CHIRAL HELICESIN MAGNETIC FIELD

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PNPI

MODEL

- Exchamge+DM+Field

$$H = (1/2)\sum J_{\mathbf{R}\mathbf{R}''}\mathbf{S}_{\mathbf{R}} \cdot \mathbf{S}_{\mathbf{R}'} + \sum \mathbf{D}_{\mathbf{R}\mathbf{R}''}[\mathbf{S}_{\mathbf{R}} \times \mathbf{S}_{\mathbf{R}'}] + \sum(\mathbf{H} \cdot \mathbf{S}_{\mathbf{R}});\ \mathbf{D}_{\mathbf{R}\mathbf{R}''} = -\mathbf{D}_{\mathbf{R}'\mathbf{R}}.$$

KAPLAN HELID

$$\mathbf{S}_{\mathbf{R}} = S[(\hat{a}\cos\mathbf{k}\cdot\mathbf{R} + \hat{b}\sin\mathbf{k}\cdot\mathbf{R})\cos\alpha + \hat{c}\sin\alpha]$$

$$|\hat{a}| = |\hat{b}| = 1;\ (\hat{a}\cdot\hat{b}) = 0;$$

$$[\hat{a}\times\hat{b}] = \hat{c};\ |\mathbf{S}(\mathbf{R})| = S.$$

Six free parameters $\mathbf{k}, \hat{c}, \alpha$.

$\mathbf{C} = S^2\hat{c}$ spin chirality.

Polarized neutrons.

MOMENTUM SPACE
Distorted AF

Classical emergy($\mathbf{k} \rightarrow \mathbf{k}_{AF} + \mathbf{k}$)

$$E_{cl} = \frac{\sim}{2}\{J_0 \sin^2\alpha - [J_{\mathbf{k}} +$$

$$2(\mathbf{d}_{\mathbf{k}} \cdot \hat{c})]\cos^2\alpha\} + S(\mathbf{H} \cdot \hat{c})\sin\alpha;$$

$$J_{\mathbf{k}} = \sum_{\mathbf{R}} J_{0,\mathbf{R}} \cos\mathbf{k} \cdot \mathbf{R};$$

$$\mathbf{d}_{\mathbf{k}} = -i\sum_{\mathbf{R}} \mathbf{D}_{0,\mathbf{R}} \sin\mathbf{k} \cdot \mathbf{R}.$$

HELIX ENERGY

$$dE_{cl}/d\alpha = 0 \rightarrow \sin\alpha = -\frac{(\mathbf{H}\cdot\hat{c})}{H_{SF}}$$

$$H_{SF} = 2SJ_0 \; SPIN \; FLIP \; FIELD$$

$$E_{cl} = -\frac{S^2}{2}[J_{\mathbf{k}} + 2(\mathbf{d}_k\cdot\hat{c})] - \frac{SH_{\parallel}^2}{2H_{SF}}$$

$$dE_{cl}/d\mathbf{k} = 0\text{-Spin structure}$$

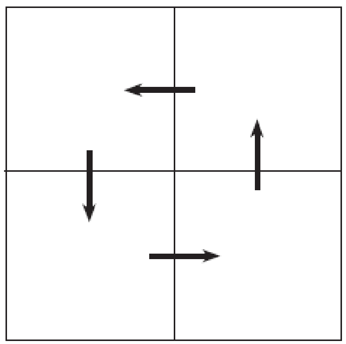
DMI and **H** ALONG $\hat{c}$!!!

SURFACE LAYER(Mn on W)

Arrows are DM vectors

Ar perpendicular to the bonds.

perpendicular to the bonds.



(Crepieux,Lacroix)

$$J_{\mathbf{q}} = 2J(\cos q_x + \cos q_y),$$

$$\mathbf{D}_{\mathbf{q}} = 2iD(\sin q_y, -\sin q_x).$$

$$\tan k_x = k_0 \hat{c}_y;\ \tan k_y = -k_0 \hat{c}_x;$$

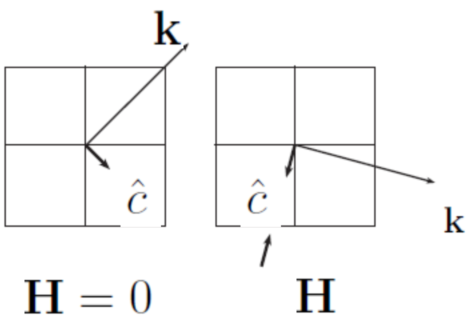
$$= 2D/J \ll 1;\ \mathbf{k}\cdot\hat{c} = 0 - CYCLOID$$

D.Serrate et al
Mn on W.

ANISOTROPY

$$E = -\frac{S^2}{2}\left[1 + \frac{k_0^2}{4} - \frac{k_0^4(\hat{c}_x^4 + \hat{c}_y^4)}{16}\right] - \frac{SH_{\|}^2}{2H_{SF}}$$

$$\hat{c}_x = \cos\phi,\ \hat{c}_y = \sin\phi, ;\ H_{\|} = H\cos(\phi - \psi)$$



DMI $\rightarrow k^4$ anisotropy.

(1, 1)-easy direction;

$\mathbf{H}$ rotates $(\hat{c}, \mathbf{k})$ cross n.

EQUATION OF STATE

$$\frac{dE}{d\phi} \to (\frac{H}{H_C})^2 \sin 2(\phi - \psi) - sin4\phi = 0;$$

$$H_C = H_{SF} k_0^2/8 \ll H_{SF}.$$

H=0, $\phi = -\pi/4$.

$H < 2H_C$. $\hat{c}$ is locked:

$0 > \phi > -\pi/2$.

$H > 2H_C$. Field rotates

$(\hat{c}, \mathbf{k})$ cross. $\phi \to \psi$ if $H \gg H_($

AF TRANSITION IN $\mathbf{H}_\perp$

The first order transition to AF state .

$$E(H_{||}=0) = E_{AF}(\mathbf{H}_\perp)$$

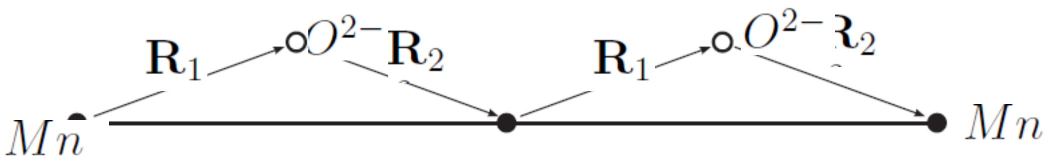
$$E(H_{||}=0) = -(S^2J_0/2)(1+k_0^2/4);$$

$$E_{AF} = -(S^2J_0/2) - SH_\perp^2/2HSF;$$

$$H_{AF} = H_{SF}k_0/2\sqrt{2} \ll H_{SF}$$

PSEUDO MF

- DMI is a result of O^{2-} shiftin from themiddle of the Mn-Mn line.



$$\mathbf{R}_1 = -a\hat{x}/2 + b\hat{y},\ \mathbf{R}_2 = a\hat{x}/2 + b\hat{y}.$$
$$\mathbf{D}_{12} \sim [\mathbf{R}_1 \times \mathbf{R}_2] \to d\hat{z},\ \hat{z} = [\hat{x} \times \hat{y}]$$

STRUCTURE

$$E_{Cl} = -\frac{S^2}{2}[2J_x \cos k_x + J_\perp(\mathbf{k}_\perp) + 4d \sin k_x] - \frac{S(\mathbf{H} \cdot \hat{c})^2}{2H_{SF}}; \; H_{SF} = 2S[2J_x + J_\perp(0)].$$

$$\tan k_x = 2d/J_x = k_0; \; \hat{c} = \hat{z};$$

$$E = 2S^2 J_x(1 + k^2/2) - SH_{||}^2/2H_{SF}$$

$\hat{c}||Z; \; XY\,AFCYCLOID$

AF TRANSITION

The first order AF transition occurs when

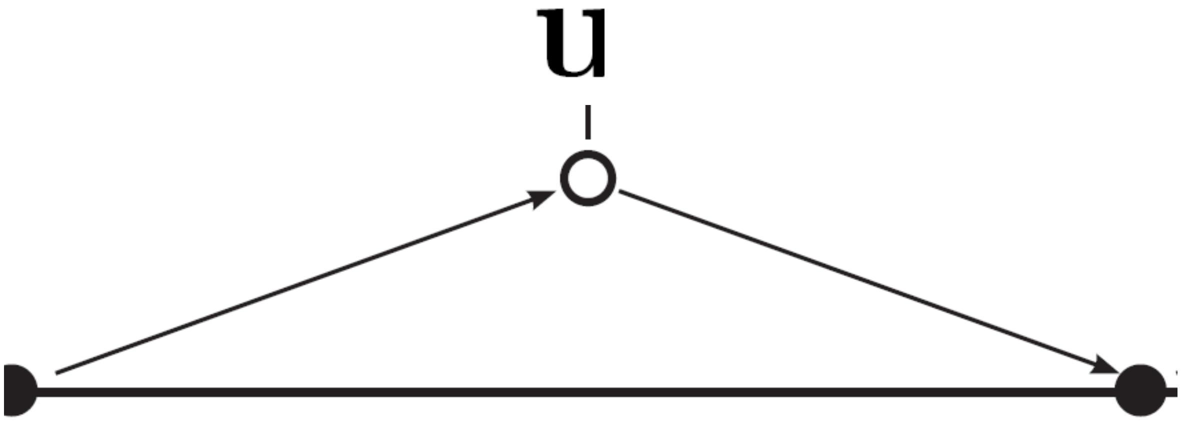
$$E_{cl} = E_{AF}(\ H_{\perp}); \mathbf{H}_{\perp} = (H_x, H_y)$$

$$H_{AF} = H_{SR} k_x \sqrt{H_{SF}/SJ_x} \ll H_{SF}.$$

SOFT LATTICE

The DM helix is a result of the lattice distortion. In the soft lattice the helix changes the distortion.

The simplest example. additional shifting.



DMI AND LATTICE

We have a sum

$$\text{Magnetic+Elastic energies}$$

$$E_{cl} = -\frac{S^2(d_0 + d_1 u_y)^2}{2J_x} + \frac{K u_y^2}{2}.$$

$$d_1 a \ll d_0;\ u_y = -\frac{S^2 d_0 d_1}{K}.$$

INSTABILITY

$$d_0 = 0 \to E_{cl} = (K - S^2 d_1^2 / J_x) u_y^2 / 2$$

$K \to 0,\ u_y \to \infty$. Instability!

u^4 terms determine u_{max}

The first order transition

to distorted lattice $T_D < T_N$.

PERPENDICULAR FIELD

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$$E_\perp = \mathbf{H}_\perp \cdot (\mathbf{S}_\mathbf{k} + \mathbf{S}_{-\mathbf{k}})/2,$$

$$S^x_\mathbf{k} \sim (a_\mathbf{k} + a^+_{-\mathbf{k}}) :$$

$$S^y_\mathbf{k} \sim (a_\mathbf{k} - a^+_{-\mathbf{k}})/i;$$

$$S^z_\mathbf{k} \sim (a^+_0 a_\mathbf{k} + a^+_{-\mathbf{k}} a_0),$$

a, a^+ are spin-wave operators..
The spin-waves with momenta $\mathbf{k}$ and 0 display Bose-Einstein condensation

CONCLUSIONS

- Perpendicular field does not interact witth the classical chiral helix. However the AF transition occurs when the AF energy becomes lesser than the helical one.
- DMI may give the ciral anisotropy of order of k^4. Examples:
- Layer’
- B20 helimagnetics.

THANK YOU!

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