# Spin Wave Excitations in the Colossal Magnetoresistive Manganite $La_{0.7}Sr_{0.3}MnO_3$

NCNR Neutron Scattering Summer School 2015

Group B: BT-7 Triple Axis Spectrometer

Connor Roncaioli

Alexander Zakjevskii

I-Lin Liu

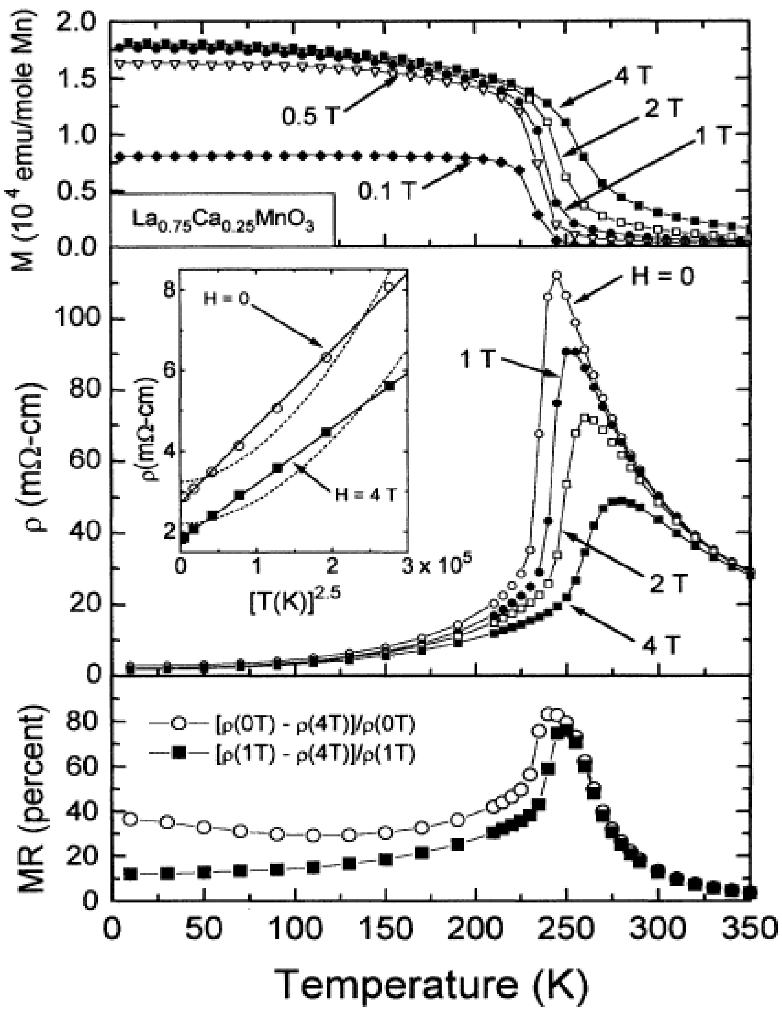
Shu Zhang

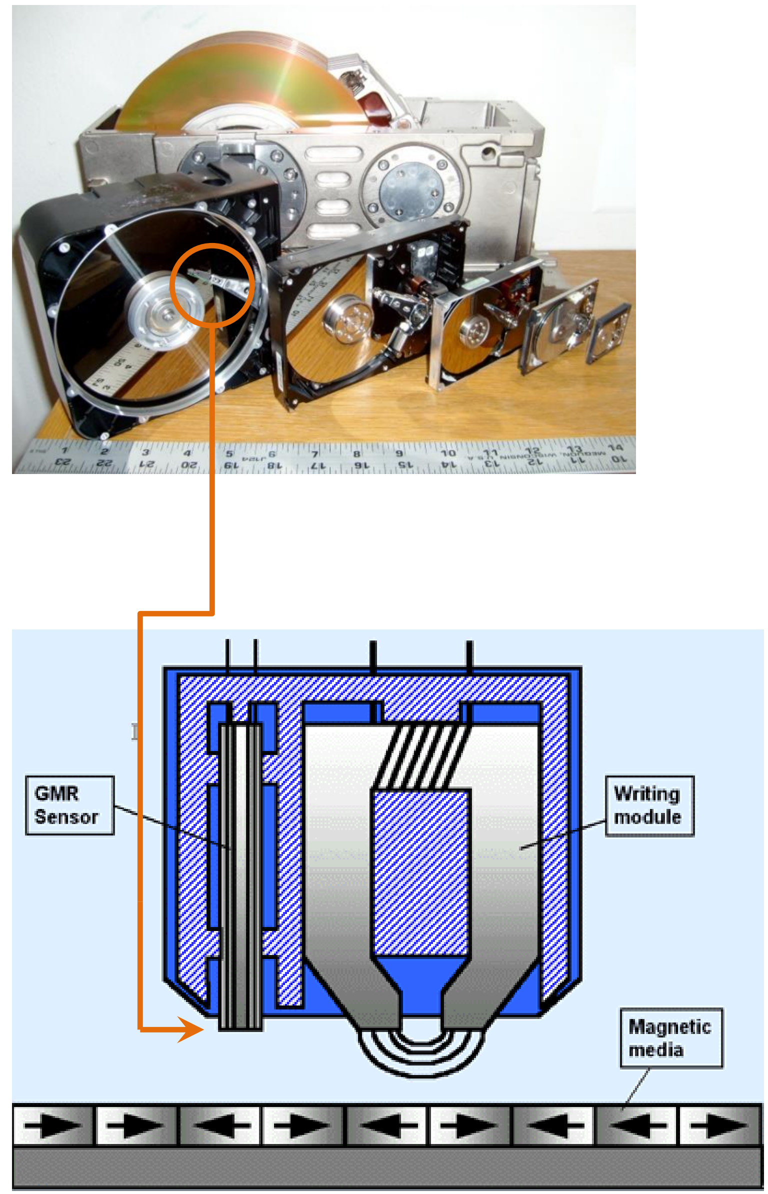
Ming Yi

Tianran Chen

Jacob Lamanna

# Colossal Magnetoresistance



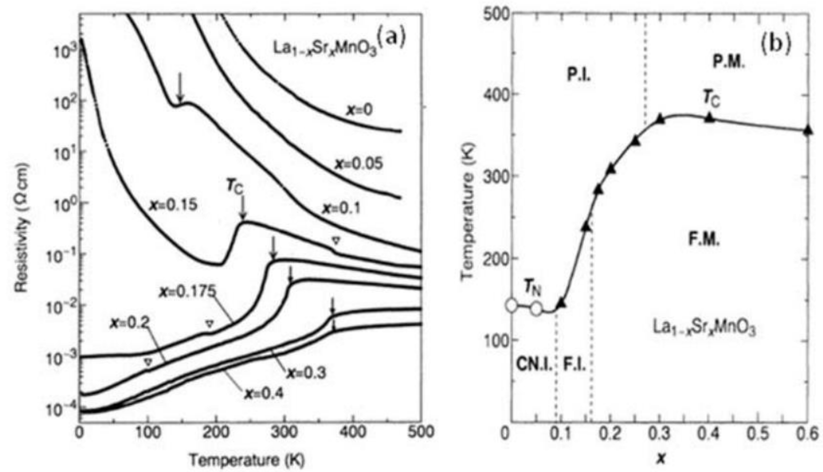



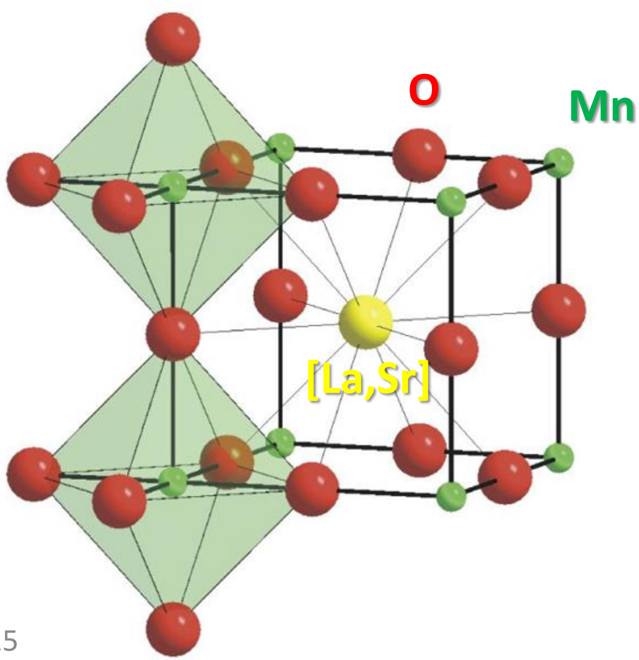
# $La_{1-x}Sr_xMnO_3$

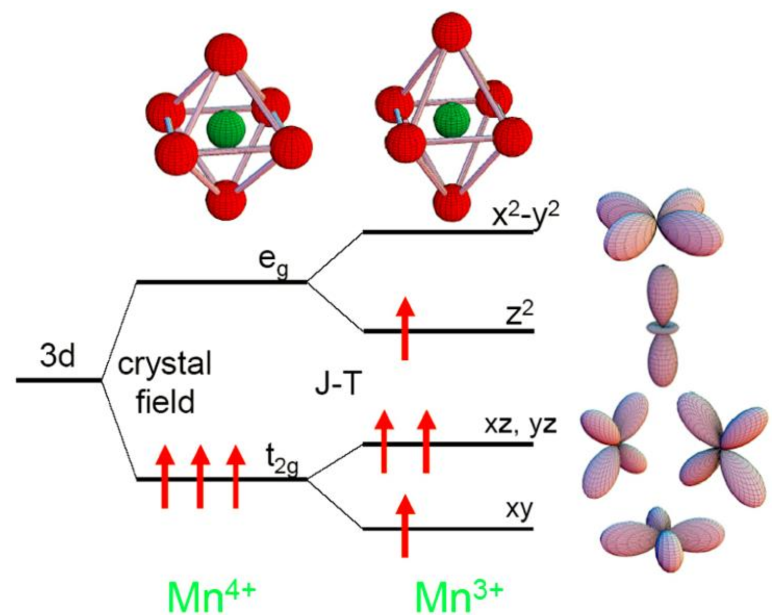
Perovskite Structure

Hole doping introduces $Mn^{4+}$ sites.

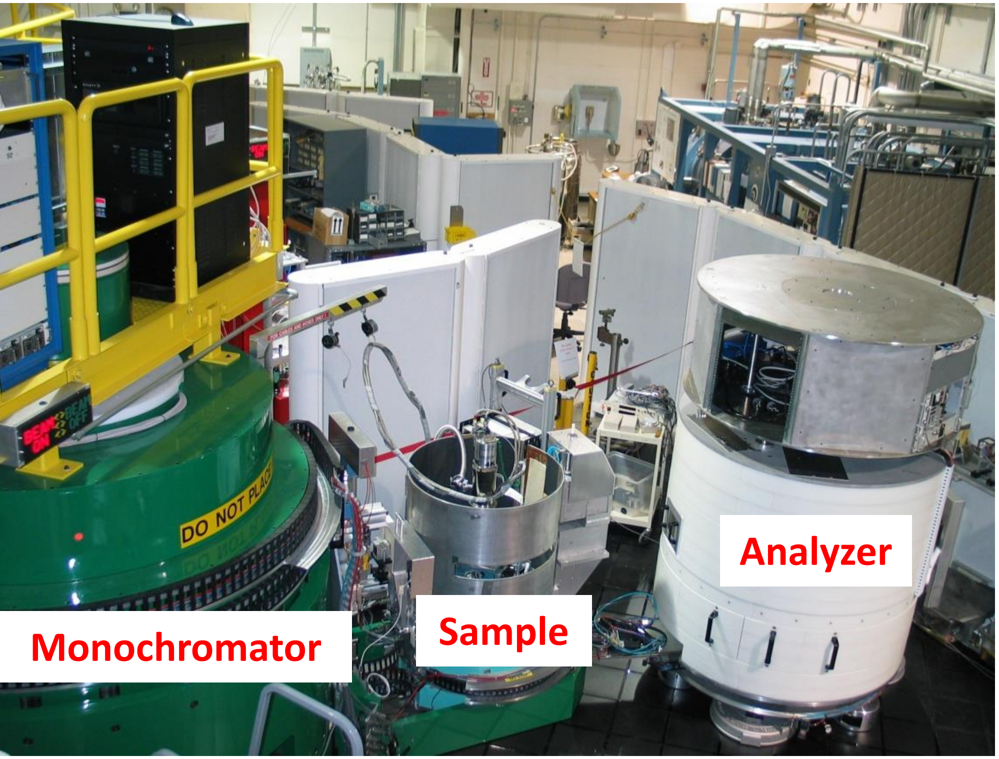
Degeneracy of the ground state allows the magnetic moments to become itinerant, leading to the magnon state.



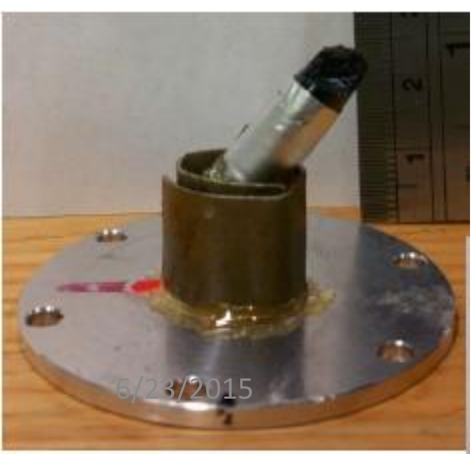



# BT-7 Triple Axis Spectrometer



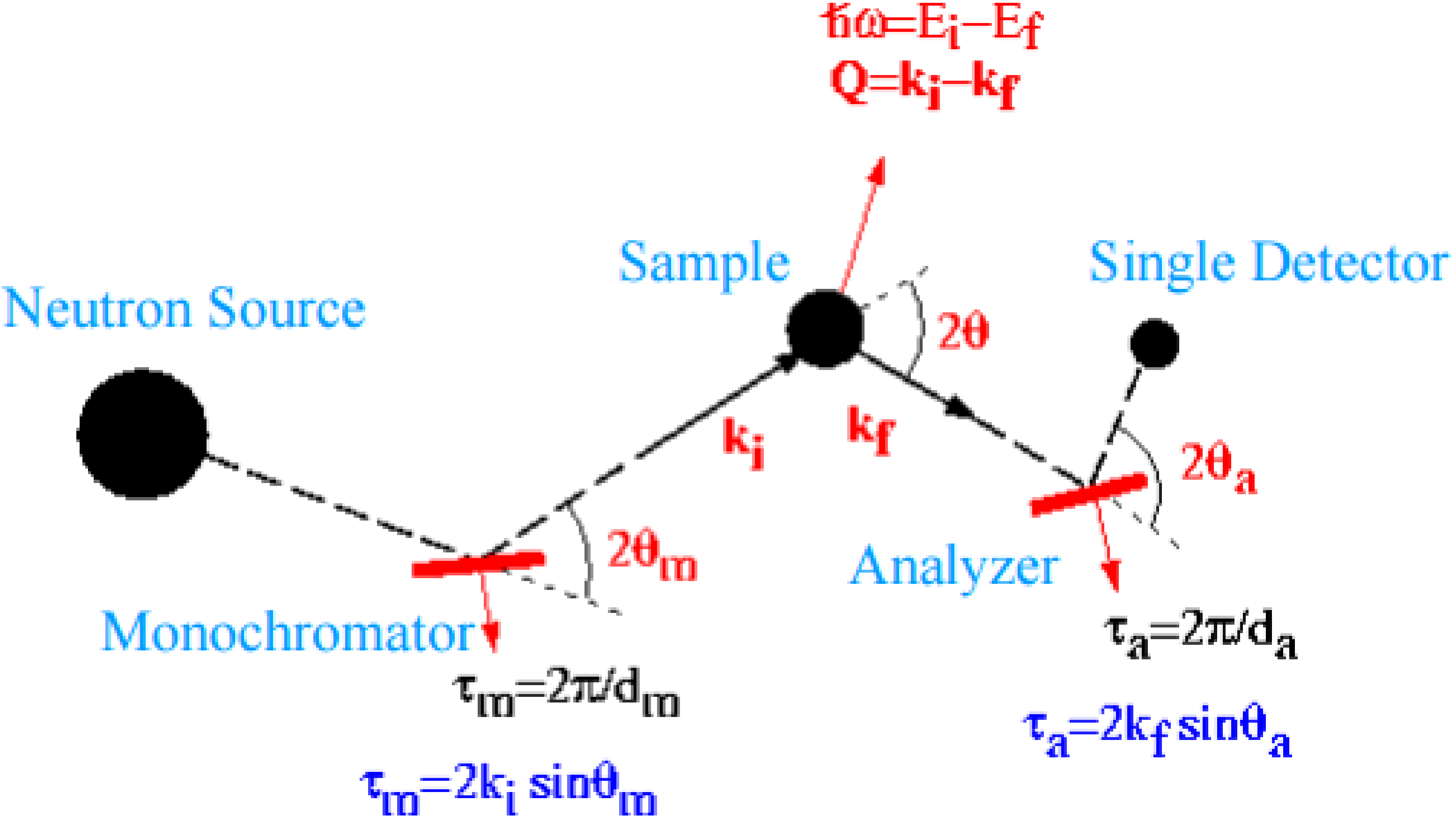

Choice of spectrometer:

- High Flux
- Steep dispersion requires large E ~10-20 meV
- Large Q

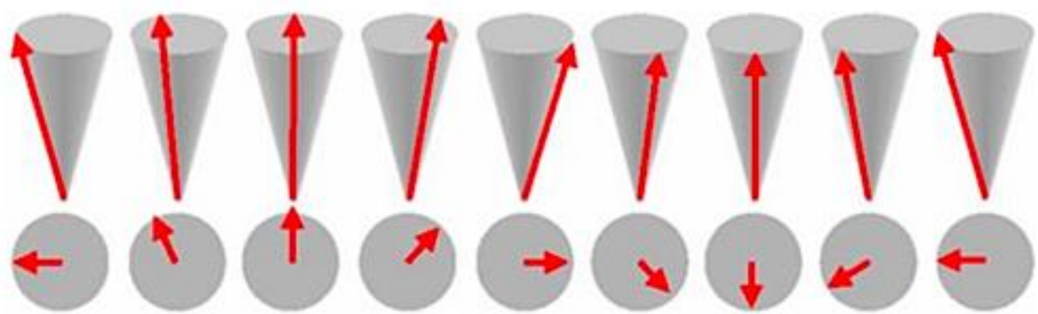


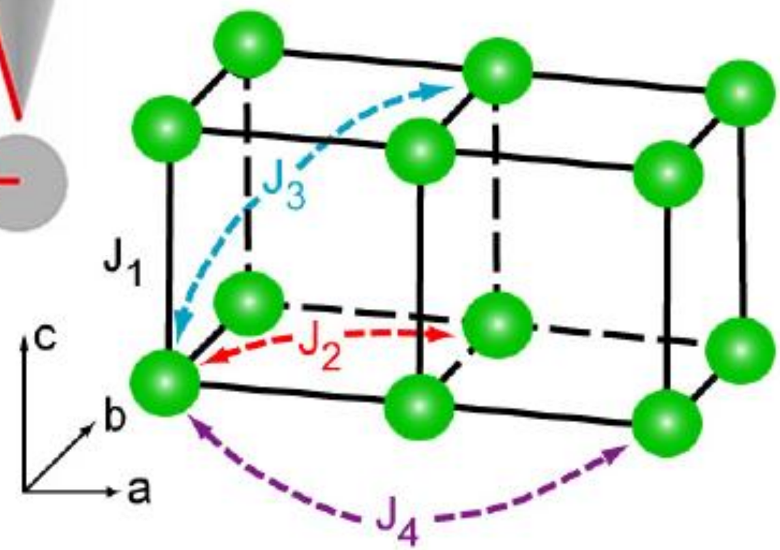
$La_{0.7}Sr_{0.3}MnO_3$ single crystal mounted on standard CCR

# Triple-Axis Spectrometer



# Spin Wave






$$H = -\frac{1}{2}\sum_{i,j} J_{i,j}\mathbf{S}_i \cdot \mathbf{S}_j$$

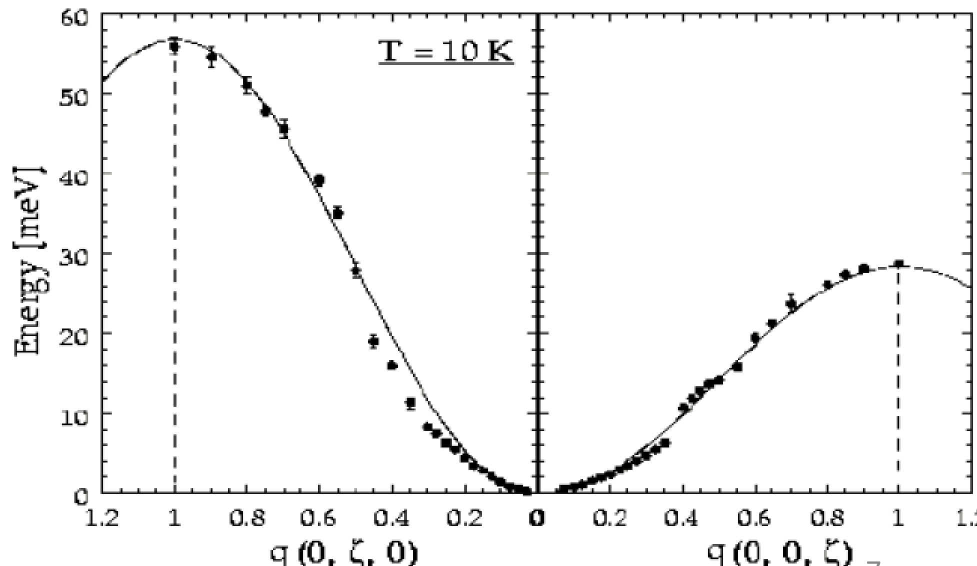
**$S_i$ : vector operator of $i^{th}$ Spin**
**J : exchange constant (magnetic exchange)**
**Competition of Coulomb repulsion and Pauli exclusion principle**

$$E_{spinwaves} = \Delta(T) + D(T)q^2 + E(T)q^4 + \ldots$$

***D*** **: the spin-wave "stiffness" parameter**

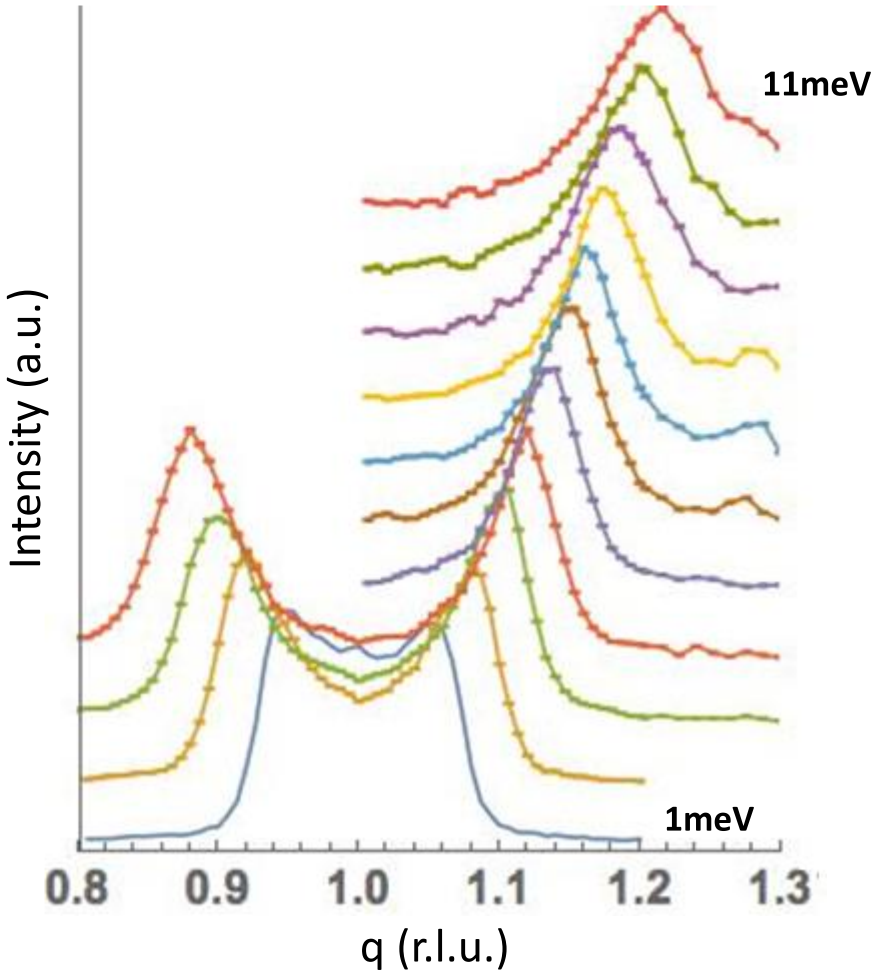
# Measurement Details

- Inelastic measurement of spin wave excitations
- Extract spin-wave "stiffness" parameter D(T) ∝ JS(T)
- Q-scans about (1 0 0) peak at selected temperatures: 180, 250, 290, 320 K
- Temperature dependence of (1 0 0) Bragg peak
- $E_f$ = 14.7 meV
- E: 1.0 - > 11.0 meV




Data for $La_{0.85}Sr_{0.15}MnO_3$

# Data at T=320K



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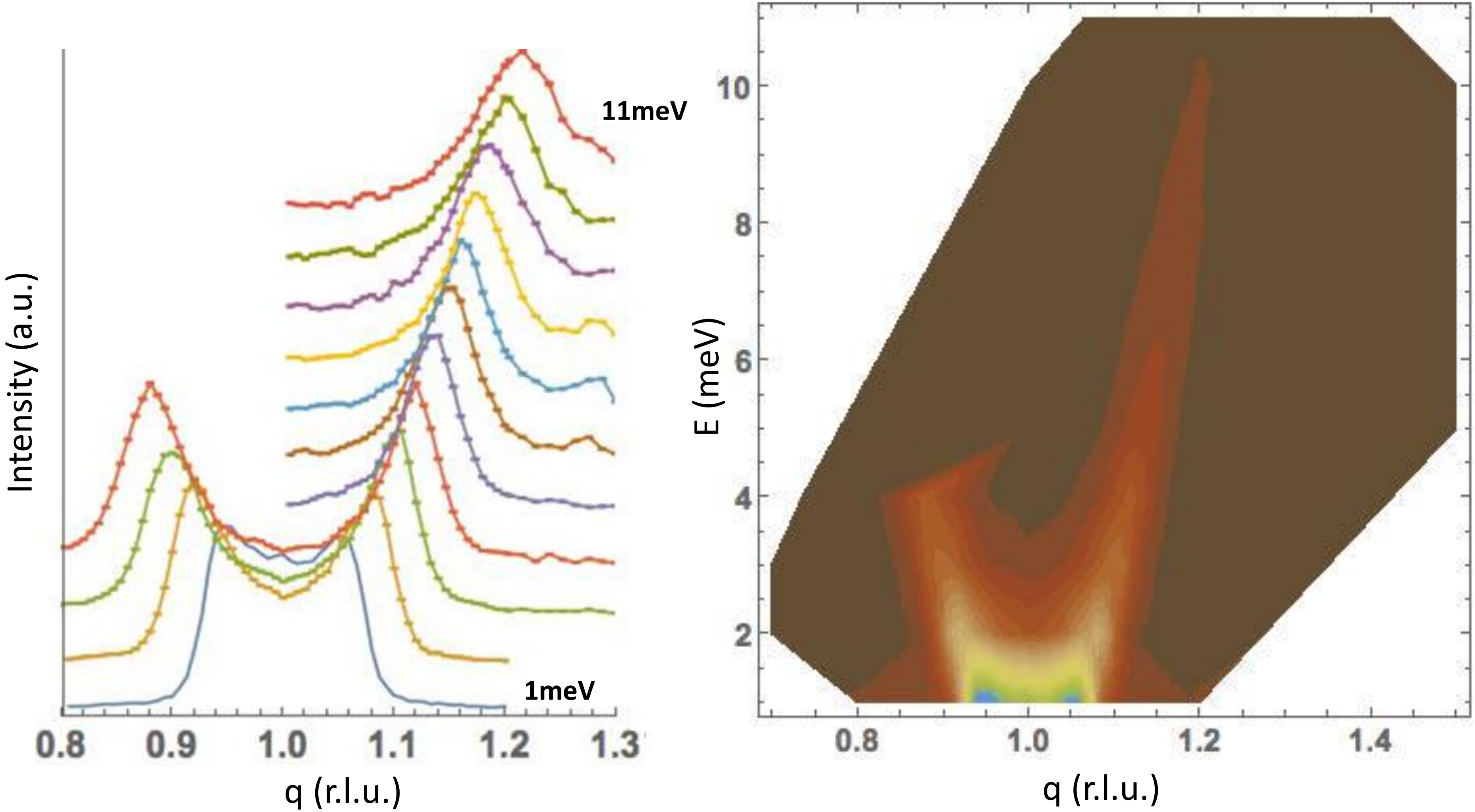

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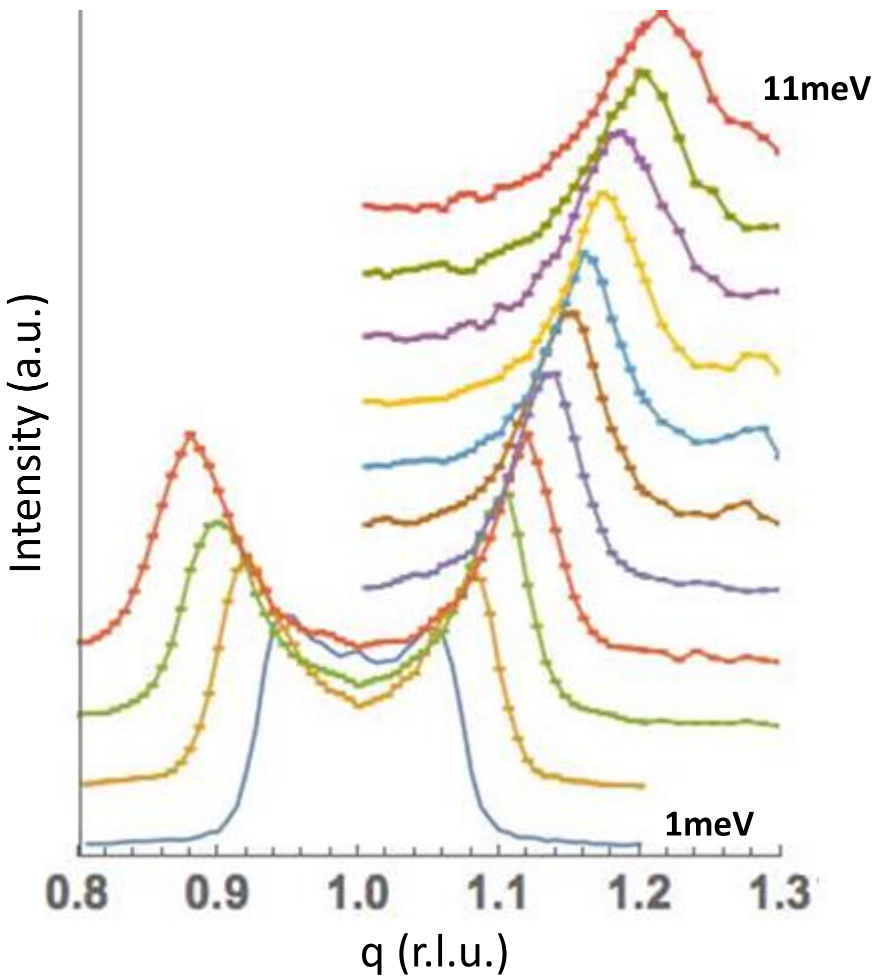
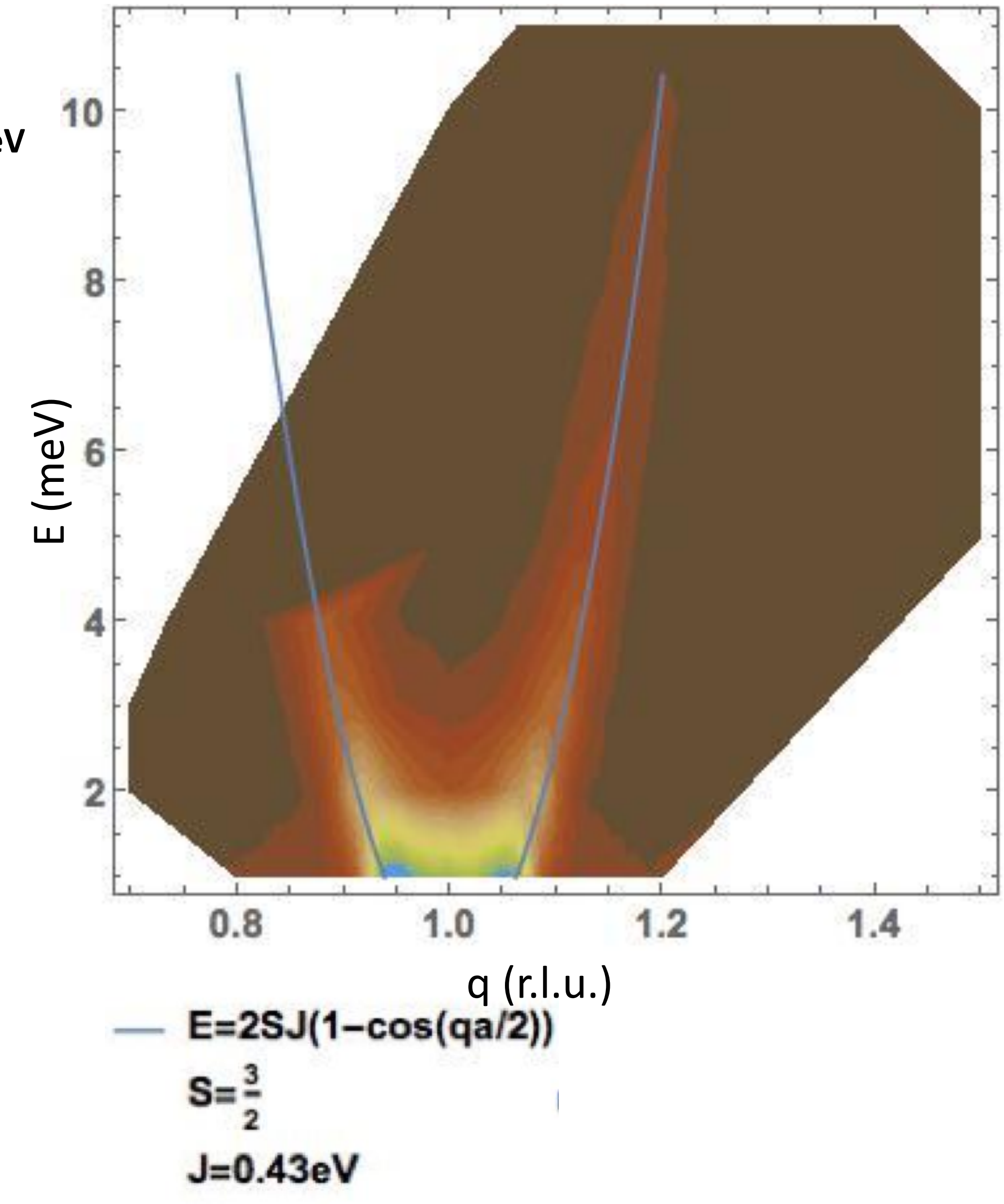



J: exchange parameter



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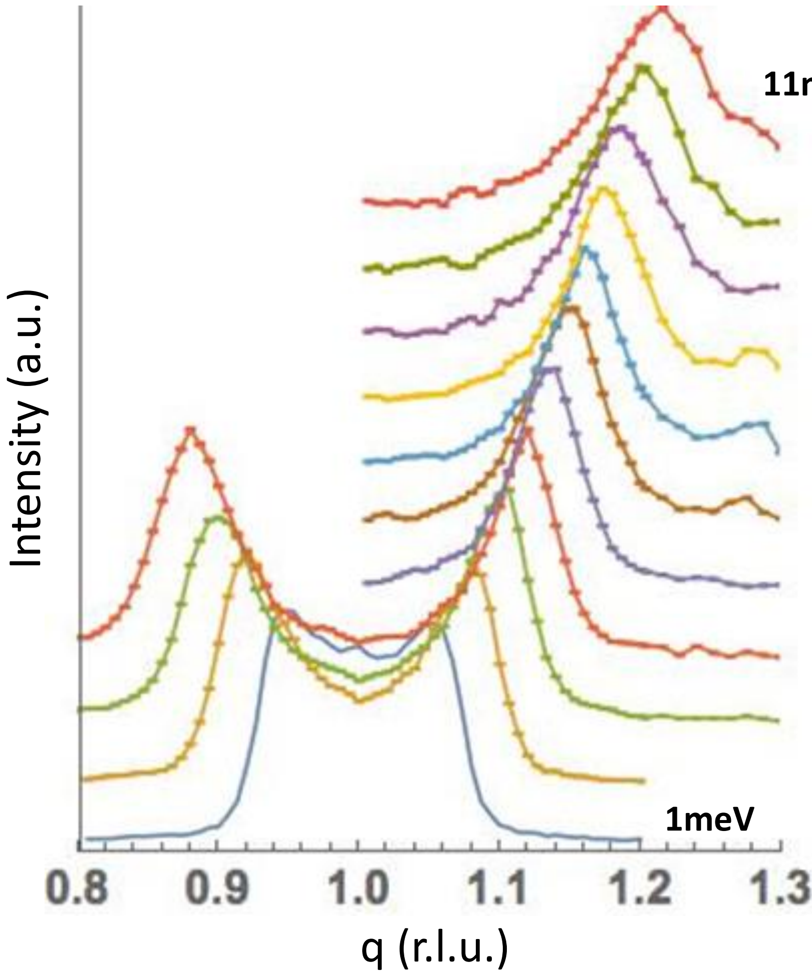
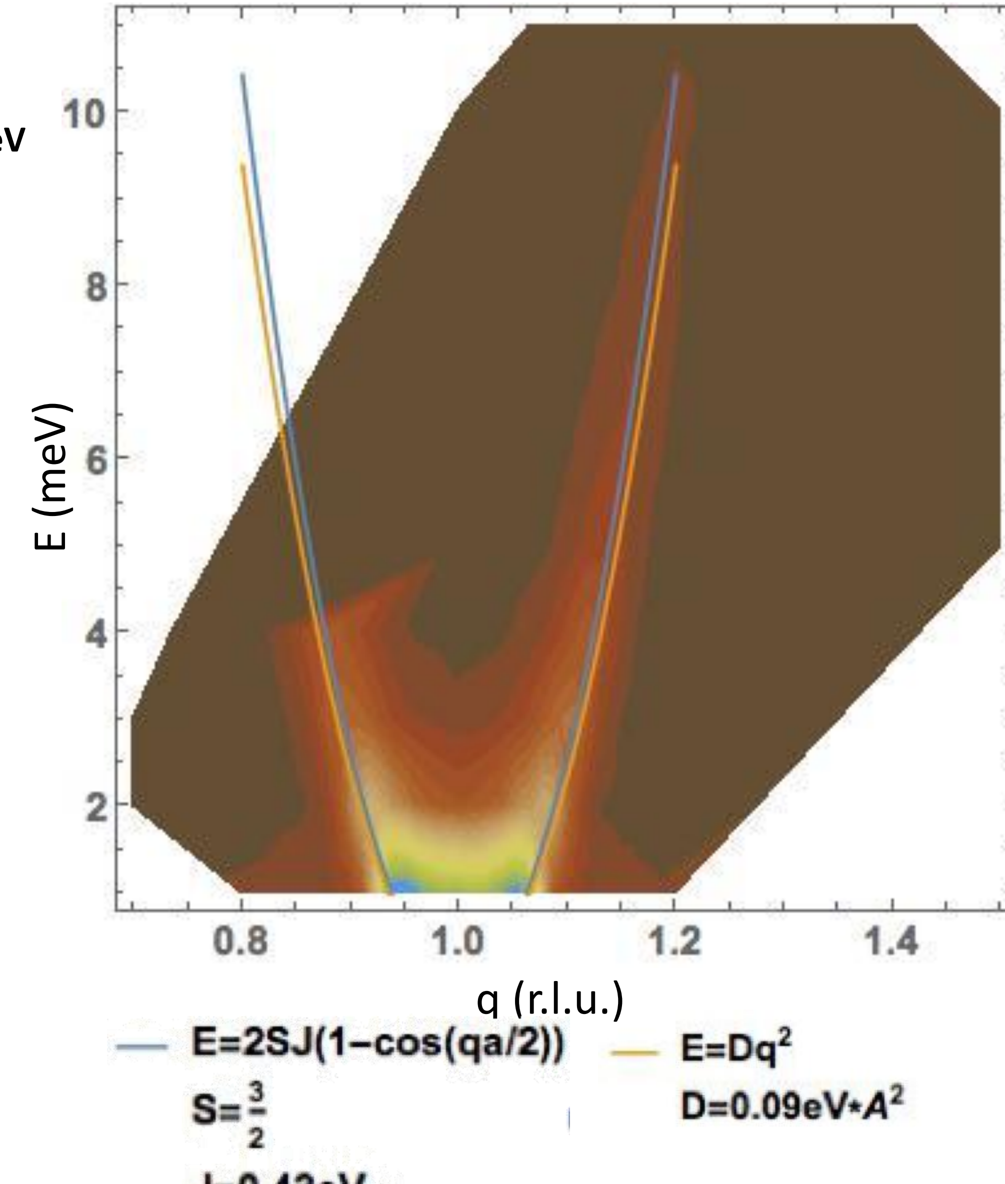


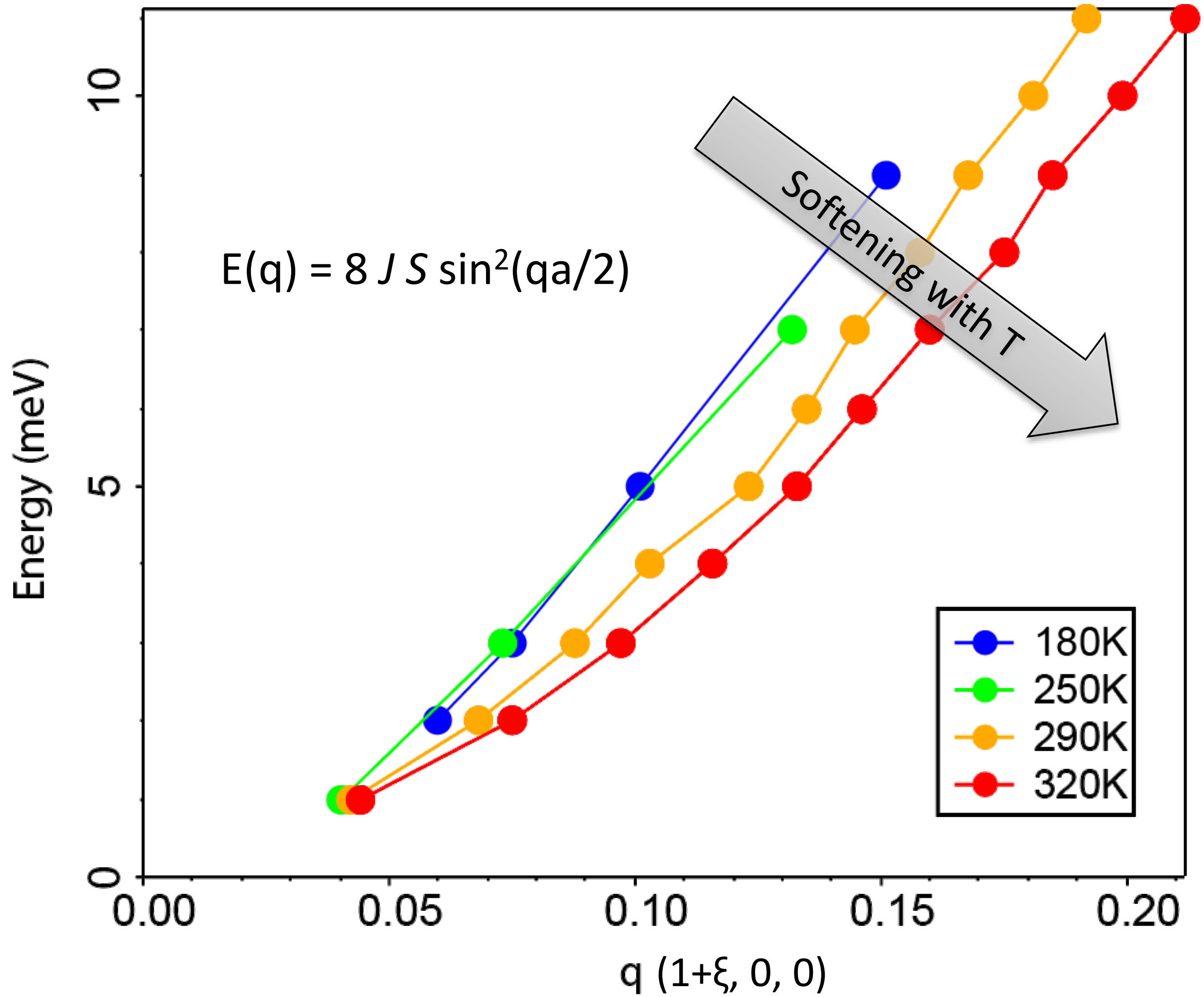

J: exchange parameter

Δ: gap parameter

D: stiffness parameter

$$E_{spinwaves} = \Delta(T) + D(T)q^2 + E(T)q^4 + \ldots$$

# Temperature Dependence of Spin Waves




*Special thanks to Groups B & D*

# Temperature Dependent Properties

$$M \propto |T_c - T|^{\beta}$$

$$I \propto M^2 \propto |T_c - T|^{2\beta}$$

$T_c$: Critical temperature

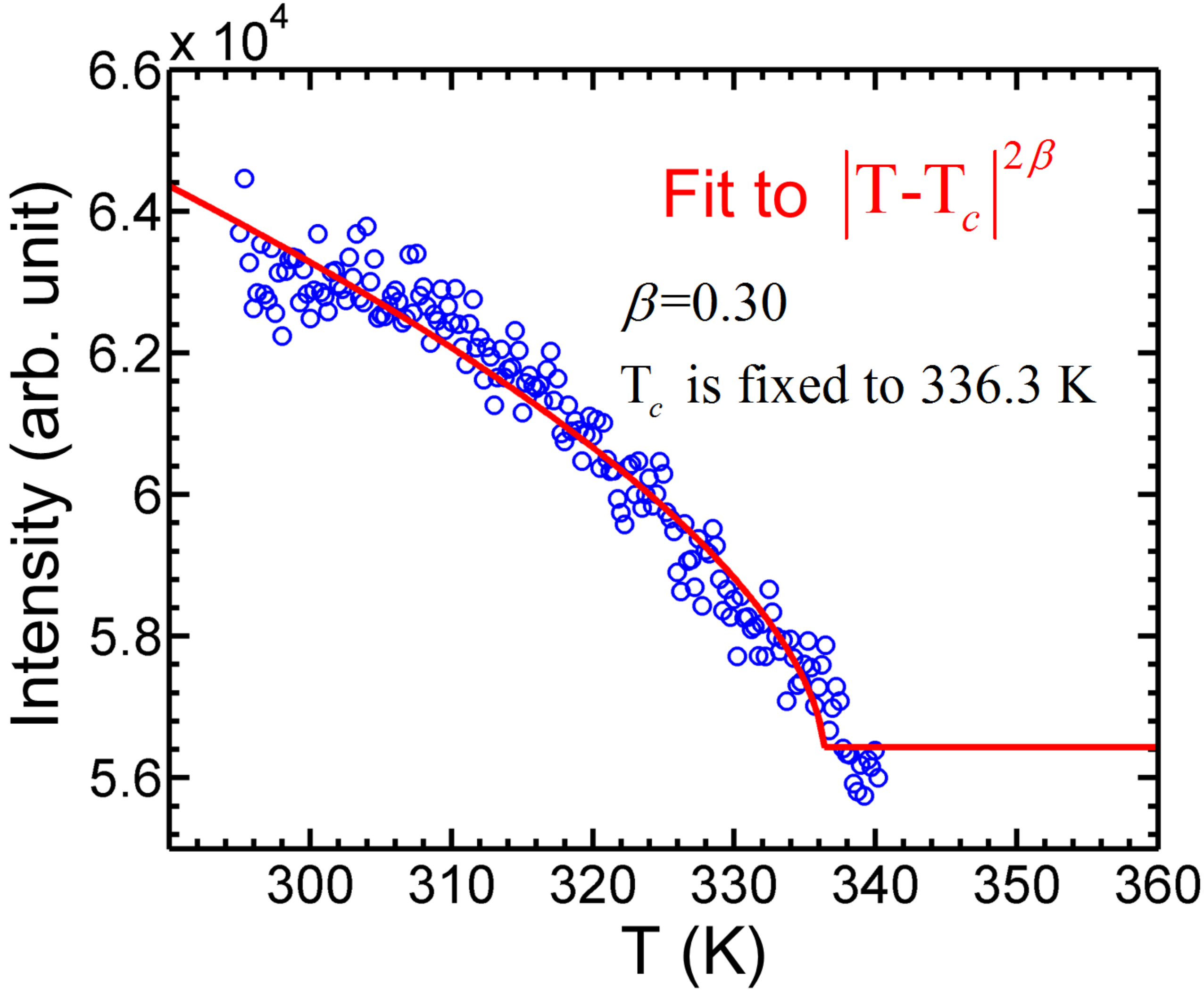
$T_c$= 336.3 K, according to previous BT7 experiment

M: Magnetic moment

I: Integrated intensity of ferromagnetic (1 0 0) peak

β: Critical exponent

β ≈ 0.30 (Yang Zhao et al, BT7 experiment handout)



# Temperature Dependent Properties

$$D \propto \left| T_c - T \right|^{\nu' - \beta}$$

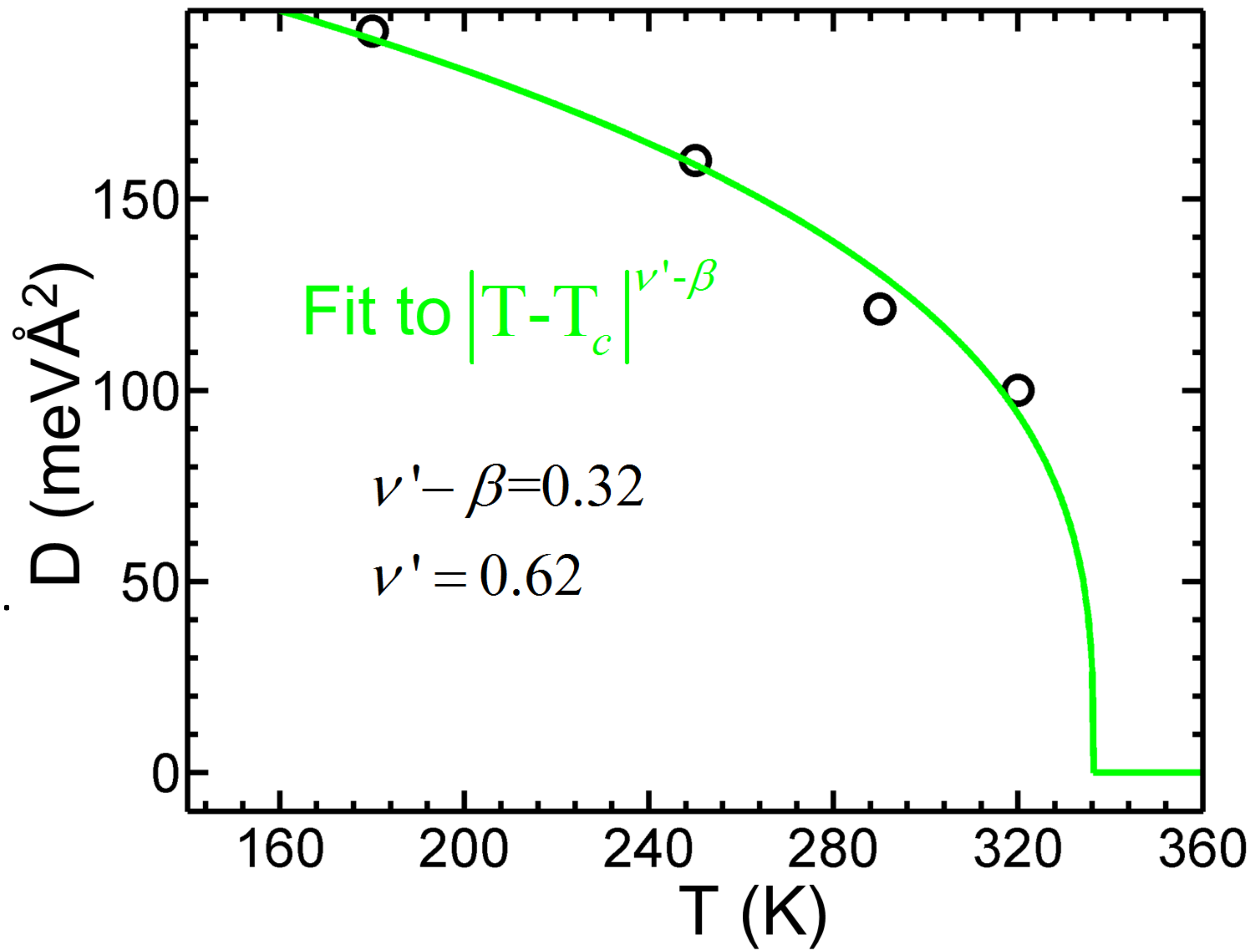
D: Spin wave "stiffness" parameter ($E = Dq^2$)

$T_c$: Critical temperature

β: Critical exponent

ν': Critical exponent for correlation length below Tc.

ν' ≈ 2/3 (Yang Zhao et al, BT7 experiment handout)



# Conclusion

- Mapped the spin wave excitations of $La_{0.7}Sr_{0.3}MnO_3$ at various temperatures using BT-7
- The spin wave softens with temperature as magnetic order weakens: $D(T) \propto M(T)$
- Ferromagnetism aligns the spins, leading to itinerancy and metallicity

**SPECIAL THANKS TO OUR INSTRUMENT SCIENTISTS: YANG ZHAO, WILLIAM RATCLIFF, DANIEL PARSHALL, AND JEFF LYNN**

**THANKS ALSO TO YUN LIU AND YAMALI HERNANDEZ!**