MAGNETIC CHIRALITY

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PNPI

MAGNETIC CHIRALTY

Chirality Skew spins: $\mathbf{C} \sim [\mathbf{S_1}$ ›

Result of inversion breaking.

Two ways:

Structure, Magnetic field.

Inversion: $(x, y, z) \rightarrow (-x, -y,$ -

$\mathbf{R} \rightarrow -\mathbf{R}$ vector.

$\mathbf{C} \rightarrow \mathbf{C}$-axial vector..

Structure: Static $\mathbf{C}$.

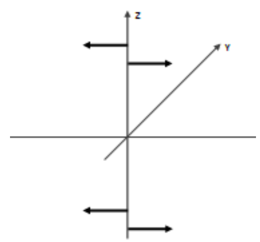
Magnetic field

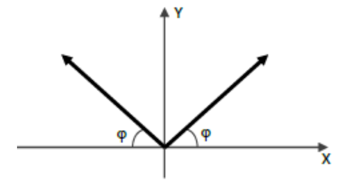
$\mathbf{H}(-t) = -\mathbf{H}(t)$,

Dynamical chirality: $\mathbf{C}(t)$.

WEAK FERROMAGNETISM
Borovik-Romanov,Dzyaloshinskii

$\alpha - Fe_2O_3$ etc. Unit cell:
Four magnetic ions along C_3 axis.
Inversion I between two pairs.
DMI into up and down pairs
$V_{DM} = \mathbf{D_{12}}[\mathbf{S_1} \times \mathbf{S_2}];\ \mathbf{D}||\mathbf{C_3}.$'
W



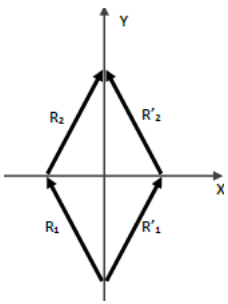


$\mathbf{D}_{1\,2} = D(z_{1\,2})[\hat{x} \times \hat{y}]||\hat{z}.\ D(-z) = -D(z).$
$\varphi \sim D/J$ where J -exchange interaction.

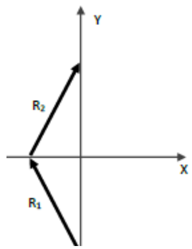
MORIYA THEOREM

DMI appears if we have not
Inversion between two spins
$V_{DM} = \mathbf{D_{1\,2}}[\mathbf{S_1} \times \mathbf{S_2}]$,
$\mathbf{D_{2\,1}} = -\mathbf{D_{1\,2}}$
$\mathbf{D}$ is a result of the
spin-orbit interaction.
It is main anisotropic
Interaction.

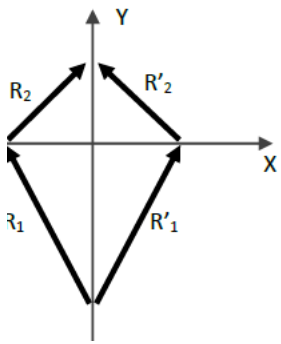
EXAMPLES



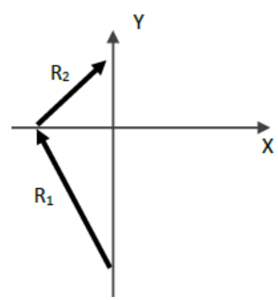
Complete symmetry
$\mathbf{D} = 0$



Left-right asymmetry
$\mathbf{D} \sim [\mathbf{R_1} \times \mathbf{R_2}]$
(Moskvin rule)



Up-down asymmetry
$\mathbf{D} || \hat{y}, \ \hat{y} = [\hat{z} \times \hat{x}]$



Total asymmetry
$\mathbf{D} = D_1 \hat{y} + D_2 [\mathbf{R_1} \times \mathbf{R_2}]$

HELICES

DMI gives HELICAL structure:

- B20 (MnSi etc) FM helix
- Surface lsyers

Fe on WW FM helix.

Mn on W AF cycloid.

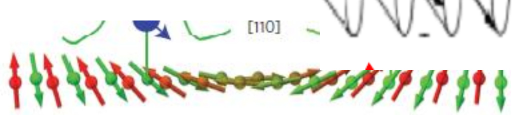
Multiferroiks: AF cycloids or weak AF

DESCRIPTION

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

Spin rotation plain $\hat{c} = [\hat{a} \times b]$.
$\mathbf{k}||\hat{c}$ planar helix. $\mathbf{k} \perp \hat{c}$ cycloid.

Six parameters: $\mathbf{k}$, $\hat{c}$ and α-angle between $\mathbf{S}$ and plane $\hat{c}$.

AF cycloid: 

THEORY I

Helix energy is sum of th
exchange and DM energies.
Both are $\mathbf{k}$ modulatedEnergy change:
$E_{\mathbf{k}} = Ak^2/2 + (\mathbf{D}_{\mathbf{k}} \cdot \hat{c})$.
Minimum $\partial E_{\mathbf{k}}/\partial \mathbf{k} = 0$.
Two models:
$\mathbf{D}_{\mathbf{k}} = D\mathbf{k}; \mathbf{k} = D\hat{c}/A$ (B2o).
$\mathbf{D}_{\mathbf{k}} = D[\mathbf{N} \times \mathbf{k}]$; $\mathbf{N}$ is $\mathbf{D}$ direction.
$\hat{c} \perp \mathbf{N}$. $\mathbf{k} = D[\mathbf{N} \times \hat{c}]/A$.
Cycloid: Multiferroiks, layers.
C

MAGNETIC FIDLD B20

In magnetic field
$E = -\frac{Ak^2}{2}\cos^2\alpha + SH\sin\alpha$; $\mathbf{k}||\mathbf{H}$.
α is an angle between spins and rotation plain.
$\hat{c}||\mathbf{H}$; $\sin\alpha = -H/H'_c\acute{H}_c = Ak^2$.
Near T_c A-phase: $\mathbf{k}||\hat{c} \perp \mathbf{H}$
with "skyrmion lattice". Both are unexplained.
$H > H_c$ Ferromagnet: Anisotropic chiral spin waves.
T

FIDLD N ANISOTRopy

F case.

In-plain field $\mathbf{H} \perp \mathbf{N}$

Conical cycloid $\hat{c}||\mathbf{H}$; $\sin\alpha = -H/Ak^2$

If spins $\mathbf{S} \perp \mathbf{N}$ DM is of.

$\mathbf{H} \perp \mathbf{N}$. Ferromagnet at $H > Ak^2/2$.

First order transition?

AF case.

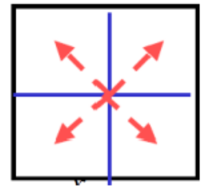
AF conical cycloid up to $H \sim J$.

$\mathbf{H}||\mathbf{N}$. AF at $H > Ak^2/2$

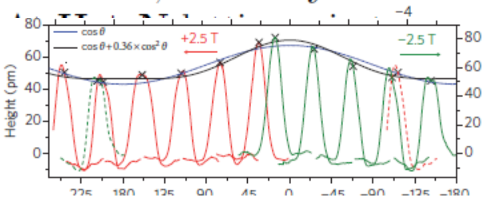
'Y

C_4 ANISOTROPY 1

Anisotropy: $\mathbf{N}||C_4$
Two A: Intrinsic, DM.
A energy
$E \sim [(\sin^4\phi + \cos^4\phi)$
-$(\mathrm{H}/\mathrm{H}_C)^2\cos^2(\phi-\psi)$
DM: $H_C \sim Ak^2$.
$\mathbf{H} = H(\cos\psi, \sin\psi)$
$\hat{c} = (\cos\phi, \sin\phi)$.
$H = 0$;=(1,1)/$\sqrt{2} \perp \mathbf{k}$.
$H > H_C$ rotate $(\hat{c}, \mathbf{k})$ cross



MnonW, 2DAFlayer



MULTIFERROIKS

- MF (Smolenskii) are compounds with strong connection between electric (P) and magnettic (M) polarizations.
- One can manipulate P by magntic field H and M by electric field E.
- However direct interactions (P H) and (M E) are forbiden as contradict parity conservation laws.

C and P CONNECTION

$\mathbf{P}$ is a result of the lattice deformation with the inversion breaking. It may be the ion (O^{2-}?) shifting:
$\mathbf{R} \rightarrow \mathbf{R} + \mathbf{u}$ with
the energy gain $\Delta E = -Ku^2/2$.
We get $\mathbf{P} \sim \mathbf{u}$ and
$\delta \mathbf{D}_{\mathbf{R_1},\mathbf{R_2}} \sim [\mathbf{R_1} - \mathbf{R_2} \times \mathbf{u}]$.
Direct connection between
chirality $\mathbf{C}$ and $\mathbf{P}$.

$$\mathbf{u} \sim [\mathbf{R_{1\,2}} \times \mathbf{C}]/K,$$
$$\mathbf{C} = [\mathbf{S_1} \times \mathbf{S_2}].$$

FINAL

WHAT IS NOT SAID?

- C fluctuations
- Dynamical chirality

MAGNETIC FIDLD N ANISOTRopy

THEORY

than the

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d.

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0.

Planar helix (Mn Si).
$\mathbf{D}$ direction.
$/A$.

ce layers).