Spin Echo Study of the Dynamics of Spin Ice $Ho_2Ti_2O_7$

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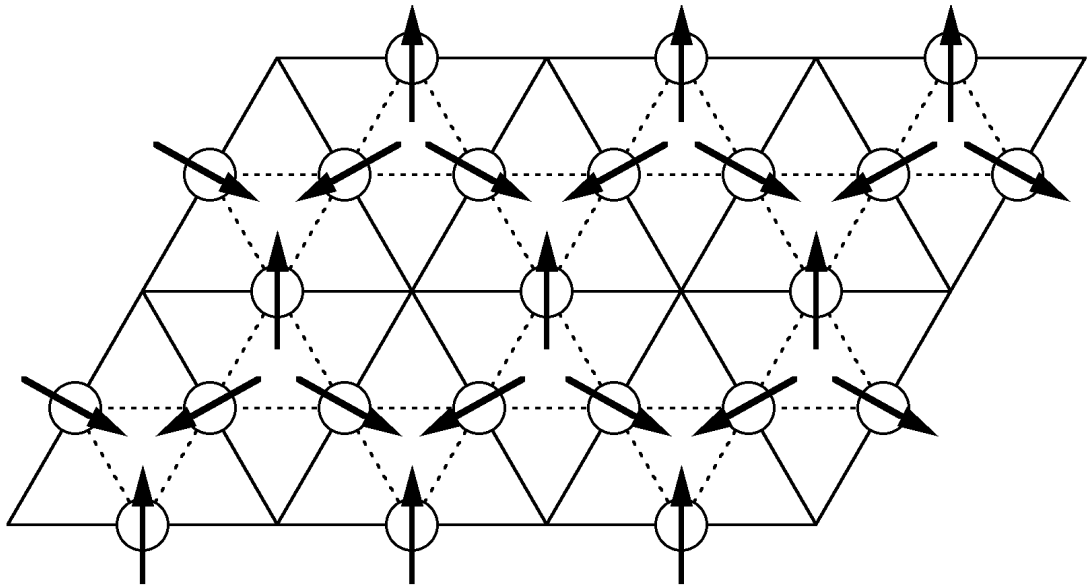
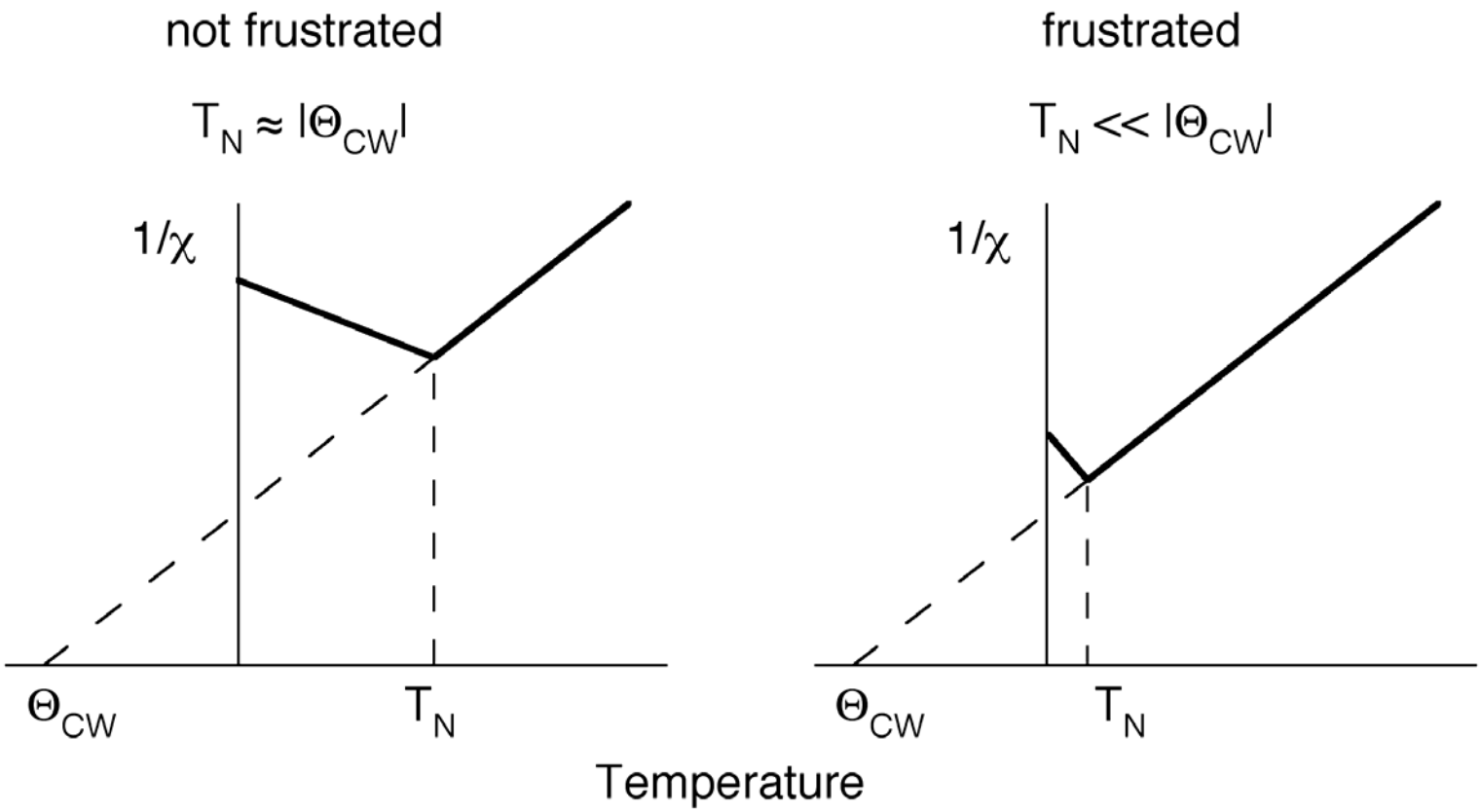
Geometrically frustrated magnet



susceptibility - schematic

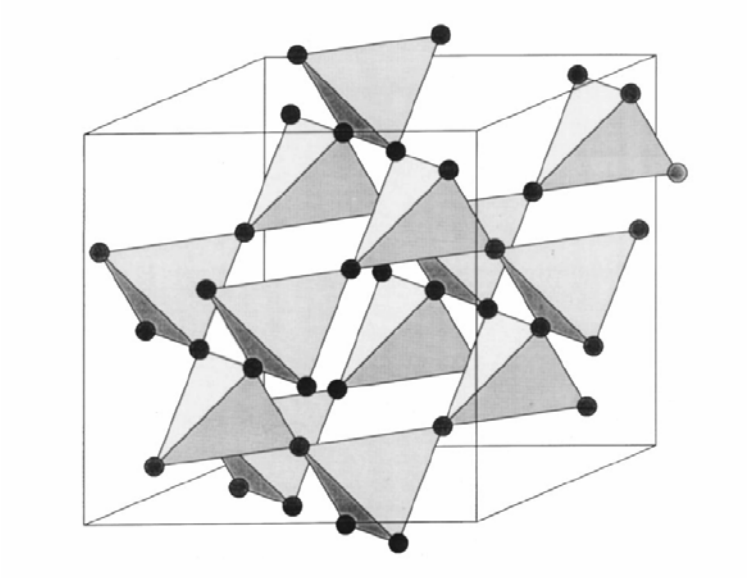


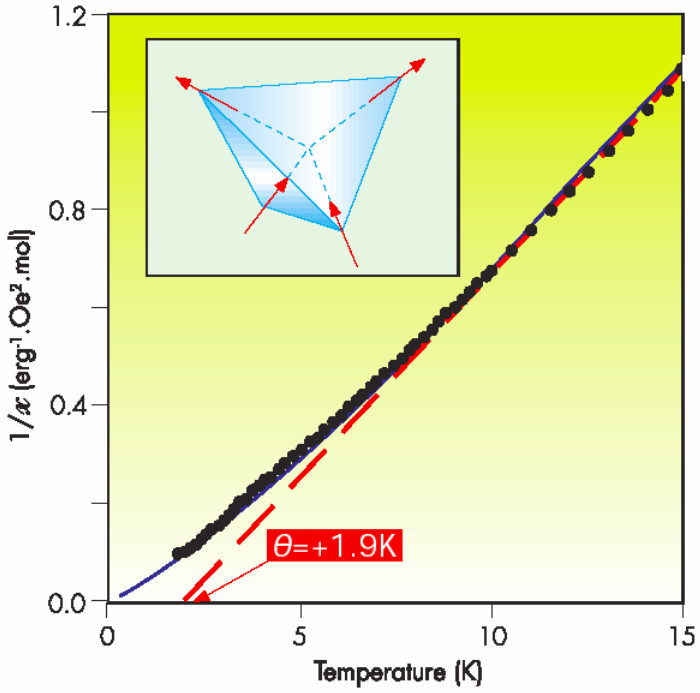
Outline

- Introduction ✓
- The physics of spin ice
- Discussion of NSE data,
  comparison to other techniques

$Ho_2Ti_2O_7$

Spin Ice Crystal Structure





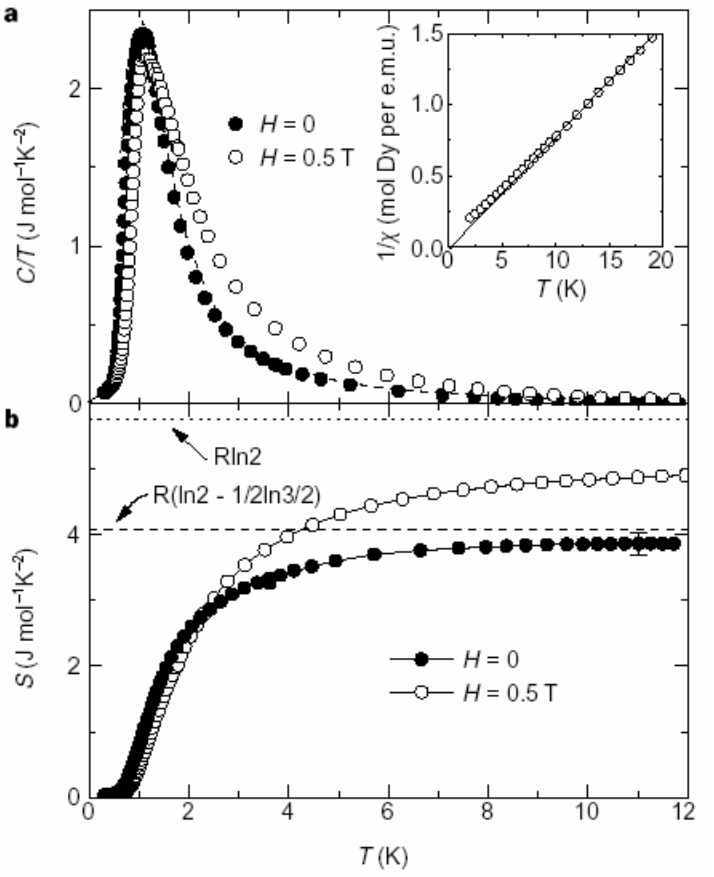
Stoichiometry

$Ho_2Ti_2O_7$, $Dy_2Ti_2O_7$,
($Ho_2Sn_2O_7$, $Dy_2Sn_2O_7$)

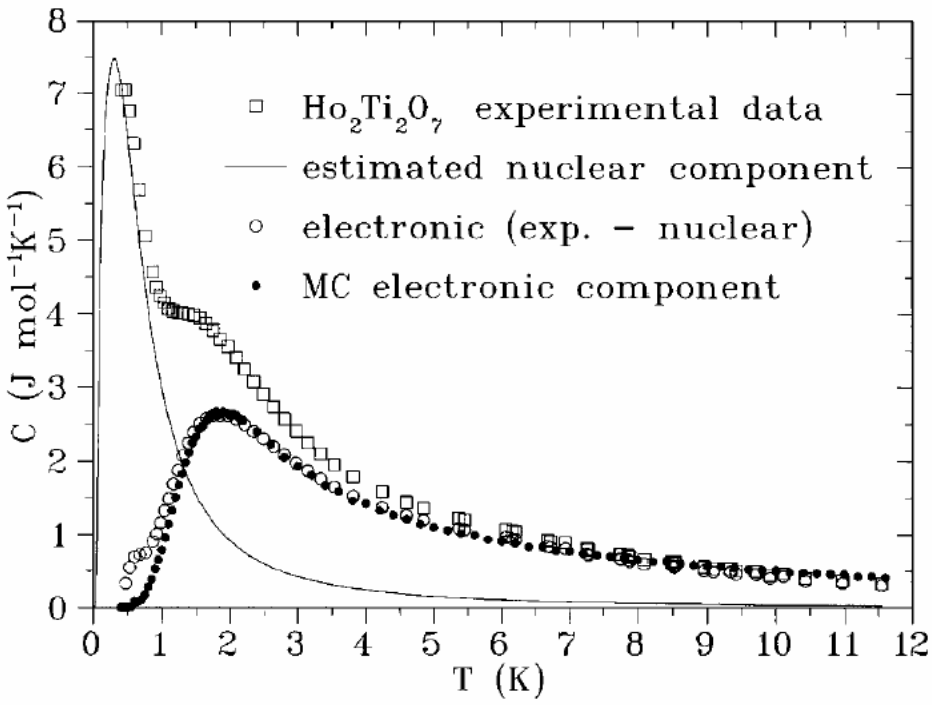
$$\chi(T) = \frac{n}{3k_B} \cdot \frac{\mu_{eff}^2}{T - \Theta}$$

$$\mu_{eff} \approx 9\mu_B \quad \Theta \approx +1.9\text{K}$$

Specific Heat

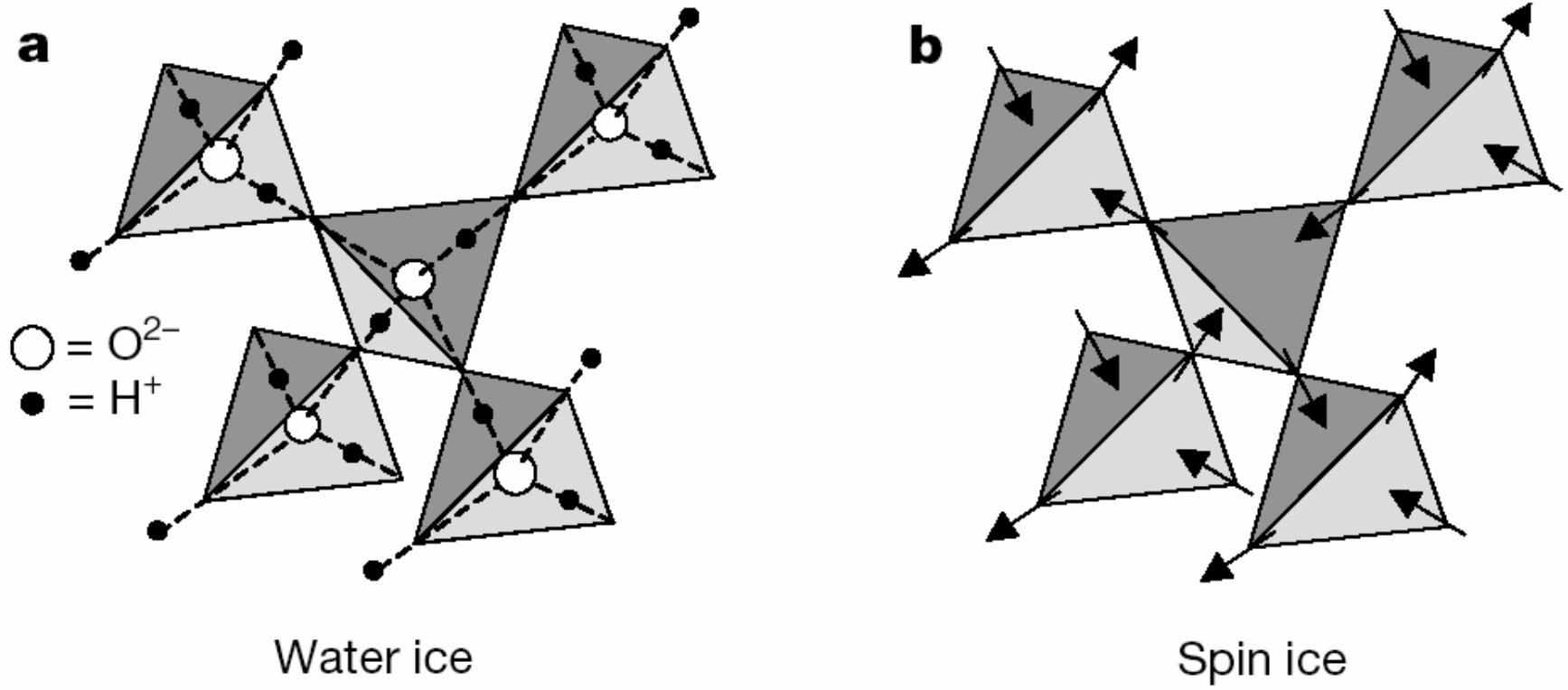


A. P. Ramirez et al.,
Nature **399**, 333 (1999).



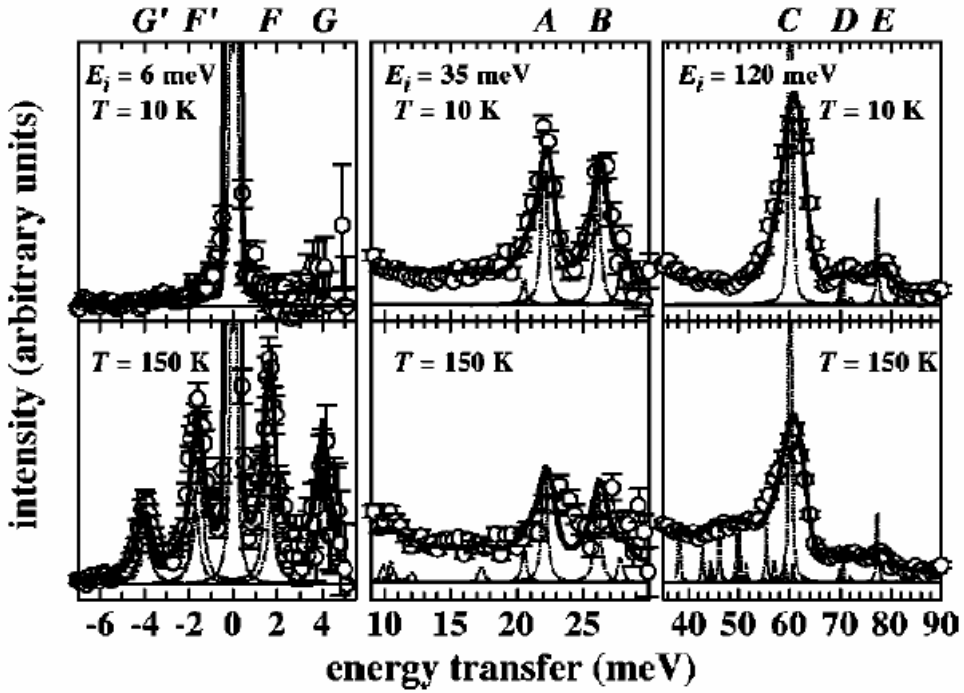
S. T. Bramwell et al.,
PRL **87**, 047205 (2001).

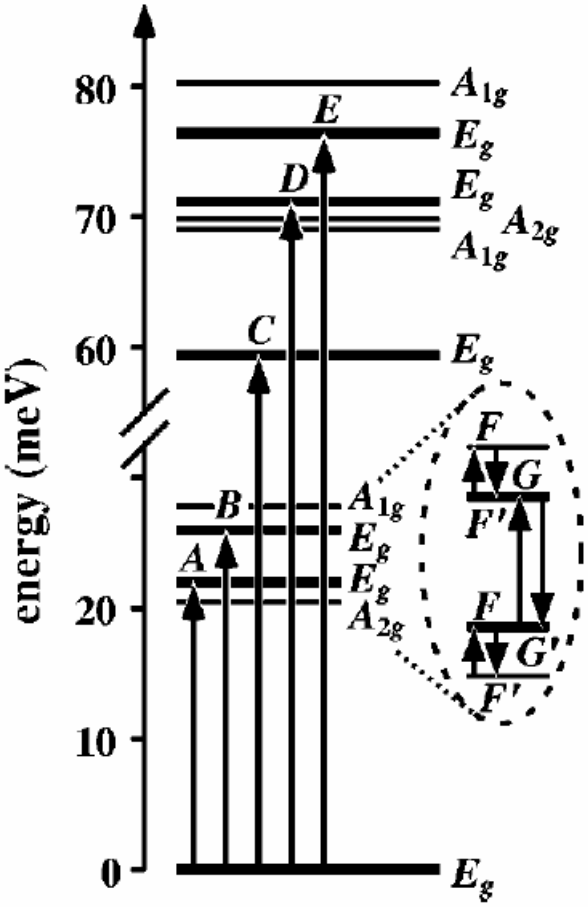
Analogy to Water Ice



CEF constraints spins to local <111> axes

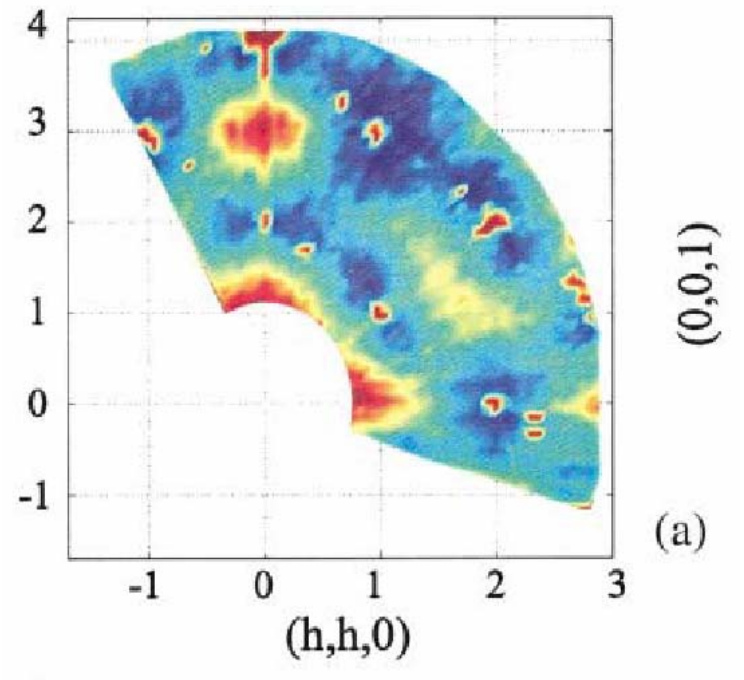
CEF Level Scheme



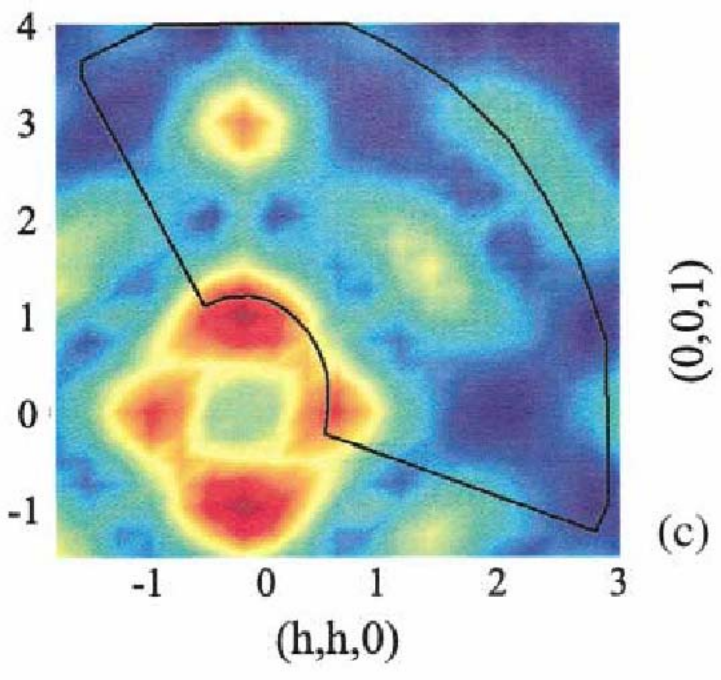


S. Rosenkranz et al.,
J. Appl. Phys. **87**, 5914-5916 (2000).

Neutron diffraction

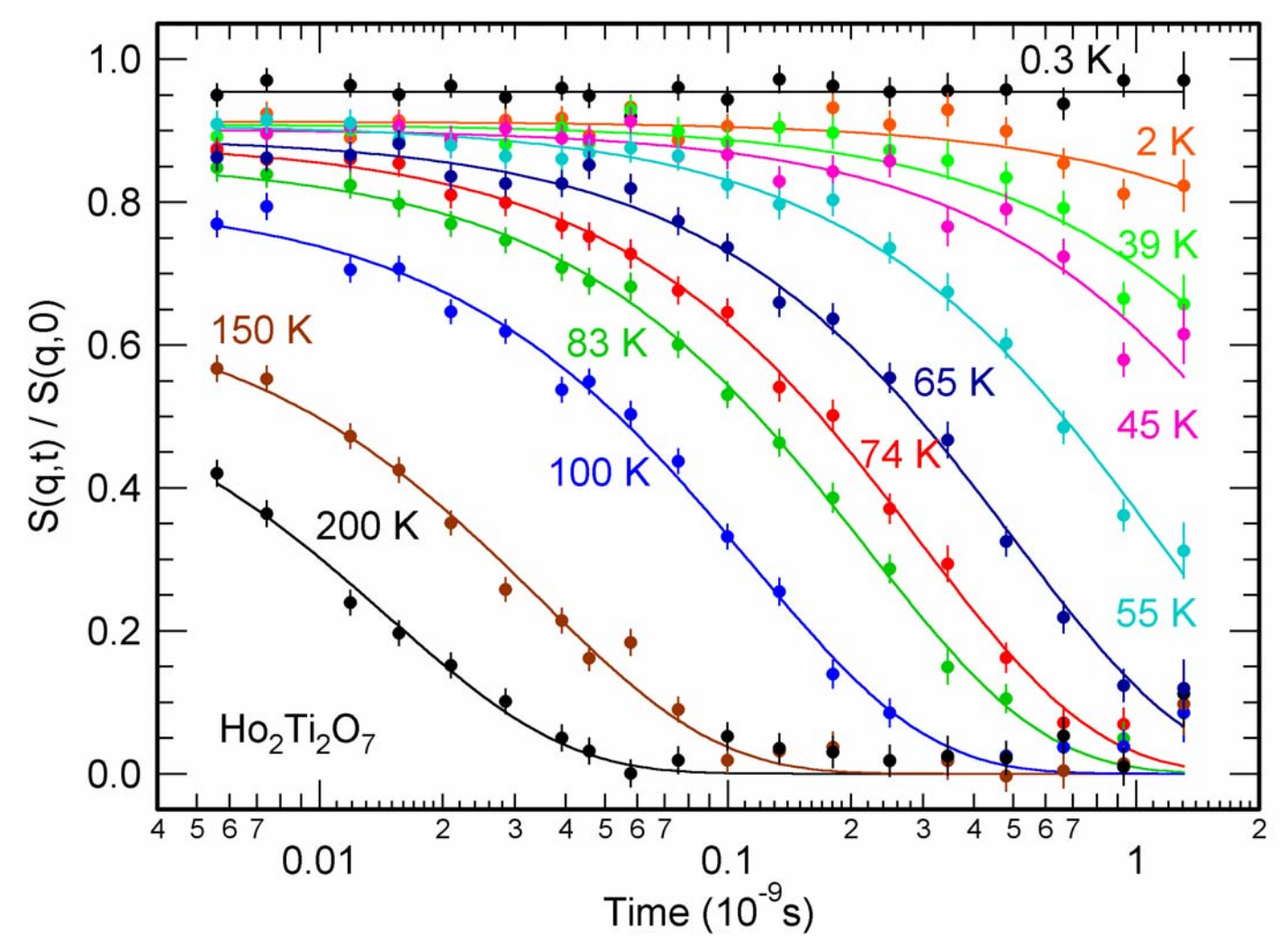


PRISMA T = 50 mK

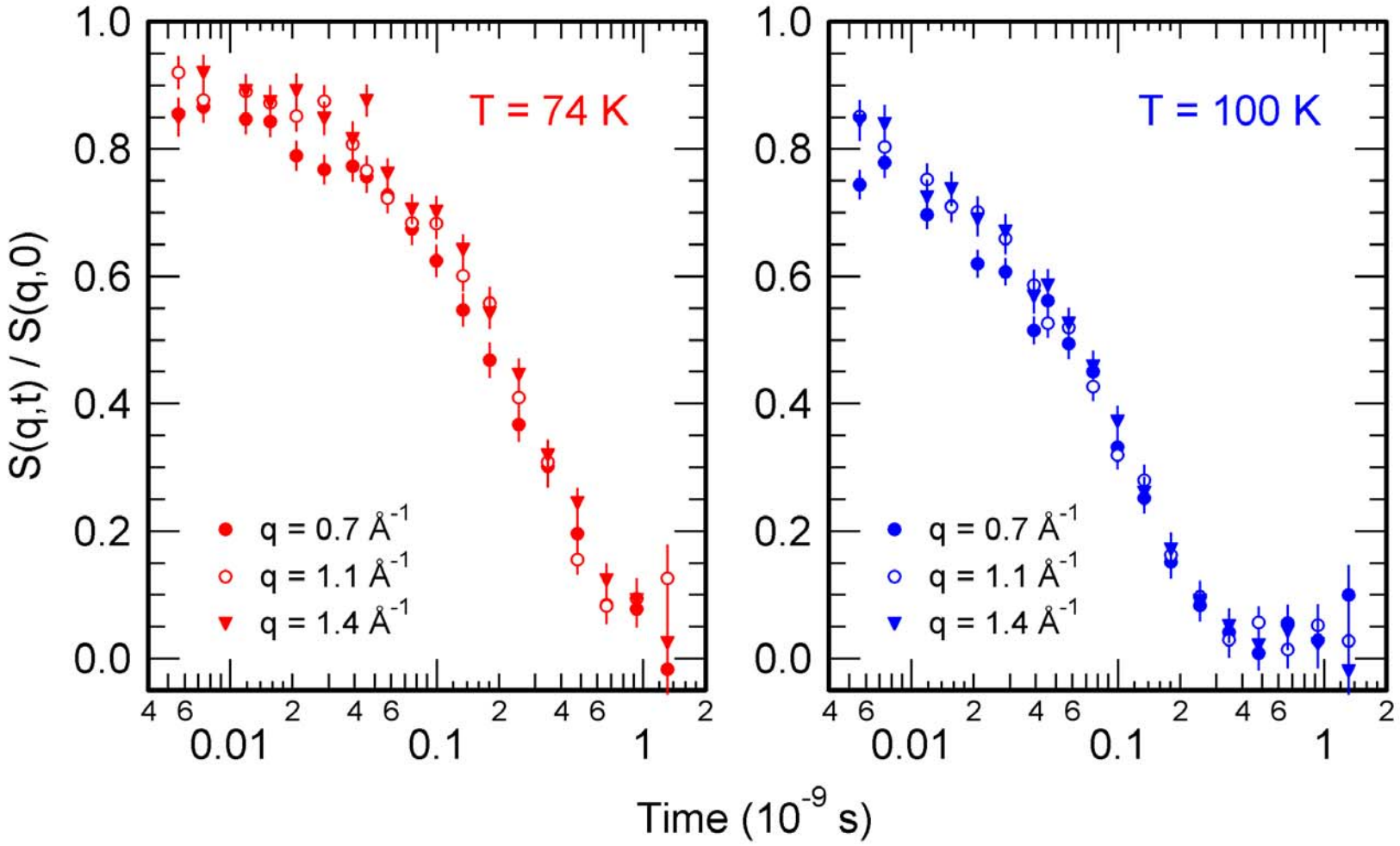


S. T. Bramwell et al.,
PRL **87**, 047205 (2001)

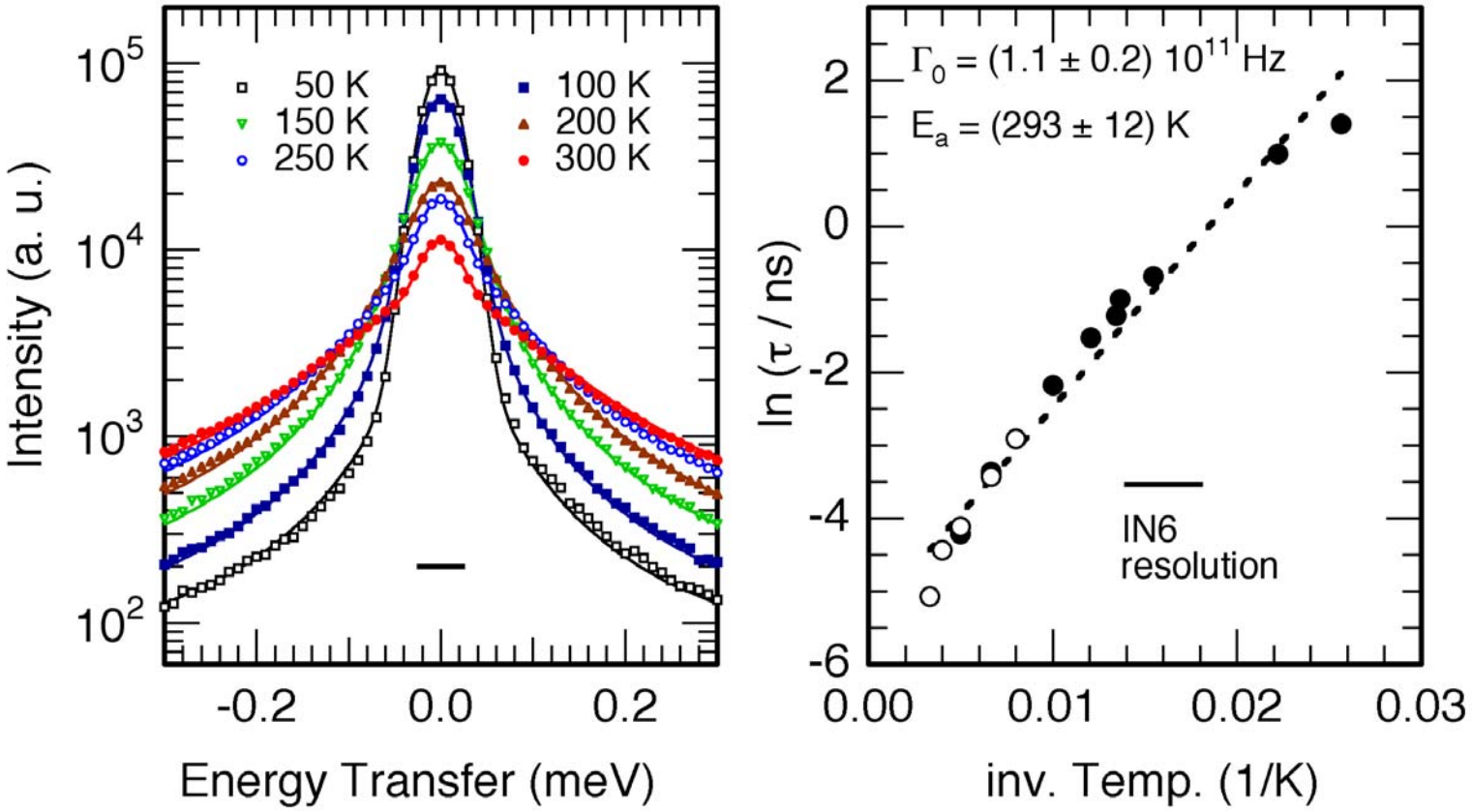
Spin Echo Results on $Ho_2Ti_2O_7$



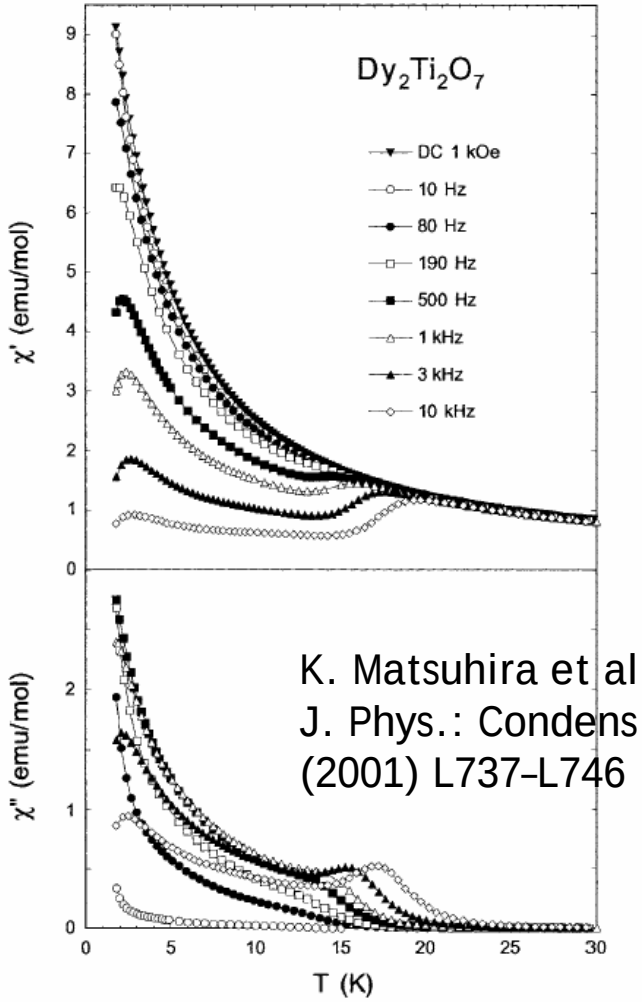
Spin Echo Results - cont'd



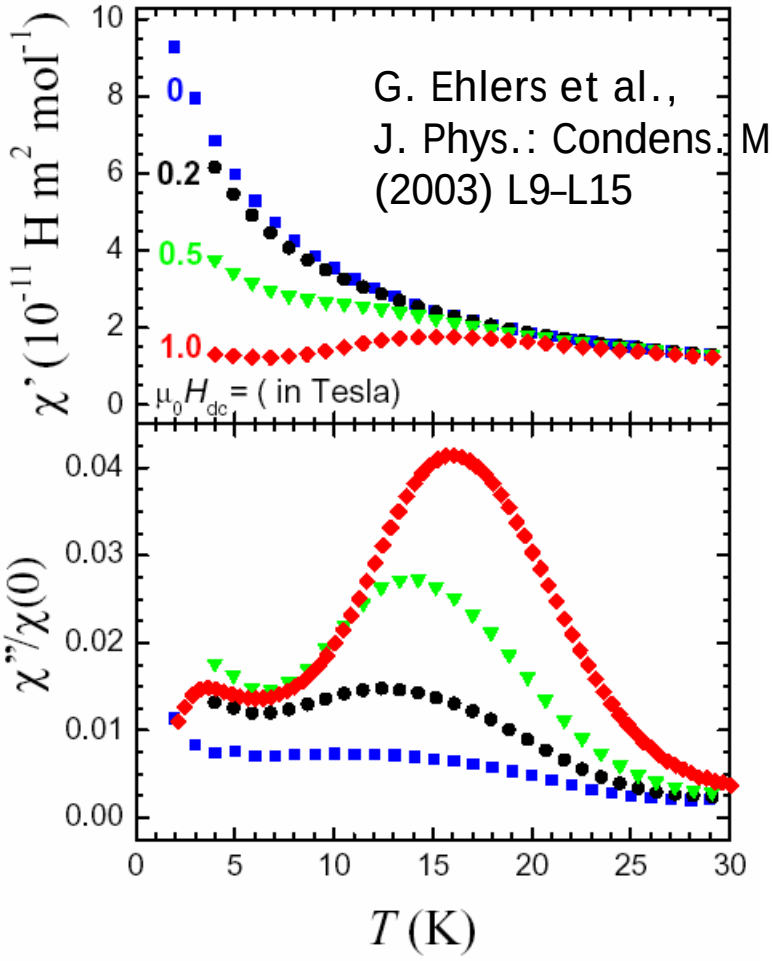
Analysis - Arrhenius Law



AC susceptibility

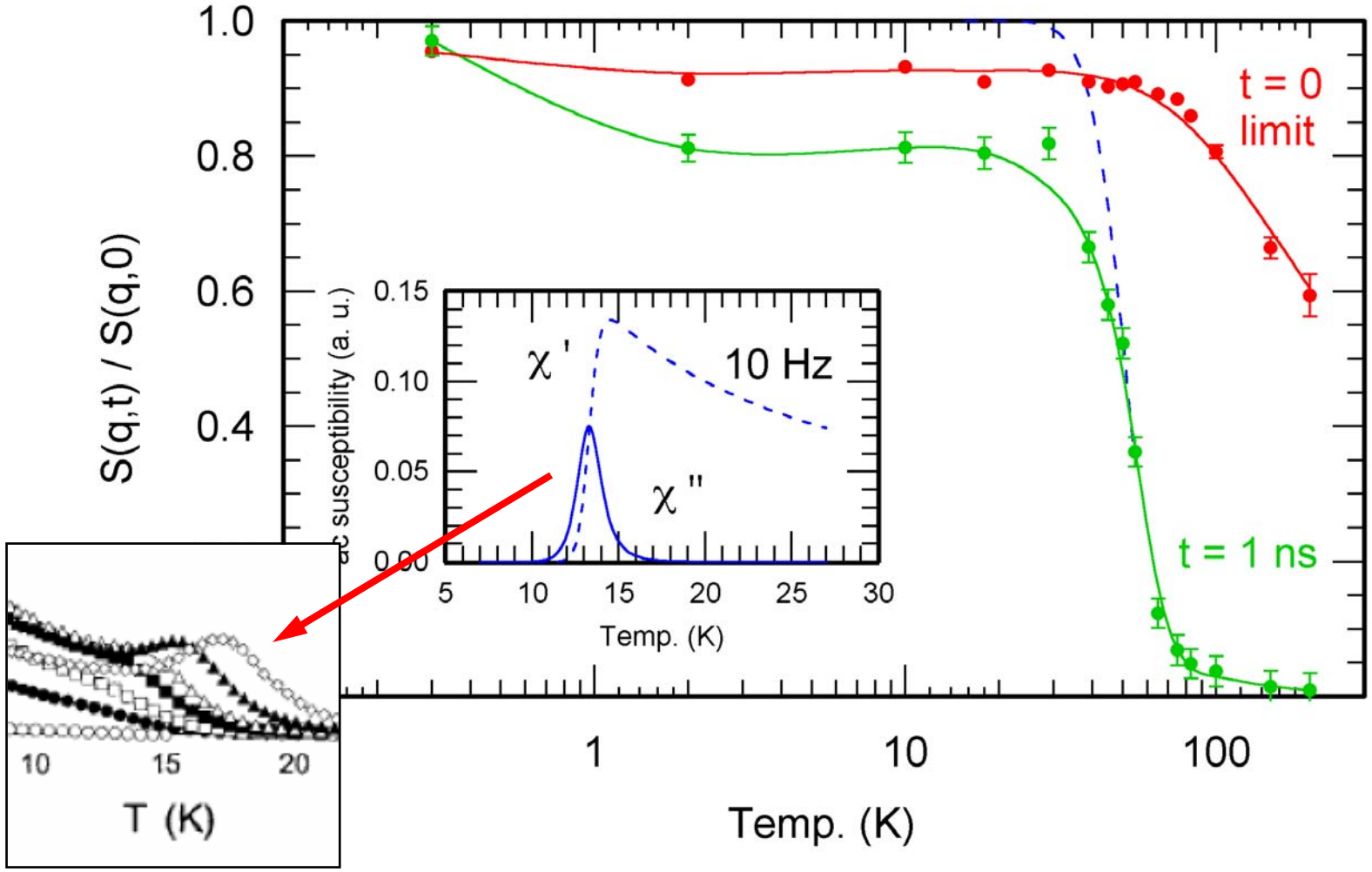


K. Matsuhira et al.,
J. Phys.: Condens. Matter **13**
(2001) L737–L746

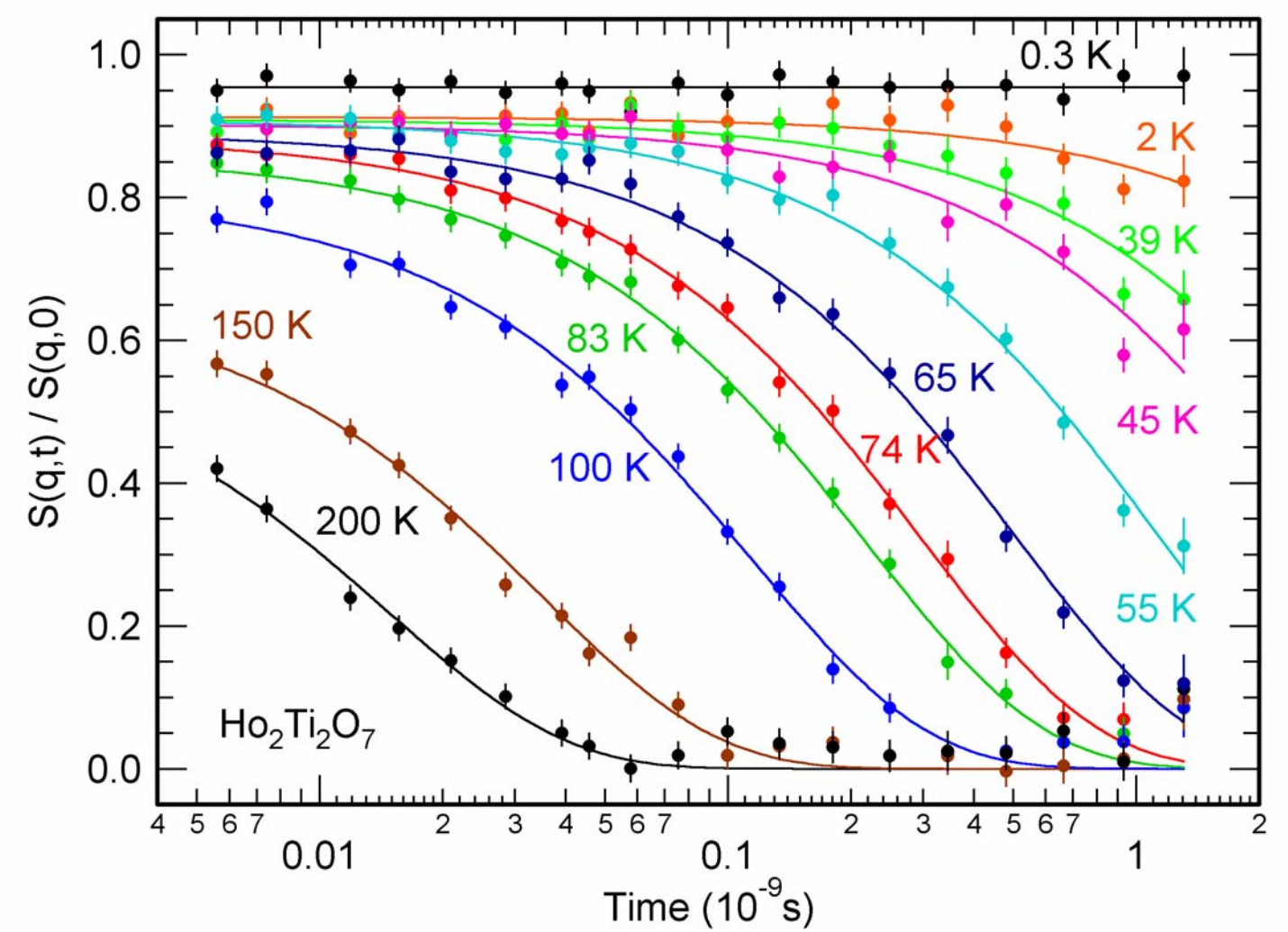


G. Ehlers et al.,
J. Phys.: Condens. Matter **15**
(2003) L9–L15

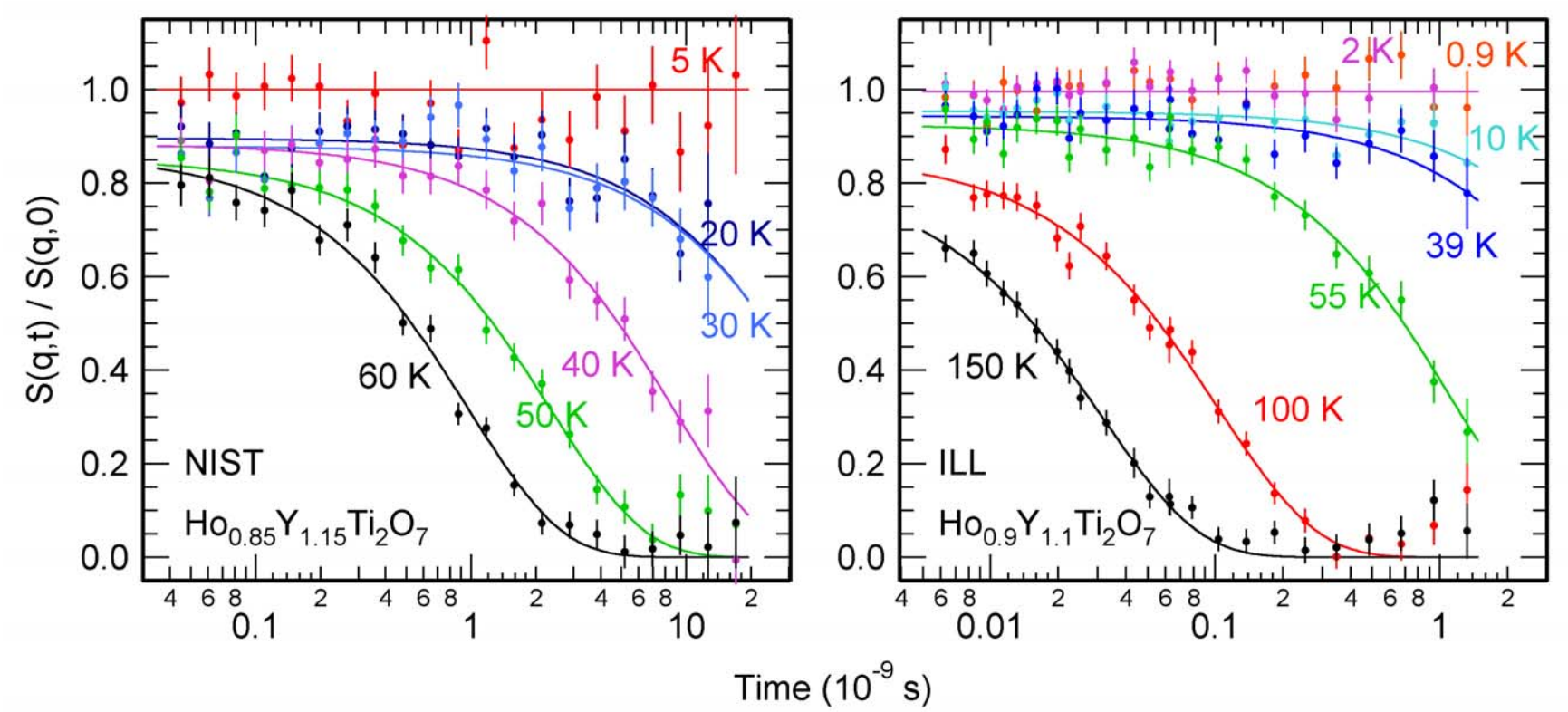
Spin Echo Results - cont'd



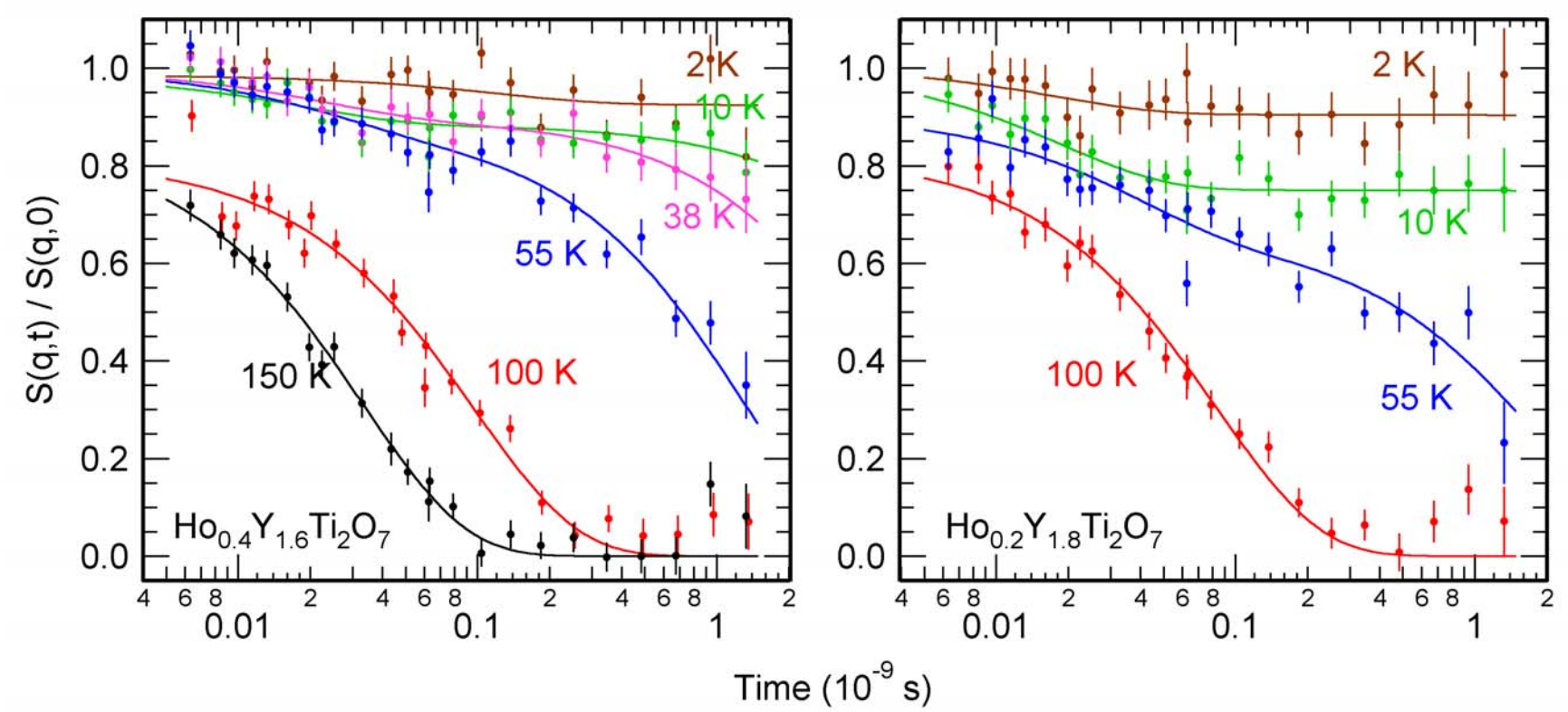
NSE results on $Ho_2Ti_2O_7$ - again



NSE results on $Ho_{2-x}Y_xTi_2O_7$



NSE results on $Ho_{2-x}Y_xTi_2O_7$



Summary on $Ho_2Ti_2O_7$

NSE works perfectly to study the dynamics of spin ice:

- works in the time domain
- gives just the right time range
- q information tells it is single ion relaxation
- data is 'clean' because magnetic scattering is separated

NSE proves that there are two relaxation mechanisms in spin ice.

Consistent picture with ac susceptibility results.

Next: extend NSE study to the Dy spin ice system
(use of isotopic sample required)
where nuclear Dy spins are much weaker than those of Ho

Acknowledgements

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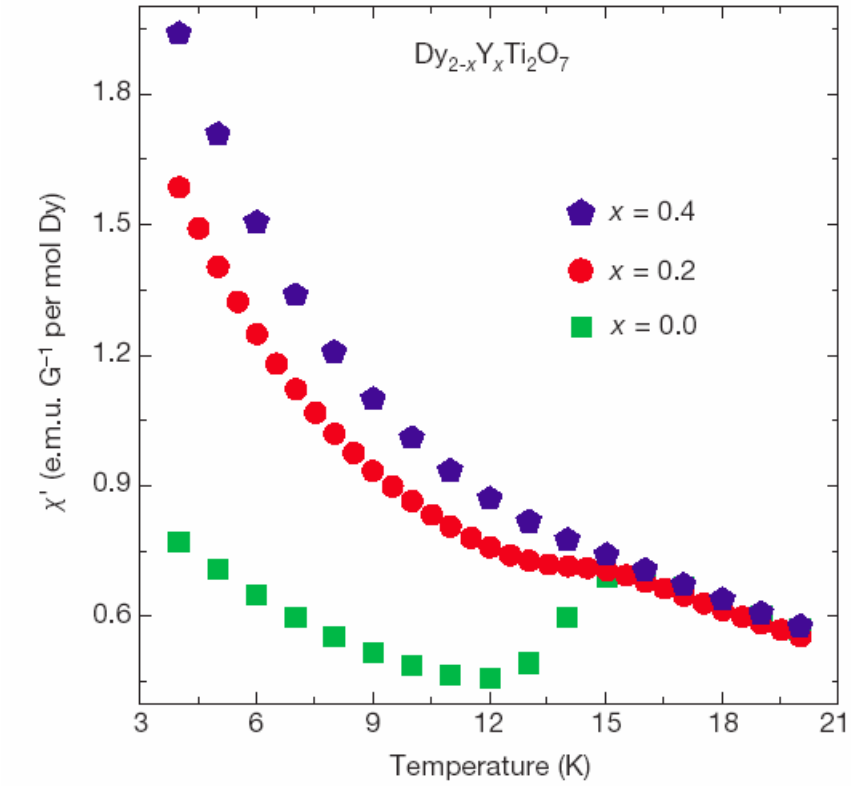
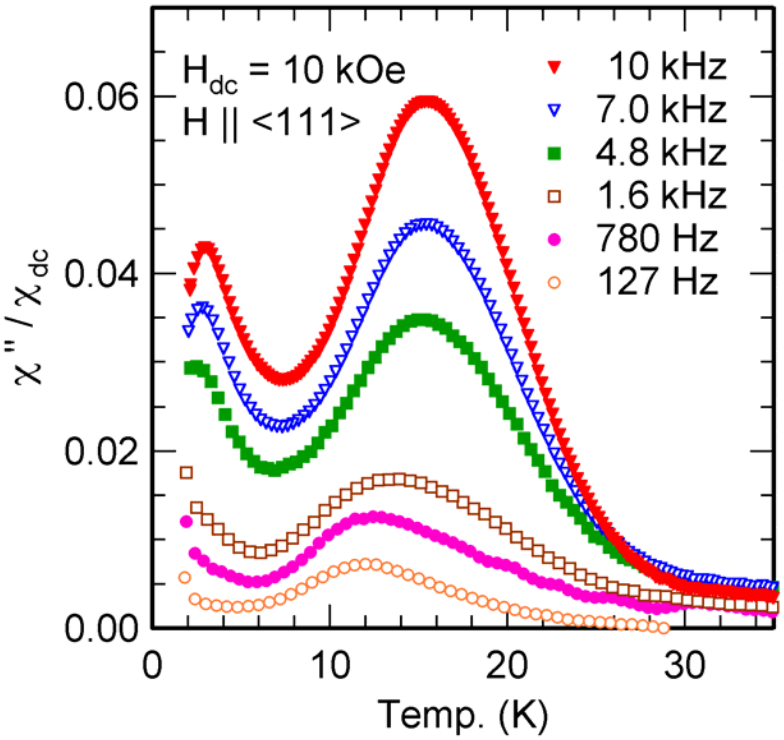
More on AC susceptibility



J. Snyder et al.,
Nature **413**, 48 (2001).



G. Ehlers et al.,
J. Phys.: Condens. Matter
16 (2004) 635