Curie Weiss model in h-$YbFeO_3$

Xiaoshan Xu

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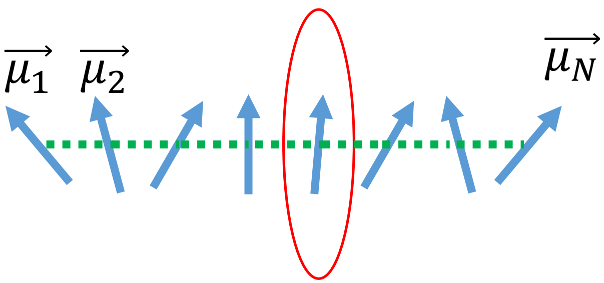
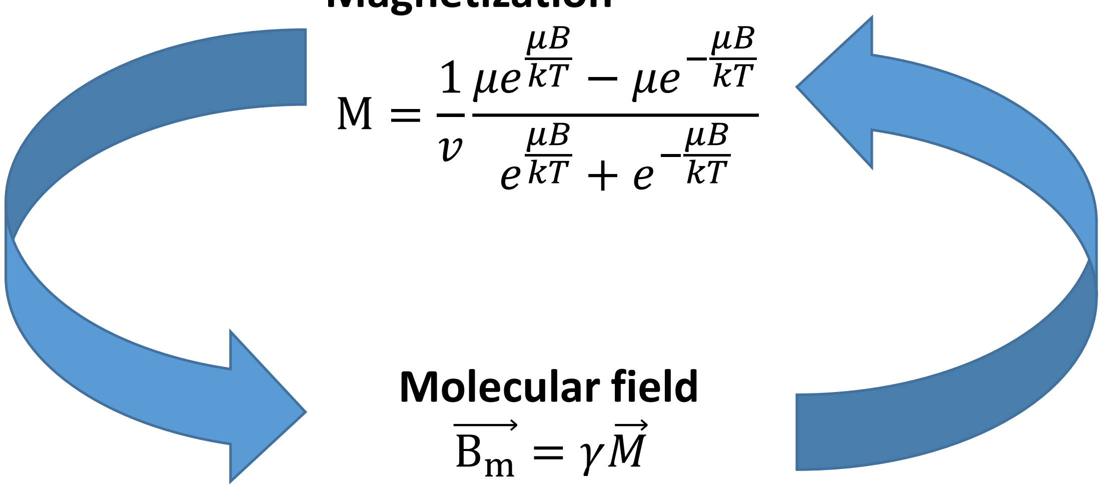
Interaction between Fe^{3+} and Yb^{3+}

Weiss molecular field model

- The moments are aligned because of exchange interaction
- The exchange interaction can be modeled by an mean molecular field (mean field)
- Molecular field $\overrightarrow{\mathrm{B_m}} = \gamma \vec{M}$, $\vec{M}$ is the magnetization, γ is the coefficient.
- $\vec{M} = \frac{\sum \overrightarrow{\mu_i}}{V} = \frac{<\overrightarrow{\mu_i}>}{v}, < \mu >= \frac{\mu e^{\frac{\mu B}{kT}} - \mu e^{-\frac{\mu B}{kT}}}{e^{\frac{\mu B}{kT}} + e^{-\frac{\mu B}{kT}}}$



$\overrightarrow{\mathrm{B_m}} = \gamma \vec{M}$



Magnetization

$$\mathrm{M} = \frac{1}{v} \frac{\mu e^{\frac{\mu B}{kT}} - \mu e^{-\frac{\mu B}{kT}}}{e^{\frac{\mu B}{kT}} + e^{-\frac{\mu B}{kT}}}$$

Magnetization of other moment collectively becomes the molecular field

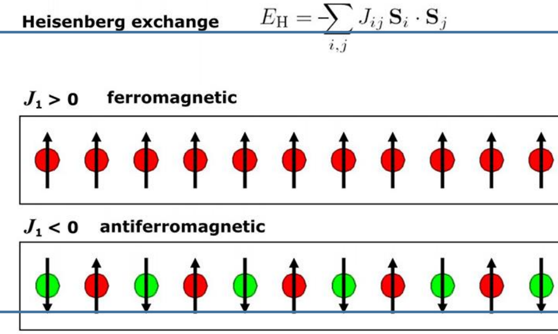
The individual moment gets magnetized because of molecular field

Molecular field

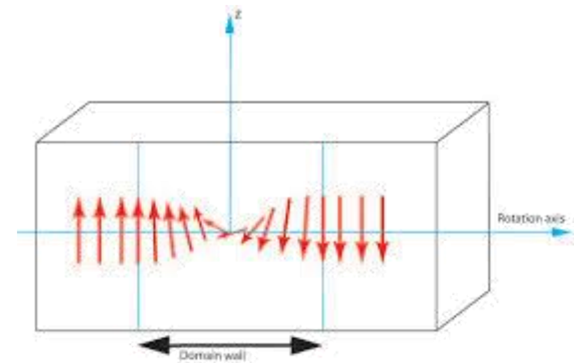
$\overrightarrow{\mathrm{B_m}} = \gamma \vec{M}$

Levels of details for ferromagnets

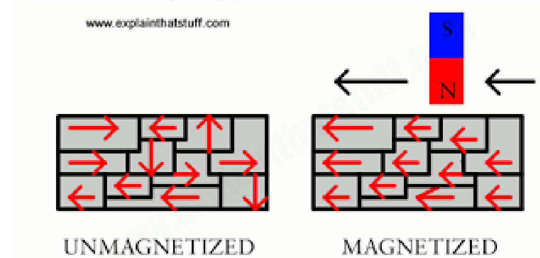
- Atomic level:
  - Exchange interaction that aligns atomic moments $J_{ij}\overrightarrow{S_i}\cdot\overrightarrow{S_j}$



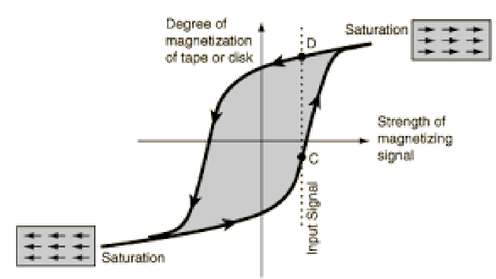
- Micromagnetic level
  - Smear the individual atoms into continuum, see magnetization as a function of position (domain wall)



- Domain level
  - Domains are separated by walls of zero thickness



- Nonlinear level
  - Average magnetization of the entire magnet



Equations of Weiss model

$$M = \frac{1}{v}\frac{\mu e^{\frac{\mu B}{kT}} - \mu e^{-\frac{\mu B}{kT}}}{e^{\frac{\mu B}{kT}} + e^{-\frac{\mu B}{kT}}},\ \mathrm{x} \equiv \frac{\mu B}{kT}$$

Then $M = \frac{1}{v}\frac{\mu e^{x} - \mu e^{-x}}{e^{x} + e^{-x}} \approx \mathrm{L(x)}$, $\mathrm{L(x)}$ is the Langevin function.

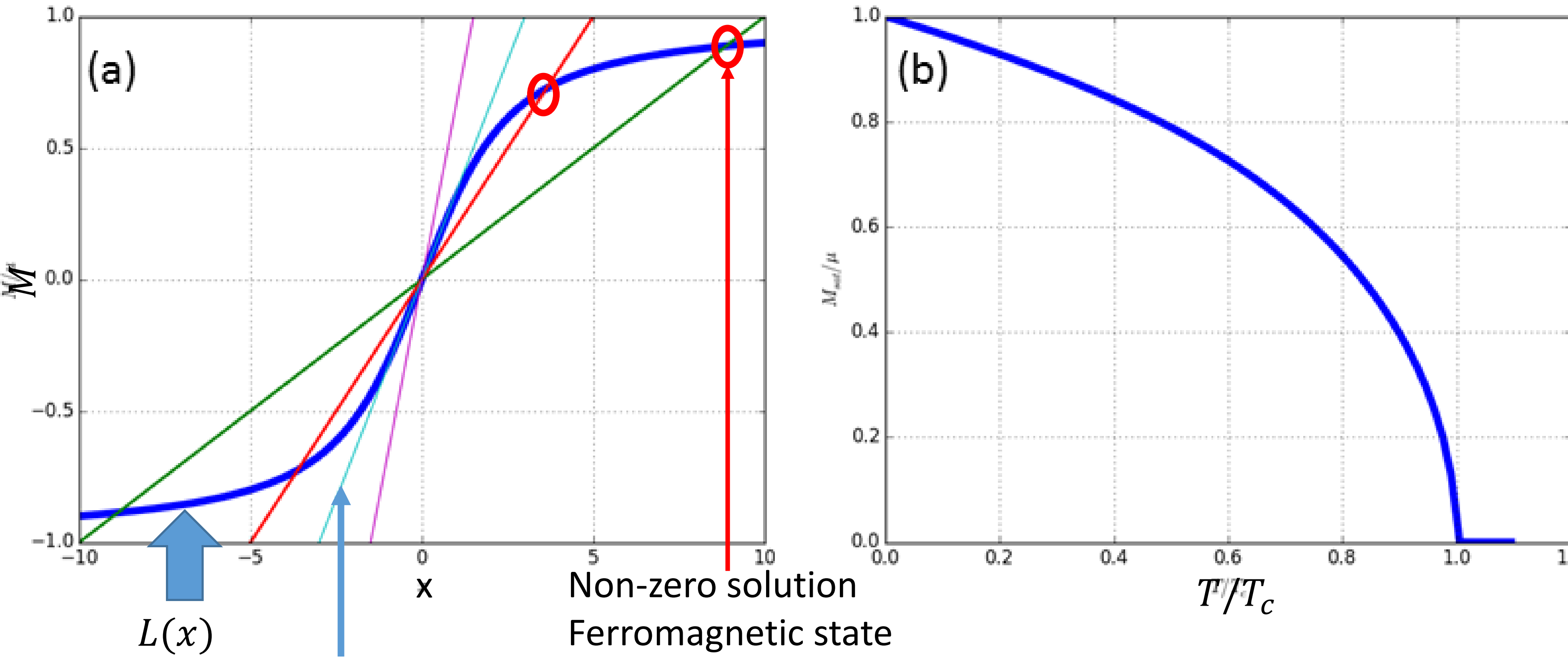
$$M = \frac{\mu}{\mathrm{v}}\mathrm{L(x)}$$

$$\mathrm{x} \equiv \frac{\mu\gamma M}{kT}$$

Solutions of Weiss Model

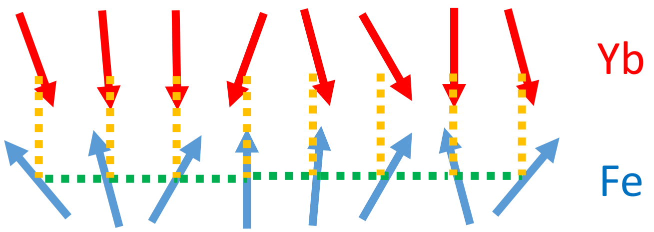
$$M = \frac{\mu}{v} L(x)$$

$$x \equiv \frac{\mu \gamma M}{kT}$$



$$x \equiv \frac{\mu \gamma M}{kT} \text{ or } M = \frac{kT}{\mu \gamma} x$$

Application on h-YbFeO3



Molecular field on Fe:

$\gamma_{YbFe} M_{Yb} + \gamma_{Fe} M_{Fe}$

Molecular field on Yb:

$\gamma_{YbFe} M_{Fe}$

$$M_{Fe} = \mu_{Fe} L(x_{Fe})$$

$$x_{Fe} = \frac{(\gamma_{YbFe} M_{Yb} + \gamma_{Fe} M_{Fe})\mu_{Fe}}{k_B T}$$

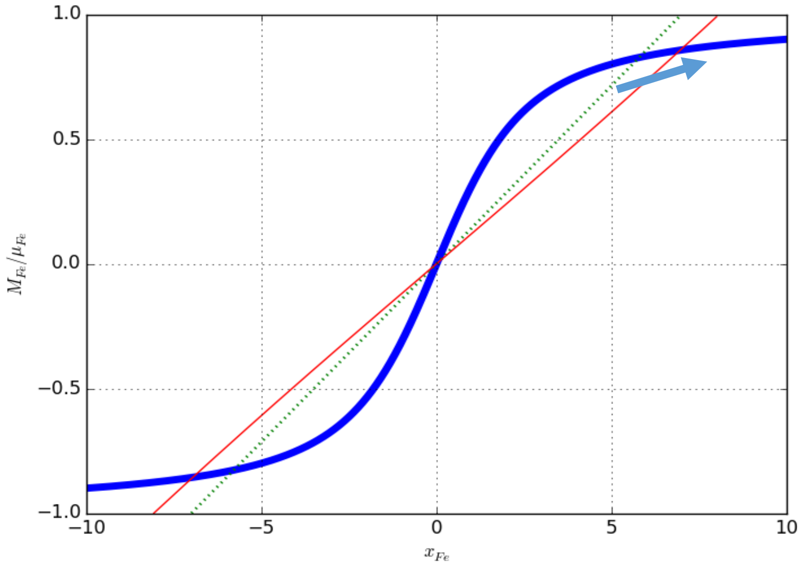
$$M_{Yb} = \mu_{Yb} L(x_{Yb})$$

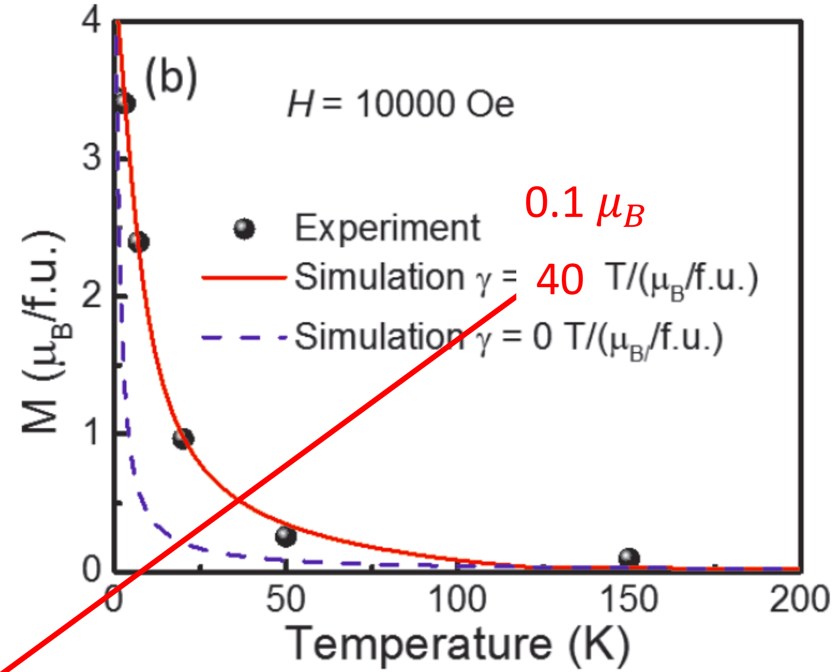
$$x_{Yb} = \frac{\gamma_{YbFe} M_{Fe} \mu_{Yb}}{k_B T}$$

$$M_{Fe} = \mu_{Fe} L(x_{Fe})$$

$$x_{Fe} = \frac{\left[\gamma_{YbFe} \mu_{Yb} L\left(\frac{\gamma_{YbFe} M_{Fe} \mu_{Yb}}{k_B T}\right) + \gamma_{Fe} M_{Fe}\right]\mu_{Fe}}{k_B T}$$

Enhancement on Fe moment





Fe→Fe: $H_{c,Fe} = \gamma_{Fe}\mu_{Fe} = 5.3 \times 10^3$ tesla

Fe→Yb: $H_{c,Yb} = \gamma_{YbFe}\mu_{Fe} = 4$ tesla

Yb→Fe: $H_{c,Fe-Yb} = \gamma_{YbFe}\mu_{Yb}$

$$M_{Yb} = \mu_{Yb} L\left(\left[\frac{(\gamma_{YbFe}M_{Fe} + B_{ext})\mu_{Yb}}{k_B T}\right]\right)$$

$$H_{c,Yb} = \gamma_{YbFe}M_{Fe}$$

Conclusion

- The general picture of magnetism in h-$YbFeO_3$ can be understood using the molecular field model
- The magnetic moment on Yb^{3+} needs to be studied, which is critical for any further study