovered by B.Lebech (1993).

It was claimed that A-phase is a new Skyrmion lattice state S.Mühlbauer at al.(2009).

Two striking features:

1.Narrow field region of the A-phase state

$$B_{A-} < B < B_{A+} < B_C$$

2.Closeness to critical temperature: $\tau = (T_C - T)/T_C \ll 1.$

Critical fluctuations have to de important and contribute to magnetic energy

$$E_M := E_{MF} + E_{Fl}.$$

UPPER BOUND B_{A+}

This bound is a condition of the spin-wave suability at **q**=0.

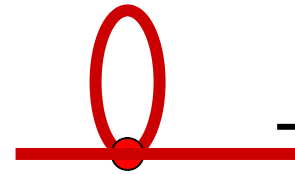
Square of the spin-wave energy in perpendicular field

$$\epsilon_{\mathbf{q}}^2 = \epsilon_{0,\mathbf{q}}^2 + \Delta^2 - 3B_{\perp}^2/8$$

In linear approximation: $\epsilon_{0,\mathbf{q}} = \begin{cases} Ak\sqrt{q_{\parallel}^2 + 3q_{\perp}^4/8k^2}; |\mathbf{q}| < k, \\ Aq^2; |\mathbf{q}| \gg k. \end{cases}$

D.Belitz et al.; S.Maleyev (2006).

The gap Δ appears due to spin-wave interaction in the Hartree-Fock approximation. Maleyev(2006).

Hartree-Fock loop  $\rightarrow \Delta$

Uniform (**q**=0) spin-waves are stable if

$$\Delta^2 - 3B_\perp^2/8 > 0.$$

$$B_{A+} = \Delta\sqrt{8/3}.$$

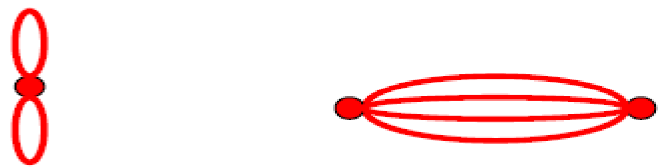
A-phase can not survive if $B > B_{A+}$!

LOWER BOUND B_{A-}

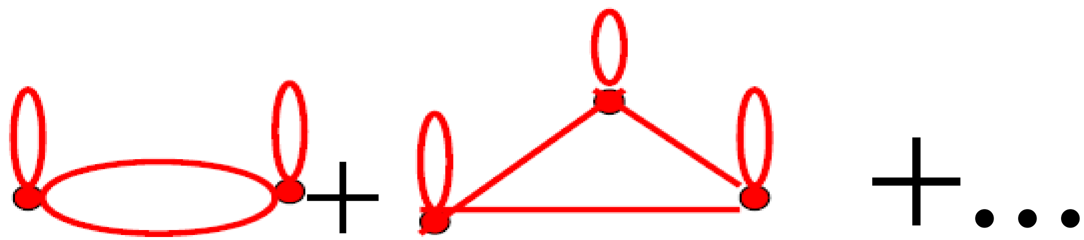
appears due to INFRARED DIVERGENCES

at $B_{\perp} \rightarrow B_{A+}$ in diagrams for magnetic energy.

Regular diagrams



IRD diagrams



FINAL RESULT

$$E_M = -\frac{SB_{\parallel}^2}{2B_C} - \frac{SB_{\perp}^2}{4B_C}\left[1 + \Lambda\frac{B_{A+}^2}{B_{\perp}^2}\ln\frac{2B_{A+}^2 - B_{\perp}^2}{2(B_{A+}^2 - B_{\perp}^2)}\right]$$

$$\Lambda = \frac{(ka)^3\sqrt{3/8}TB_C(\tau)}{4\pi[A(\tau)k^2]^2S(\tau)}; \tau = (T_C - T)/T_C.$$

and a is the lattice spacing..

A-phase transition holds when [...]=2.

From rough experimental data [S.Mühlbauer at al.(2009)]

near T_C we have $\Lambda_C \approx 1.7.$

Using well known low T parameters for MnSi we get $\Lambda_{C0} \approx 0.005!$

We need 340 times amplifying!

Near T_C we have $S(\tau) = S_0 \tau^{0.22}$ where $S_0 \sim 1.$

R.Georgii et al.(2004), S.Grigoriev et al. (2005).

Comparison of data by Ishikawa et al. (1977) and F.Semadeni et al.(1999) shows that A decreases strongly with $T \to T_C.$

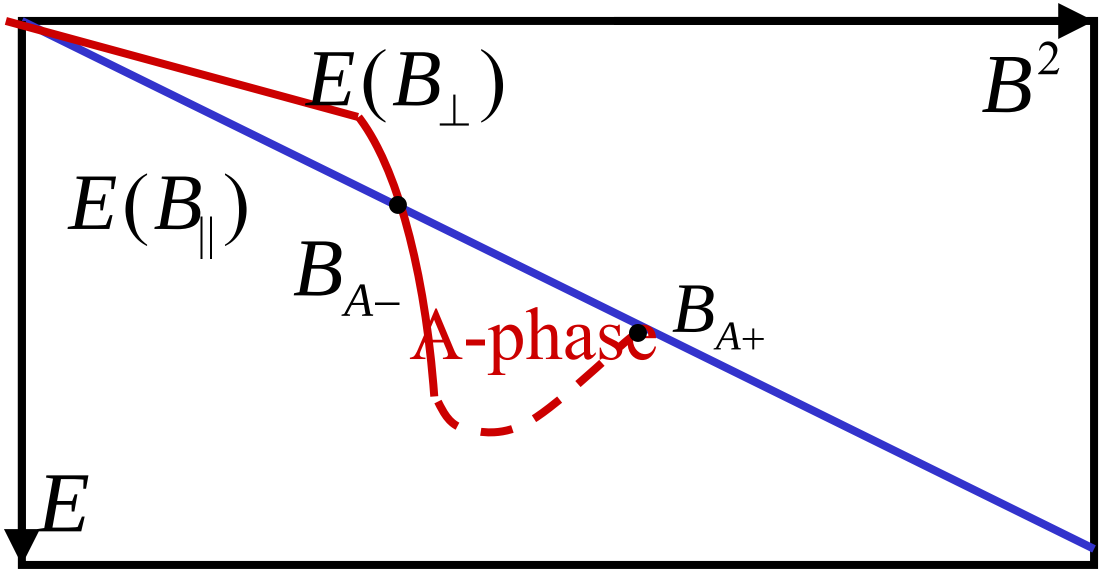
Assuming dynamical scaling $A = A_0 \tau^{x}$

one can obtain corresponding amplifying at $\tau = 1/30$ $(T = T_C - 1K)$ if $x \sim 0.7.$

More precise data are urgent to determine real x value.and $B_{A-}(\tau).$

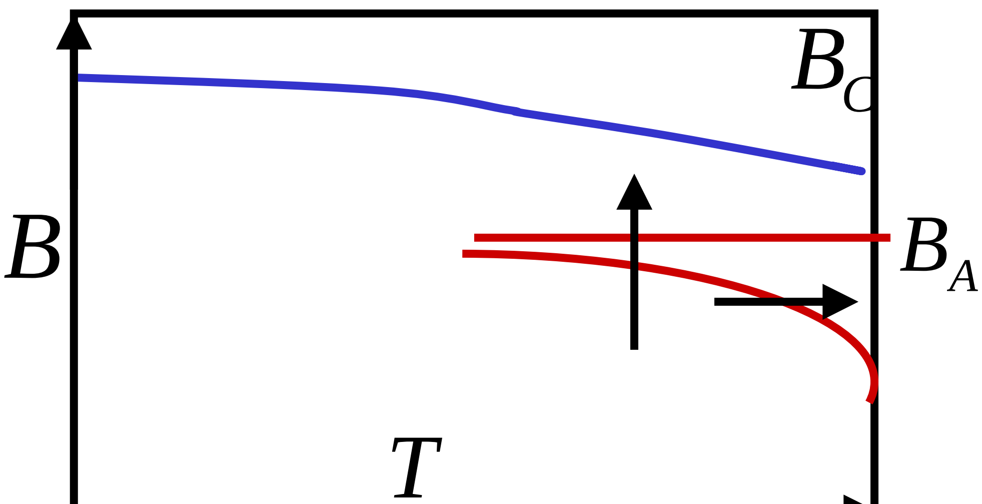
H_{A1}

TWO FIRST ORDER TRANSITIONS



ENERGY AS FUNCTION OF B

SPECIFIC HEAT JUMPS



$\Delta C_{B_\pm}(T)$?

$\Delta C_T(B_\pm)$?

SUMMARY

- ORIGIN OF THE A-PHASE BOUNDARIES IS EXPLAINED
- CRUCIAL ROLE OF THE CRITICAL FLUCTUATIONS IS DEMONSTRATED

THANK YOU FOR ATTENTION