THE EFFECT OF SPIN WAVES IN THE SPIN SEEBECK EFFECT

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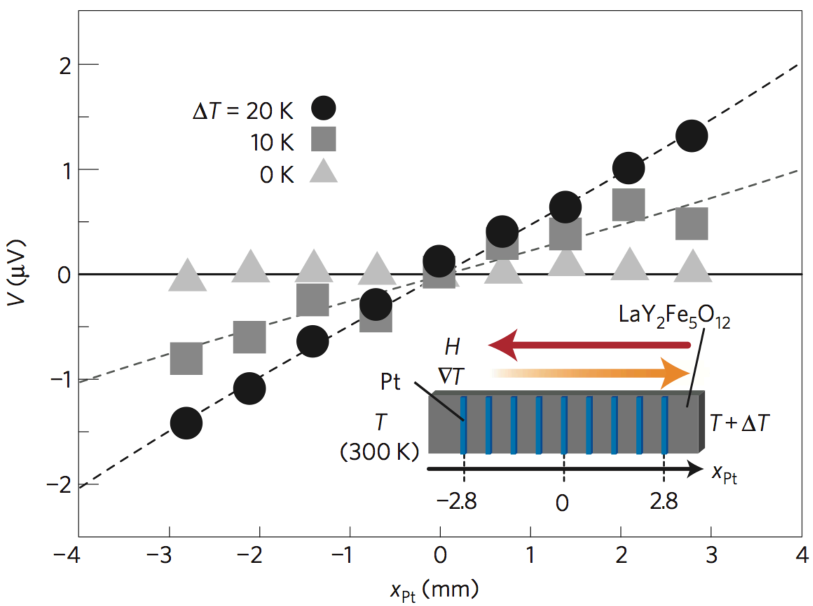
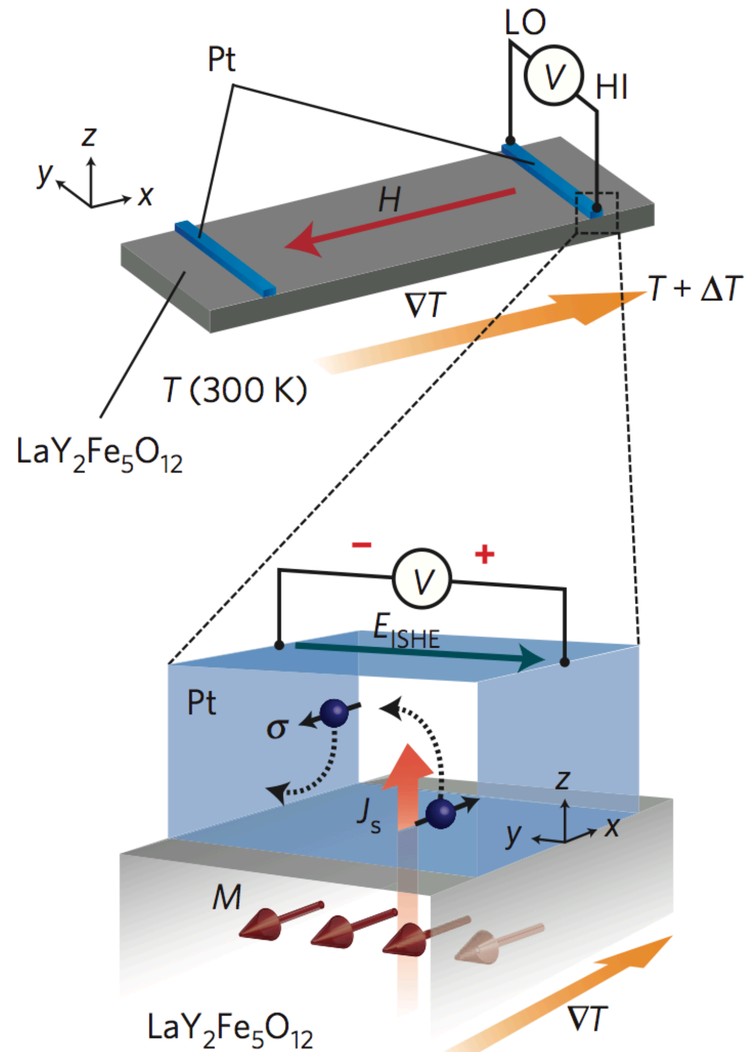
Net spin current injected into Pt

$$J_s = \frac{\gamma\hbar}{2\pi M_s V}\mathrm{Re}[g_{\uparrow\downarrow}]k_B(T_F - T_N)$$





K. Uchida et al., Nature Mater. **9**, 894 (2010).

J. Xiao et al., Phys. Rev. B **81**, 214418 (2010).

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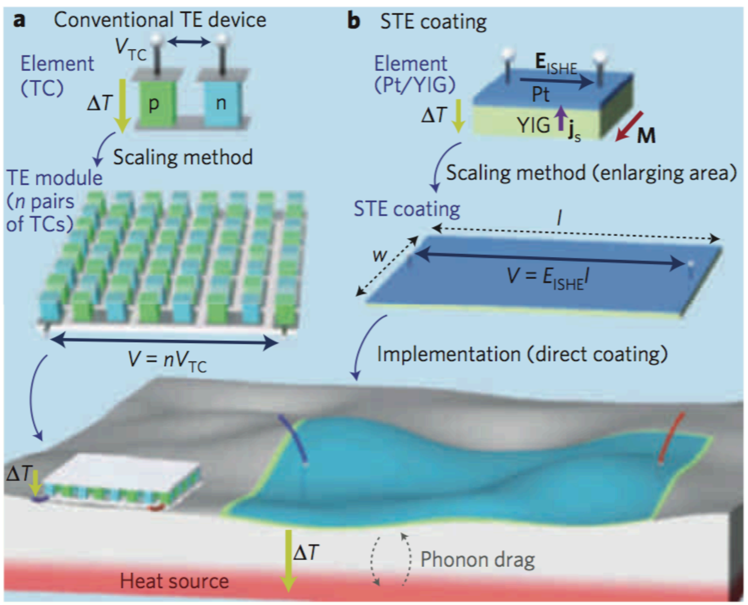
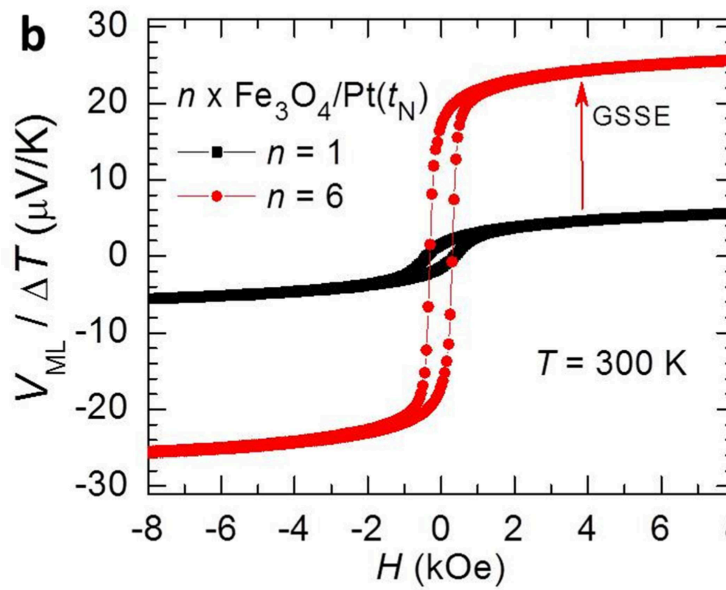
Ability to coat surfaces in continuous films



A. Kirihara et al.,
Nature Mater. **11**, 686 (2012).

Enhancement using multilayers



R. Ramos et al.,
arXiv **cond-mat.mtrl-sci**, (2015).

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Transverse dynamical susceptibility

Not known in general and enters the spin current term.

$$J_s = \frac{M_s V}{\gamma}\left(\frac{\alpha_N}{\alpha_F}\sigma_N^2 - \sigma_F^2\right)\int \chi_{xy}(\omega) - \chi_{yx}(\omega)\mathrm{d}\omega$$

$$\sigma_{F,N}^2 = \frac{2\alpha_{F,N}\gamma k_B T_{F,N}}{M_s V}$$

$$\alpha_N = \frac{\gamma\hbar}{4\pi M_s V}\mathrm{Re}[g_{\uparrow\downarrow}]$$

Assumption of simple FM

$$J_s = \frac{\gamma\hbar}{2\pi M_s V}\mathrm{Re}[g_{\uparrow\downarrow}]k_B(T_F - T_N)$$

Even exchange spin wave dispersion will determine the result.

J. Xiao et al., Phys. Rev. B **81**, 214418 (2010).

YIG – A COMPLICATED FERRIMAGNET

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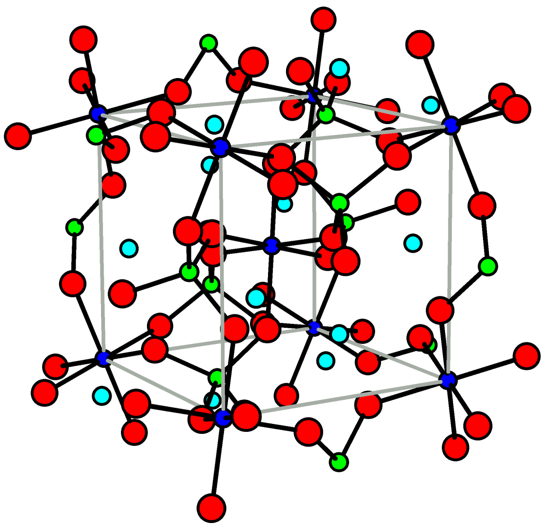
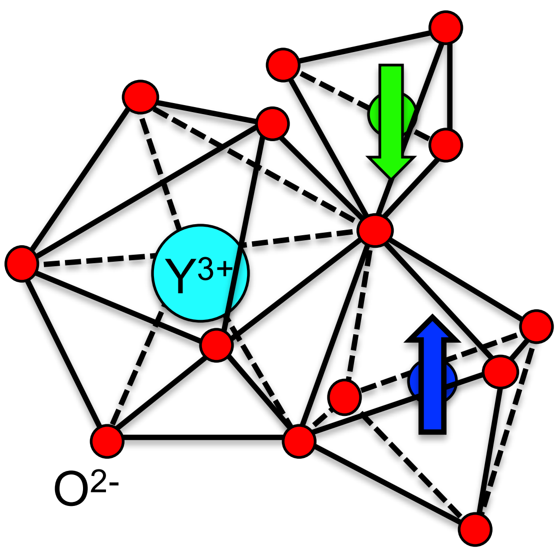
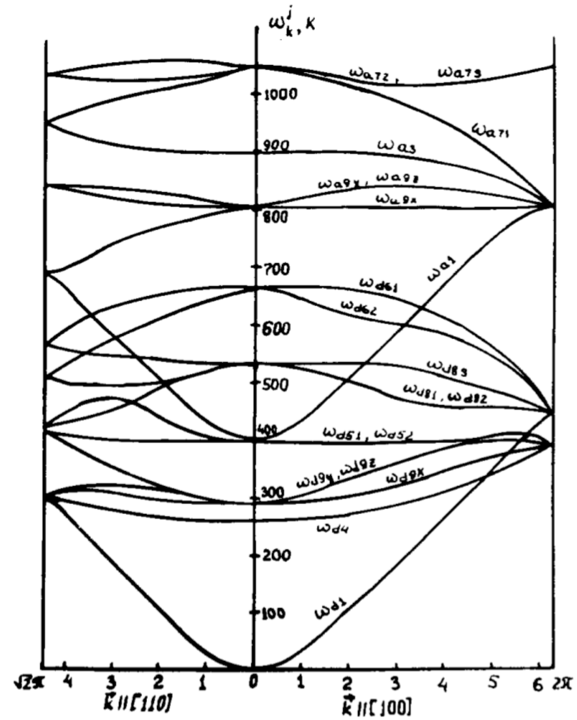


Fe^{3+} Tetrahedral (d)



Fe^{3+} Octahedral (a)

Spin wave spectrum of YIG



V. Cherepanov et al., Phys. Rep. **229**, 81 (1993)

$$\mathcal{H} = -\sum_{ij} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j$$

Nearest neighbour exchange interactions

J_{ad} = -39.8 K J_{dd} = -13.4 K J_{aa} = -3.8 K

V. Cherepanov et al. *Phys. Rep.* ***229**, 81 (1993)*

Landau-Lifshitz-Gilbert

Equation of motion for a classical spin in a local field.

$$\frac{\partial \mathbf{S}_i}{\partial t} = -\frac{\gamma_i}{(1+\alpha_i^2)} \left(\mathbf{S}_i \times \mathbf{H}_i + \alpha_i \mathbf{S}_i \times \mathbf{S}_i \times \mathbf{H}_i \right)$$

Langevin thermostat

Equation of motion for a classical spin in a local field.

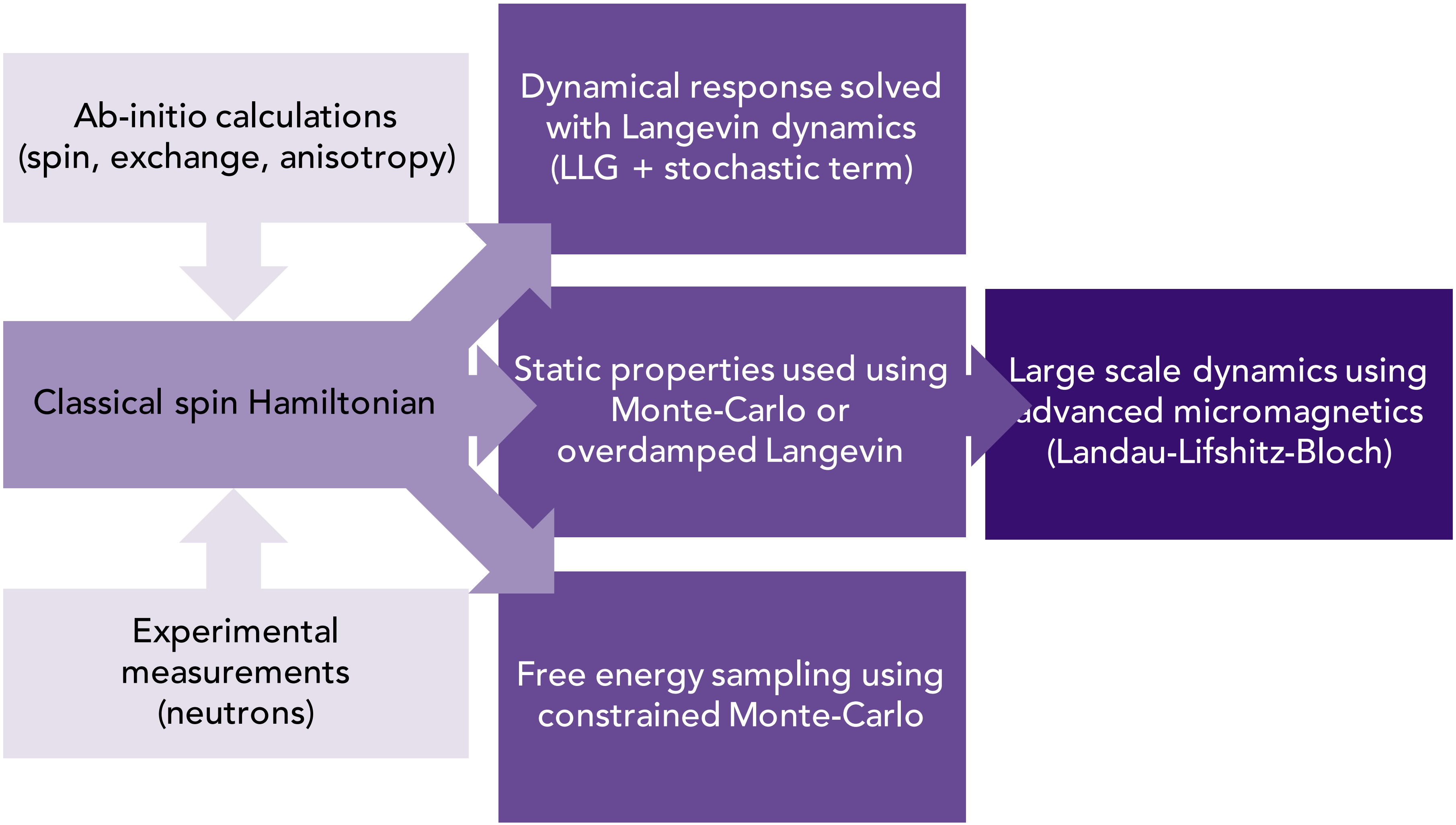
$$\mathbf{H}_i(t) = -\frac{\partial \mathcal{H}}{\partial \mathbf{S}_i} - \eta \int_{-\infty}^{t} \varphi(t-t') \frac{d\mathbf{S}_i}{dt'} dt' + \boldsymbol{\xi}_i(t)$$

$$\langle \xi_{i,a}(t) \rangle = 0$$
$$\langle \xi_{i,a}(t), \xi_{j,b}(t') \rangle = 2 k_B T \eta \varphi(|t-t'|) \delta_{ij} \delta_{ab}$$

$$\varphi(|t-t'|) = \delta(|t-t'|)$$

White noise is usually used, coloured noise adds significant computational overhead.

ASD - MULTISCALE MODELLING



Atomistic model allows the study of finite temperature effects
Spin wave interactions to arbitrary order

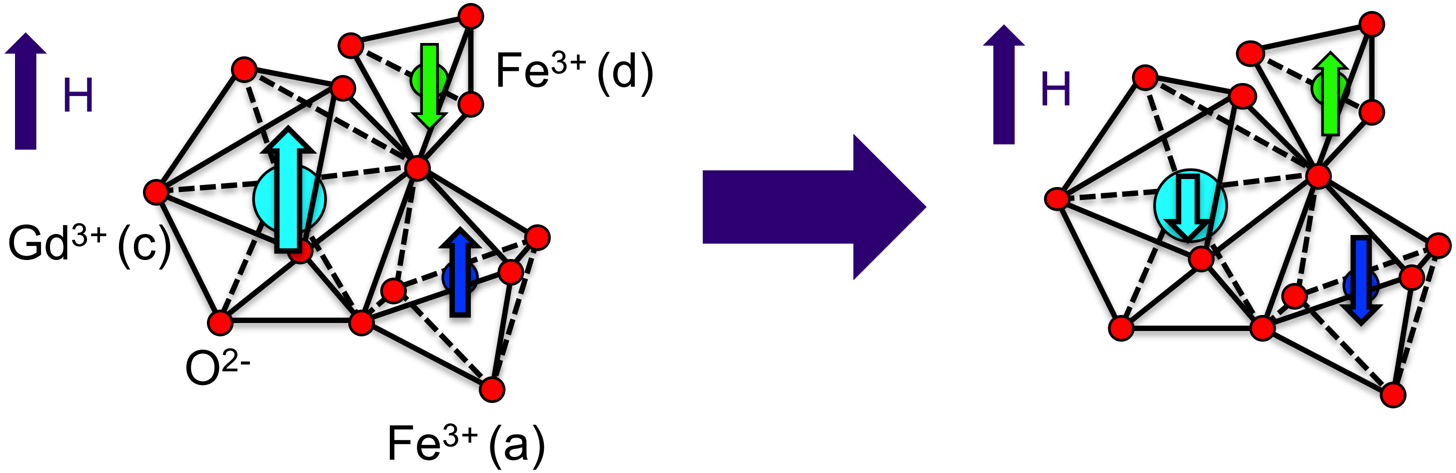
$$\mathcal{S}_k\left(\mathbf{q},\omega\right) = \frac{1}{\mathcal{N}\sqrt{2\pi}} \sum_{\mathbf{r},\mathbf{r}'} \mathrm{e}^{\mathrm{i}\mathbf{q}\cdot\left(\mathbf{r}-\mathbf{r}'\right)} \int_{-\infty}^{+\infty} \mathrm{e}^{\mathrm{i}\omega t}\; C_k\left(\mathbf{r}-\mathbf{r}',t\right)\mathrm{d}t$$

Spin-spin correlation function

$$C_k(\mathbf{r}-\mathbf{r}',t) = \langle S_k(\mathbf{r},t)S_k(\mathbf{r}',0)\rangle - \langle S_k(\mathbf{r},t)\rangle\langle S_k(\mathbf{r}',0)\rangle$$

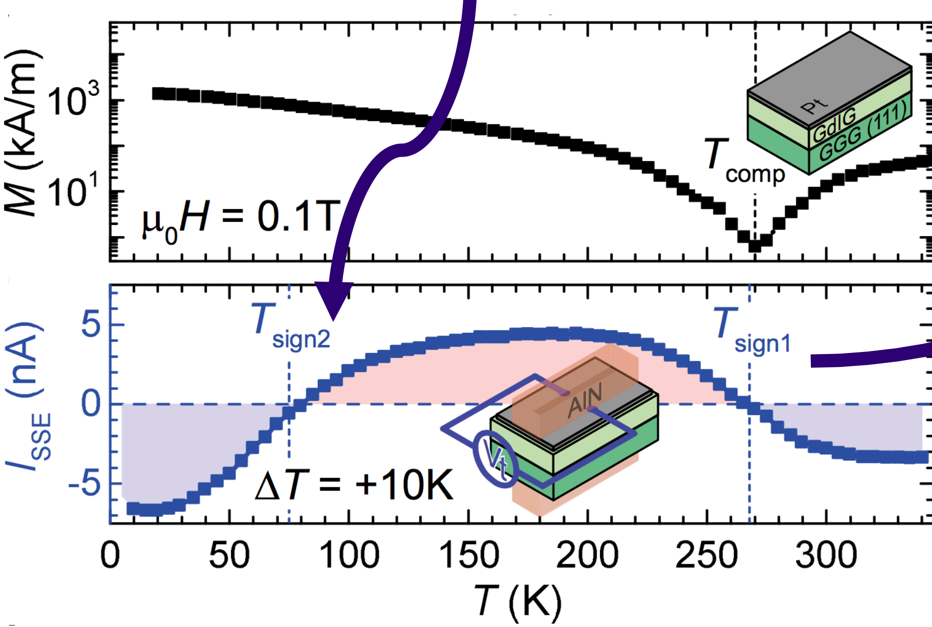
- Space-time Fourier transform
- The same quantity is measured in neutron scattering
- K-space resolution is limited by lattice size
- Frequency resolution is limited by simulation time

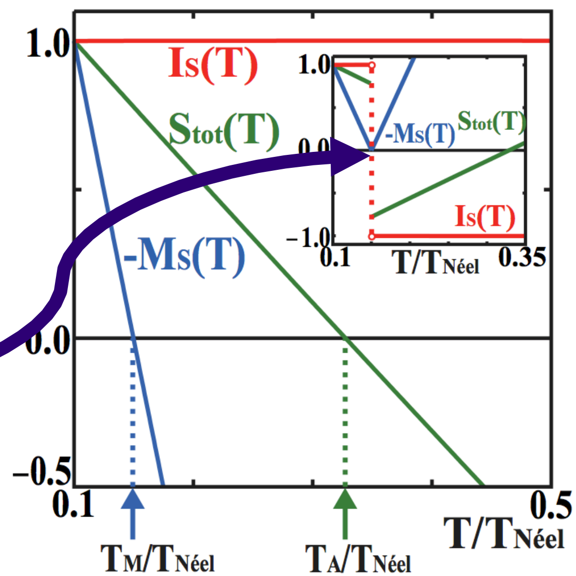
GIG – TWO SSE SIGN CHANGES



No macroscopically observable changes ?

Reorientation through T_{comp} reverses SSE sign





Y. Ohnuma et al.
Phys. Rev. B **87**, 014423 (2013).

- Quantitative analysis for direct comparison to experiments.
- Many different rare-earth iron garnets to investigate.
- Look at interface effects including disorder.
- Improve understanding to maximize the voltage from SSE.