Magnetic Phase Transition and Spin-wave Dispersion in $La_{0.7}Sr_{0.3}MnO_3$

Group C Members:

Zoghbi, Bilal; Chi, Songxue; Dailly, Anne; Graetz, Jason; Guo, Song; Kim, JungHwa; Svitelskiy, Oleksiy; Youk, Hyun

Group B Members:

Li, Jiying; Clancy, Patrick; Fullerton, Susan; Lee, Ted; Savici, Andrei; Shogbon, Chris; Stowe, Ashley; Hsieh, David

Beam Scientist and Staff at SPINS:

Jae-Ho Chung, William Ratcliff and Owen Vajk

NIST Center for Neutron Research, National Institute of Standard and Technology, Gaitherburgy, MD USA

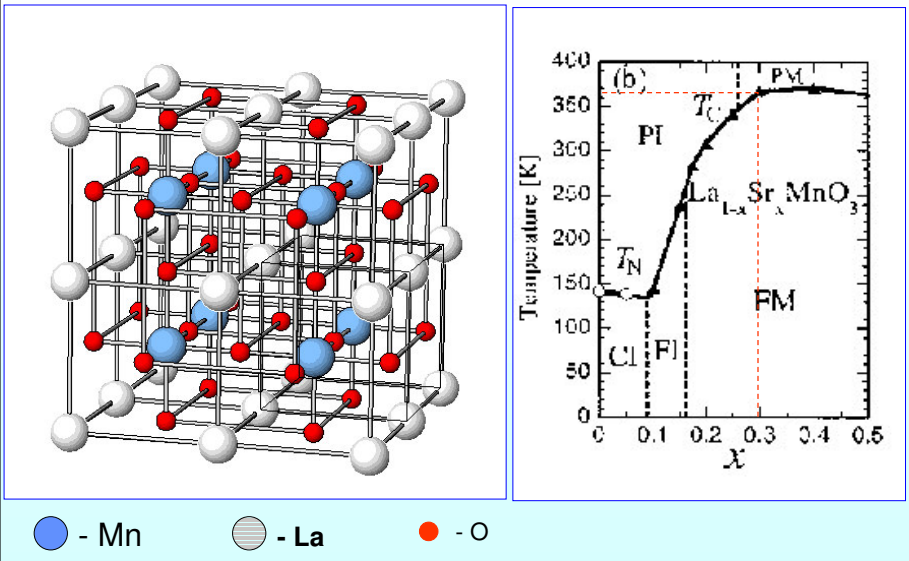
Outline

- Motivation.
- Introduction.
- Experimental set-up.
- Magnetic phase transition.
- Temperature dependent spin-wave dispersion.
- Temperature dependent spin wave stiffness constant.
- Acknowledgments.

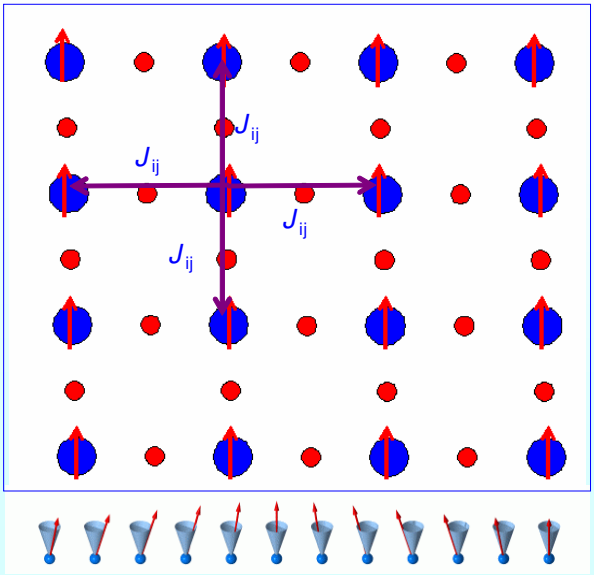
Motivation

1. Gain basic understanding of the principles and operations of the Triple Axis Spectrometer.
2. Observe the ferromagnetic phase transition in the perovskite $La_{0.7}Sr_{0.3}MnO_3$ and its spin-wave dispersions due to cooperative fluctuations of ordered spins.

Introduction – Atomic Structure and Phase Transition



Introduction – Spin Wave



Isotropic Hamiltonian:

$$H = J_{i,j}\sum_{i,\varsigma} S_i S_{i+\varsigma}$$

$$wh = JS\sum_{\varsigma}(k\cdot\varsigma)^2$$

If $|k\cdot\varsigma| \ll 1$

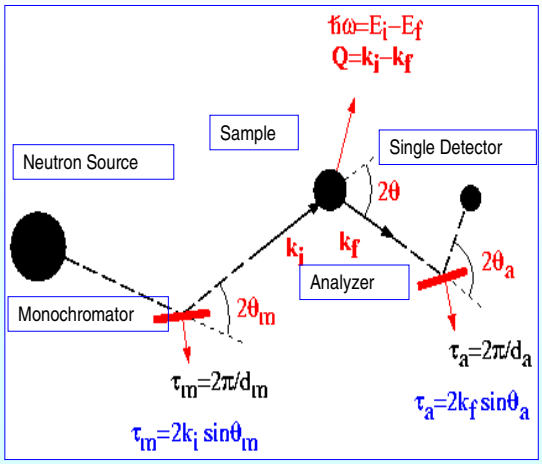
$$= 2JS(ka)^2$$

Therefore, the spin-wave dispersion in ferromagnet is

$E = 2JSa^2k^2$

$=DK^2$

Schematic of SPINS

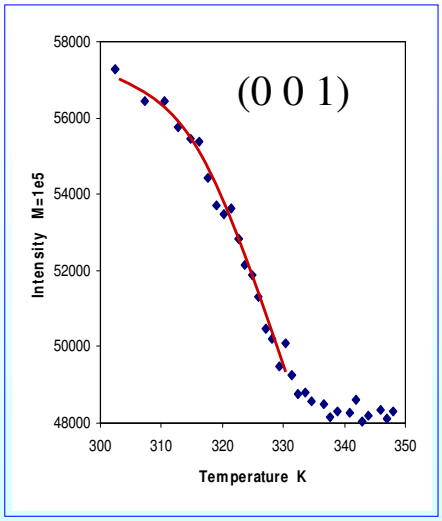


- Incident Energy
  - 14 ~ 2 meV (2.4 ~ 6.1 Å)
- Energy Resolution
  - 0.02 ~ 1 meV
- Special Equipments
  - Supermirror Transmission Polarizer
    - A stack of single crystal Si plates with Fe/Si supermirror coatings
  - Multi-crystal Analyzer
    - 11 Horizontally Focusing PG Blades
  - Position Sensitive Detector
    - 3He, 20 × 25 cm2
  - Filters
    - PG or Be filters before sample
    - Be or BeO filters after sample

Experimental Set-up

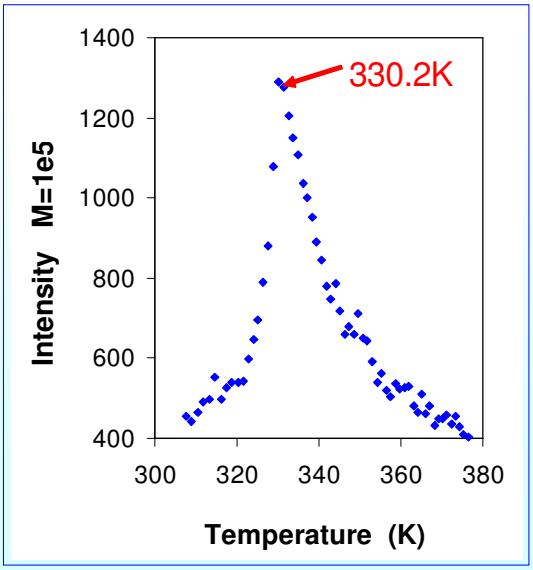
1. A 4 gram $La_{0.7}Sr_{0.3}MnO_3$ single crystal is mounted on an aluminum post and sealed in an aluminum container. The temperature control is achieved by a closed-cycle displex. The scattering plane is (hhl).
2. A monochromatic neutron beam of wavelength λ = 4.76 Å (3.6 meV) was selected using the (0, 0, 2) Bragg reflection of highly oriented pyrolytic graphite (HOPG) crystal analyzer.
3. The collimation configuration 38`-80`-sample-80`-open was used throughout the experiments.
4. The λ/2 contamination was removed by a BeO filter.
5. The experimental data were analyzed using DAVE software package

Magnetic Phase Transition



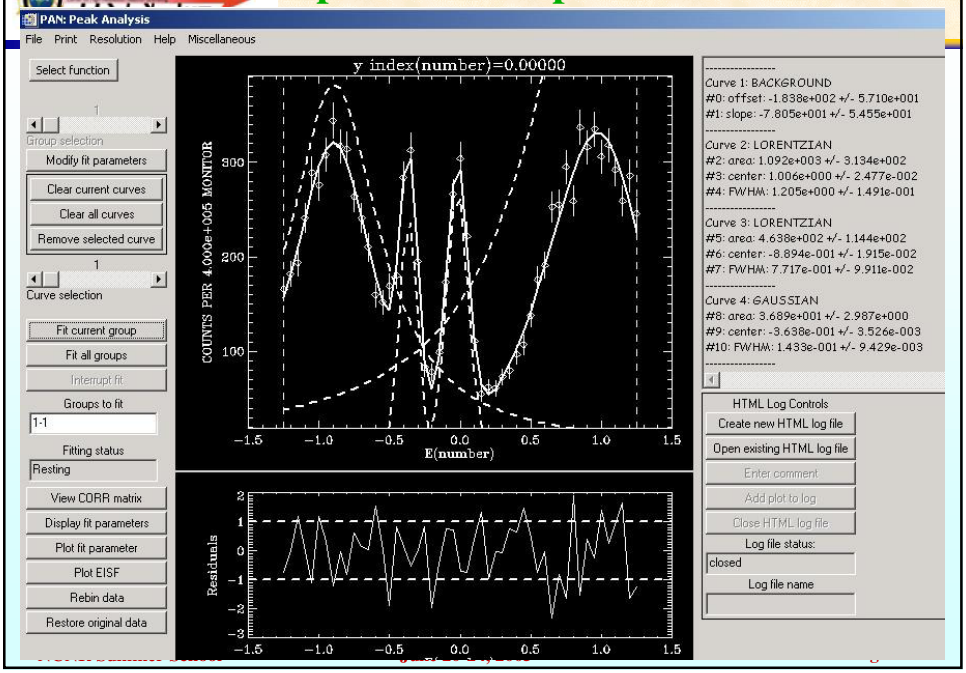
I ~ (1-T/Tc)$^{2\beta}$, the fitted parameters Tc =330K and β= 0.333

Magnetic Phase Transition

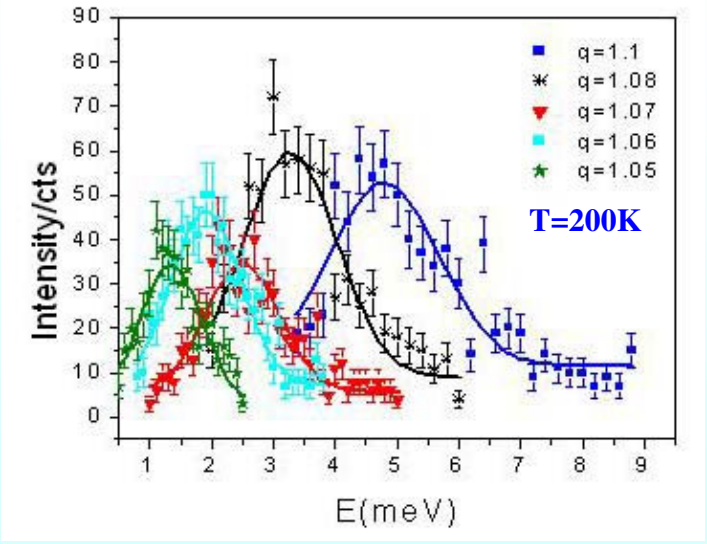


Quasi-elastic Critical scattering at (0, 0, 1.03)

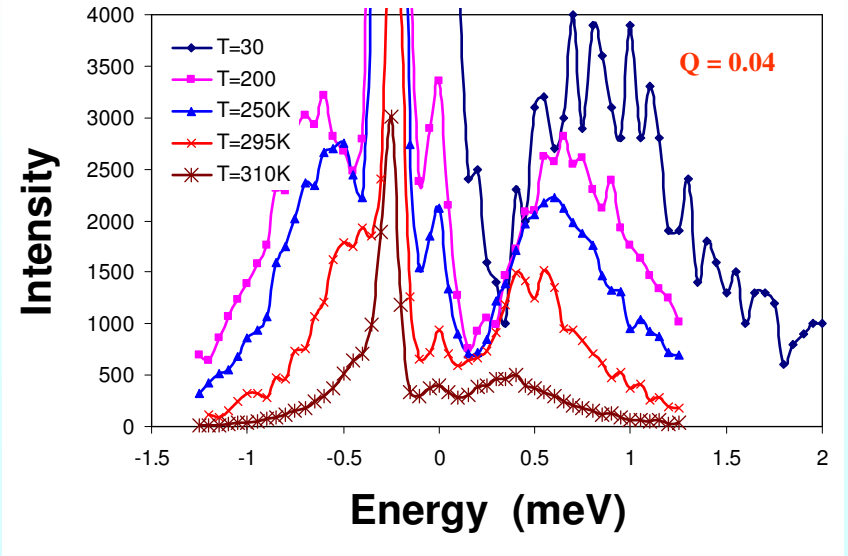
Spin-wave Dispersion



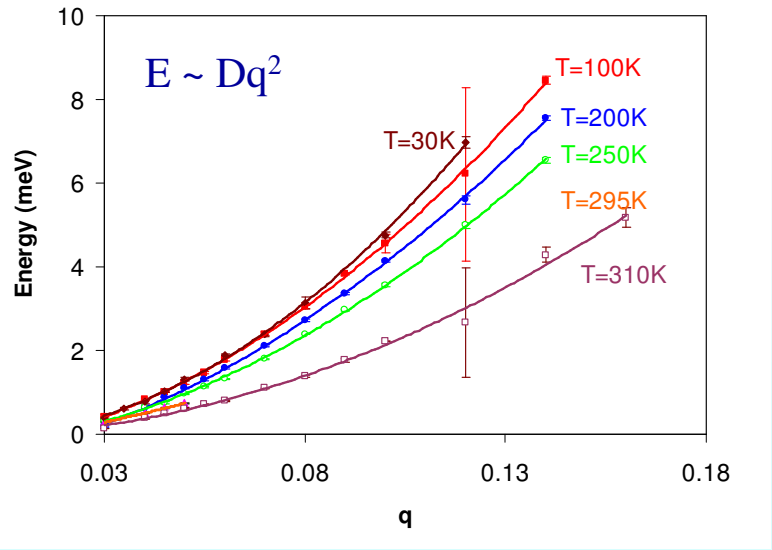
Q Dependent Spin-wave Excitation



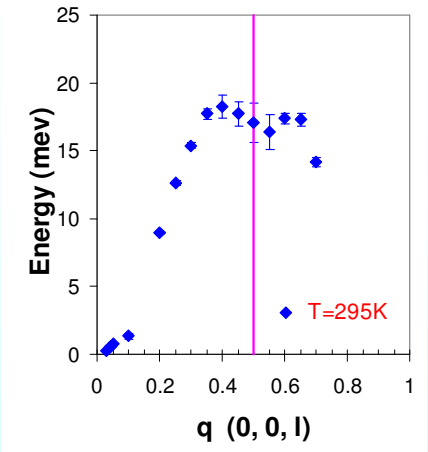
Temperature Dependent Spin-wave Excitation

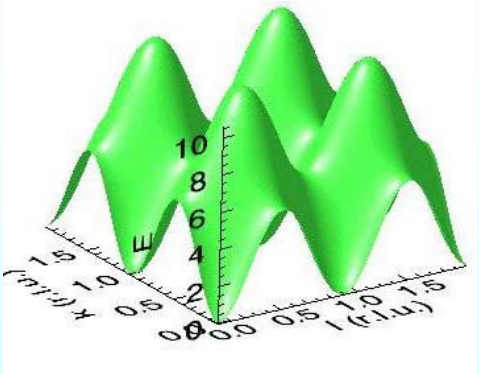


Spin-wave Dispersion at Different Temperatures



Spin-wave at Q

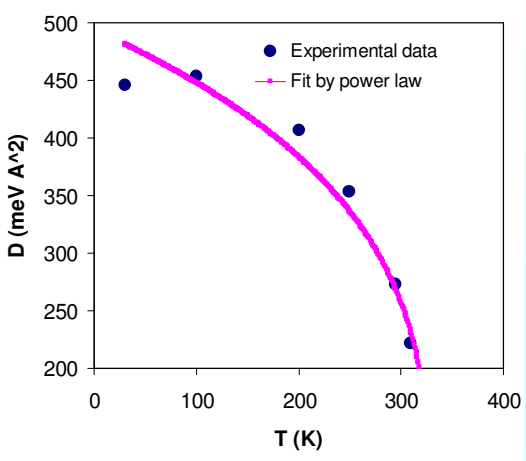




E=4JS(2-cos(2pi*k)-cos(2*pi*l)

Temperature dependent spin-wave stiffness constant

	30K	100K	200K	250K	295K	310K
D	446	453	407	354	273	222



The Fitted equation is:

$D = 494*(1-T/330)^{0.2711}$

The critical exponent for the correlation length below Tc is:

$\nu' = 0.2711 + \beta$

$=0.6041$

$\beta = 0.333$

Conclusions

1. The magnetic phase transition from paramagnetic to ferromagnetic is around 330K.
2. The spin-wave dispersion was measured as function of q between 30 K and 310 K.
3. Spin wave stiffness increased with decreasing temperature.
4. The critical exponent of the temperature dependent magnetization β =0.3, and ν'=0.6 which is consistent with critical value for isotropic 3D Heisenberg ferromagnet.

Acknowledgements

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5. Julie Keyser for the travel arrangement.
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