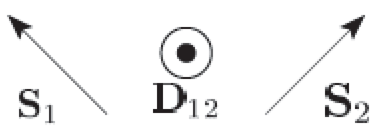
Origin of Dzialoshinsky-Moriya interactions

$$H_{\mathrm{DM}} = \mathbf{D}_{12}.(\mathbf{S}_1 \times \mathbf{S}_2)$$

-Antisymmetric interaction: ≠ 0 only if there is no center of symmetry between sites 1 and 2

- $\vec{D}_{12} = -\vec{D}_{21}$

- Produces a canting of the spins



$J = 0$

$J_{AF} \neq 0$

Moriya' s rules for $\vec{D}_{12}$

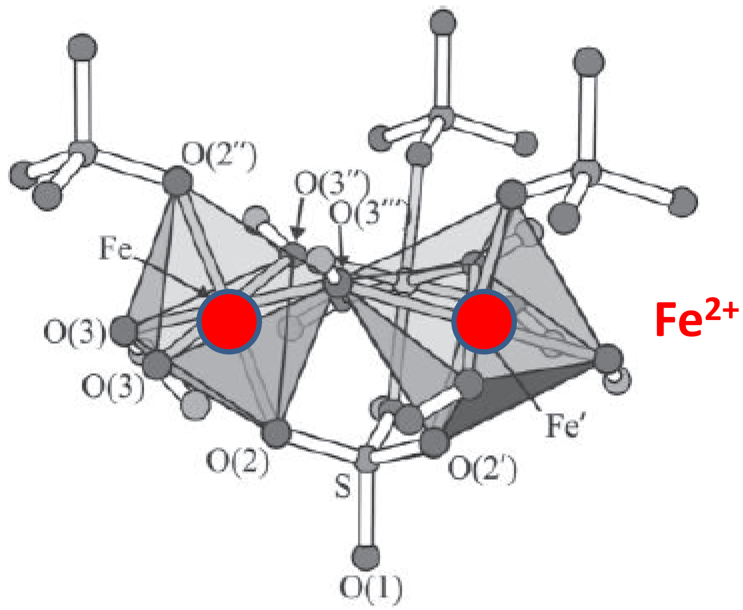
M is the middle point between 1 and 2

-If M is an inversion center: D=0

-If the plane perpendicular to 1-2 (containing M) is a mirror plane, D is in this plane

-If 1 plane containing 1 and 2 is a mirror plane, D is perpendicular to this plane

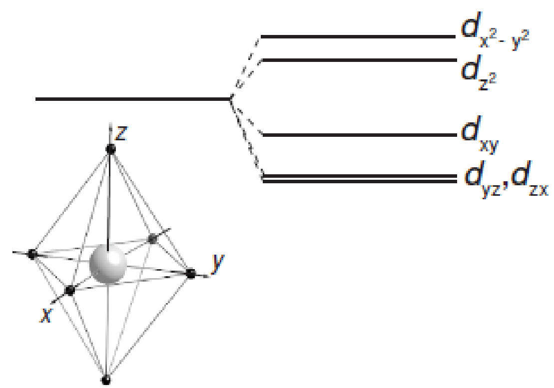
(+ other rules related to the existence of rotation axis)



Example: Fe jarosite

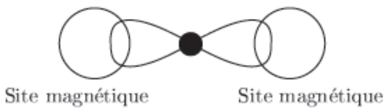
2nd rule can be applied

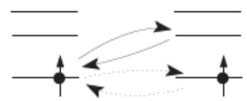
Crystal field splitting around each Fe ion:



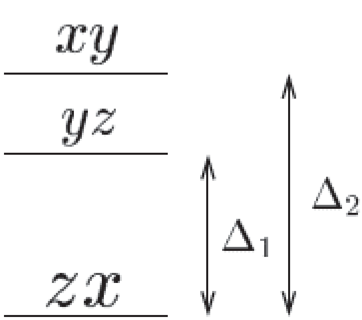
But x, y and z axis are different for each Fe site!

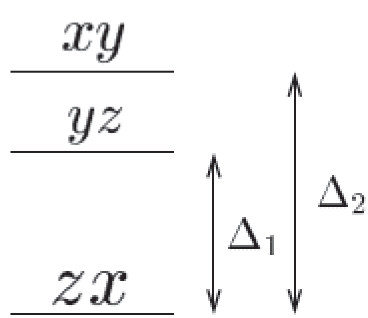
Superexchange:



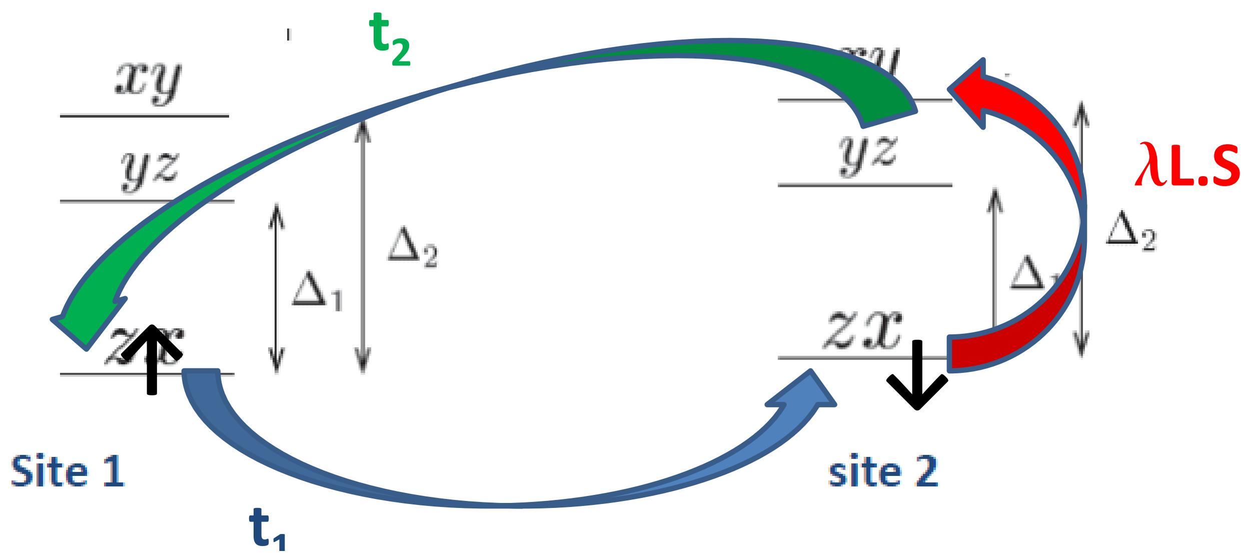


D.M. interactions: involve spin-orbit interactions





Site 1 **site 2**



$$d_{xy} = -(i/\sqrt{2})(\psi_2 - \psi_{-2})$$
$$d_{yz} = (i/\sqrt{2})(\psi_1 + \psi_{-1})$$

Matrix elements of λL.S $\neq 0$

$$d_{zx} = -(1/\sqrt{2})(\psi_1 - \psi_{-1})$$

Contribution to the energy: perturbation in t and λ $\Rightarrow \lambda \frac{t_1 t_2}{\Delta U}$

Superexchange : $\frac{{t_1}^2}{U}$

$$D \sim \lambda \frac{t_1 t_2}{\Delta U} \qquad J \sim \frac{{t_1}^2}{U}$$

To next order in λ, anisotropic exchange: $\sum_{\alpha\beta} \Gamma_{\alpha\beta}(S_1^\alpha S_2^\beta + S_2^\alpha S_1^\beta)$

$$\Gamma \sim \lambda^2 \frac{t_1 t_2}{\Delta^2 U}$$

D/J ≈ λ/Δ Γ/J ≈ $(\lambda/\Delta)^2$

Small interactions, play an important role in multiferroics

Observed in many oxydes of TM ions: Fe2O3, CoCO3, ….

Weak ferromagnetism, canting angle ≈ D/J