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Spin-liquid Behaviour in $Sc_2Ga_2CuO_7$

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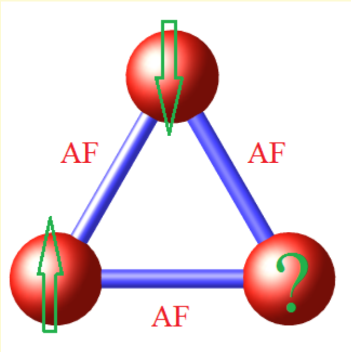
GENERAL THEME OF OUR WORK

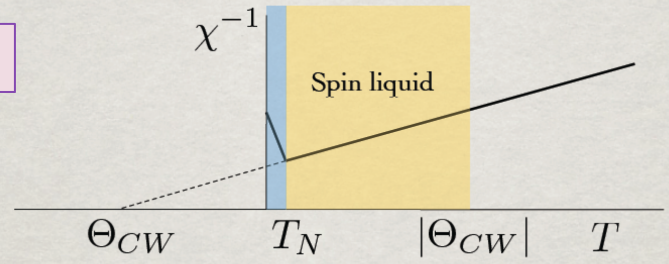
- Explore systems for novel magnetism
- Low dimensional, frustrated magnets and spin-liquid behaviour
- 3*d*/4*d*/5*d* systems… strong spin-orbit coupling
- Characterisation…structure, $\chi(T)$, $C_P(T)$, NMR

- Here, I will focus on $Sc_2Ga_2CuO_7$

Magnetic Frustration



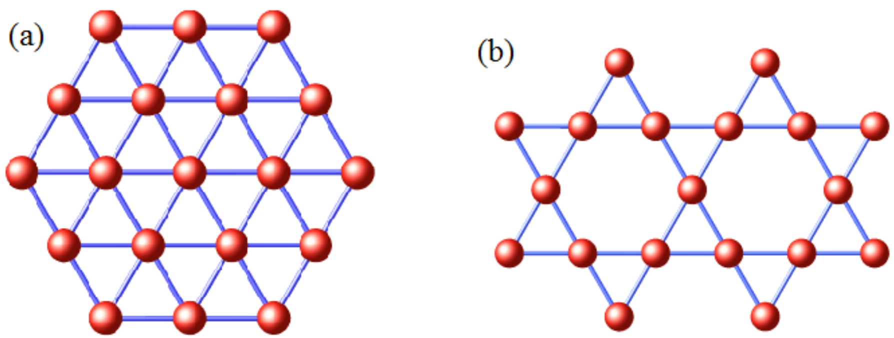
Balents, KITP

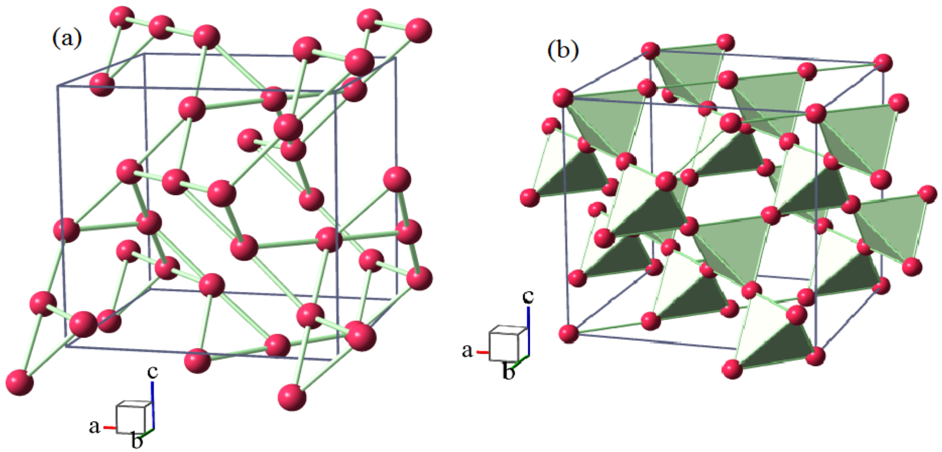


- Local moments: Curie-Weiss law at high T

$$\chi \sim \frac{A}{T - \Theta_{CW}}$$

- Frustration parameter: $f = |\Theta_{CW}|/T_N$
  - $f>>1$: wide regime $T_N < T < |\Theta_{CW}|$





Few examples:

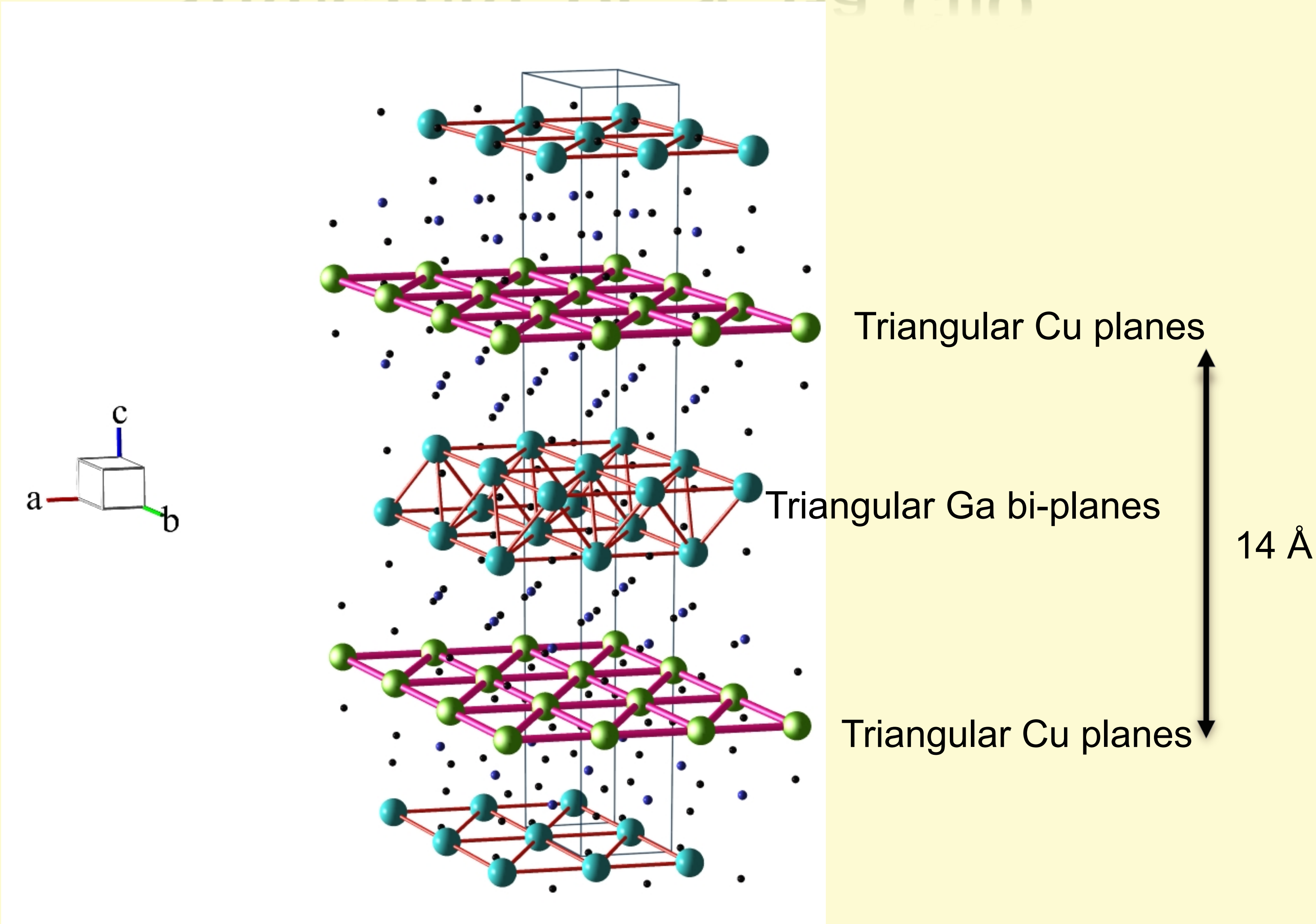
Triangular: $NiGa_2S_4$, $Ba_3CuSb_2O_9$

Kagome: $ZnCu_3(OH)_6Cl_2$, $SrCr_{9p}Ga_{12-9p}O_{19}$

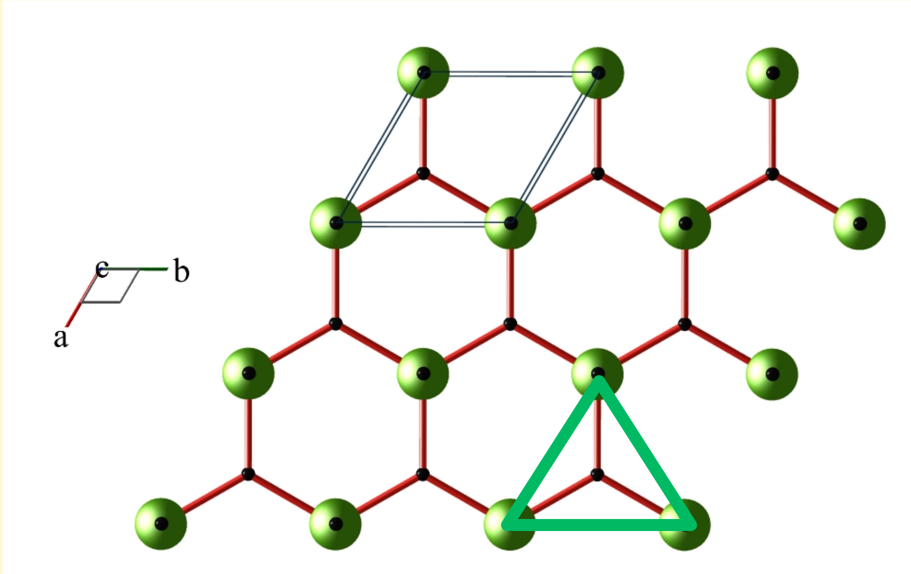
Hyperkagome: $Na_4Ir_3O_8$

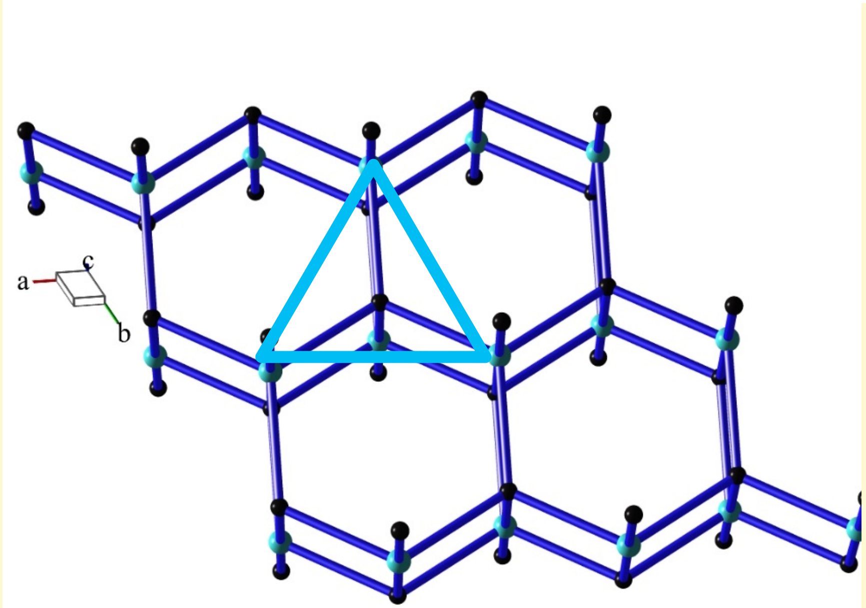
Pyrochlore: $Y_2Mo_2O_7$, $Ho_2Ti_2O_7$

STRUCTURE OF $Sc_2Ga_2CuO_7$



Cu PLANE AND Ga BI-PLANE

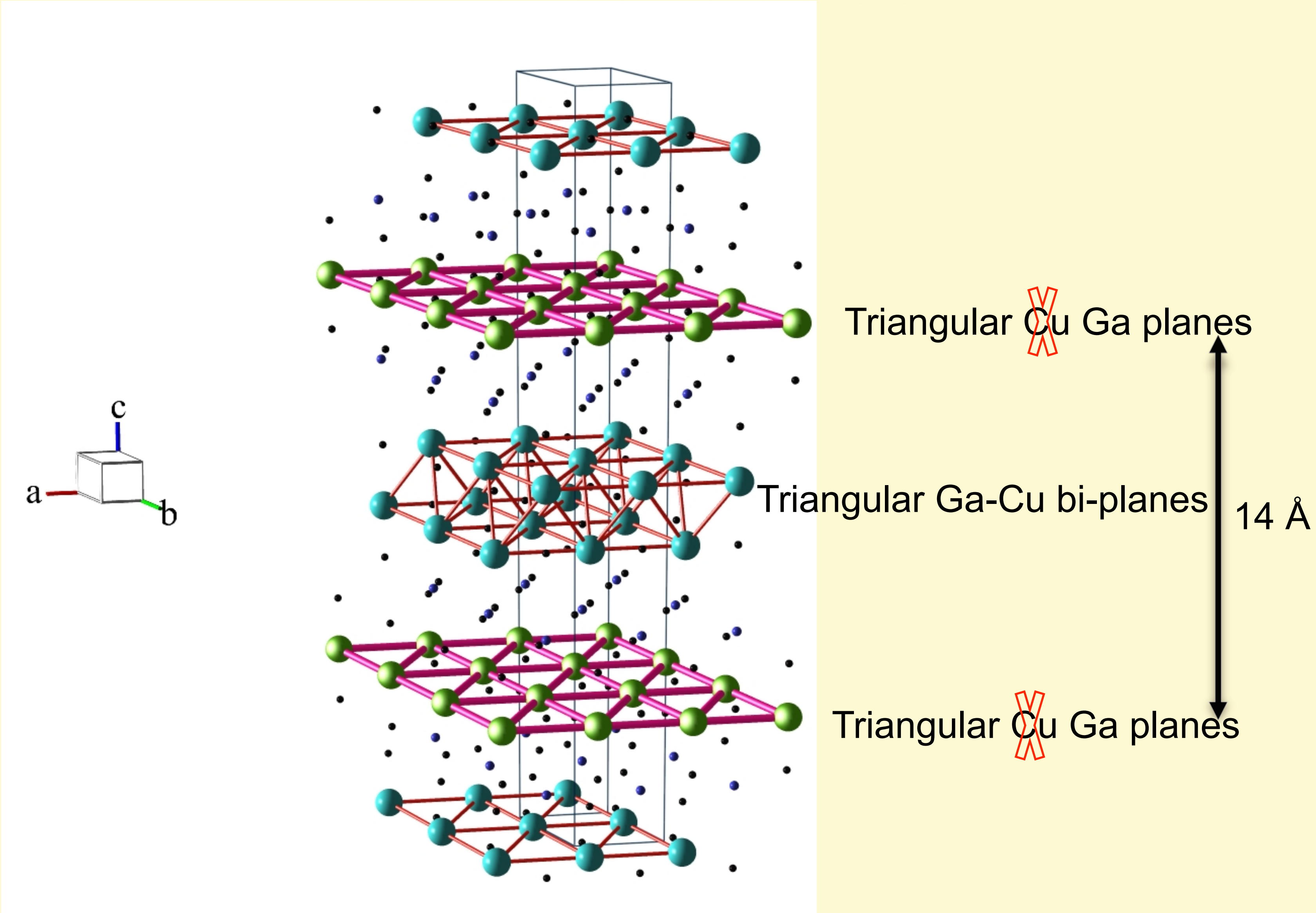




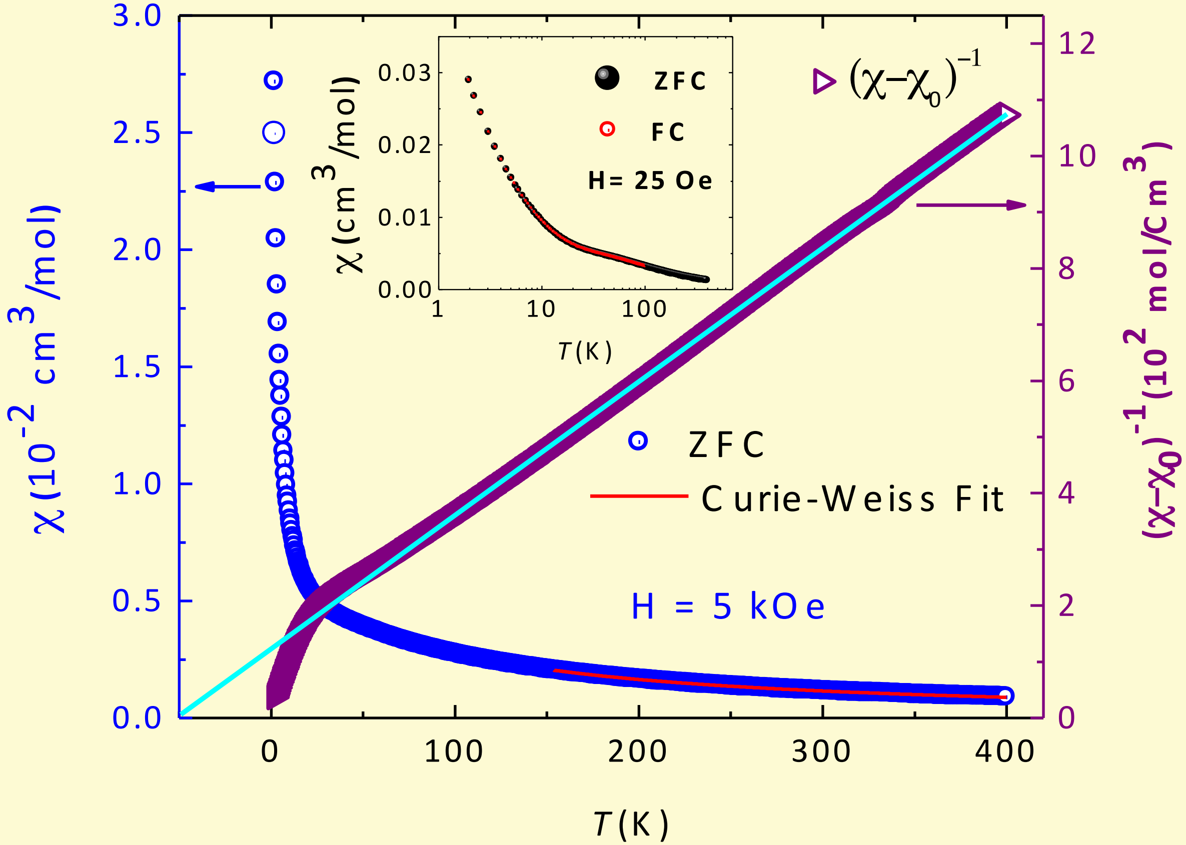
X-RAY AND NEUTRON DIFFRACTION (PSI)

- Small amts of impurities….Sc_2O_3~1.2 %, $CuGa_2O_4$~0.5%
- Cu-Ga antisite disorder expected due to their similar ionic sizes.
- Due to similar scattering lengths of Cu and Ga (in both XRD and ND), refinements are very similar for various occupancies
- The (0, 0, 0.25) planes are nearly fully Ga (10-15% Cu). The biplanes are an equal mix.

ACTUAL STRUCTURE

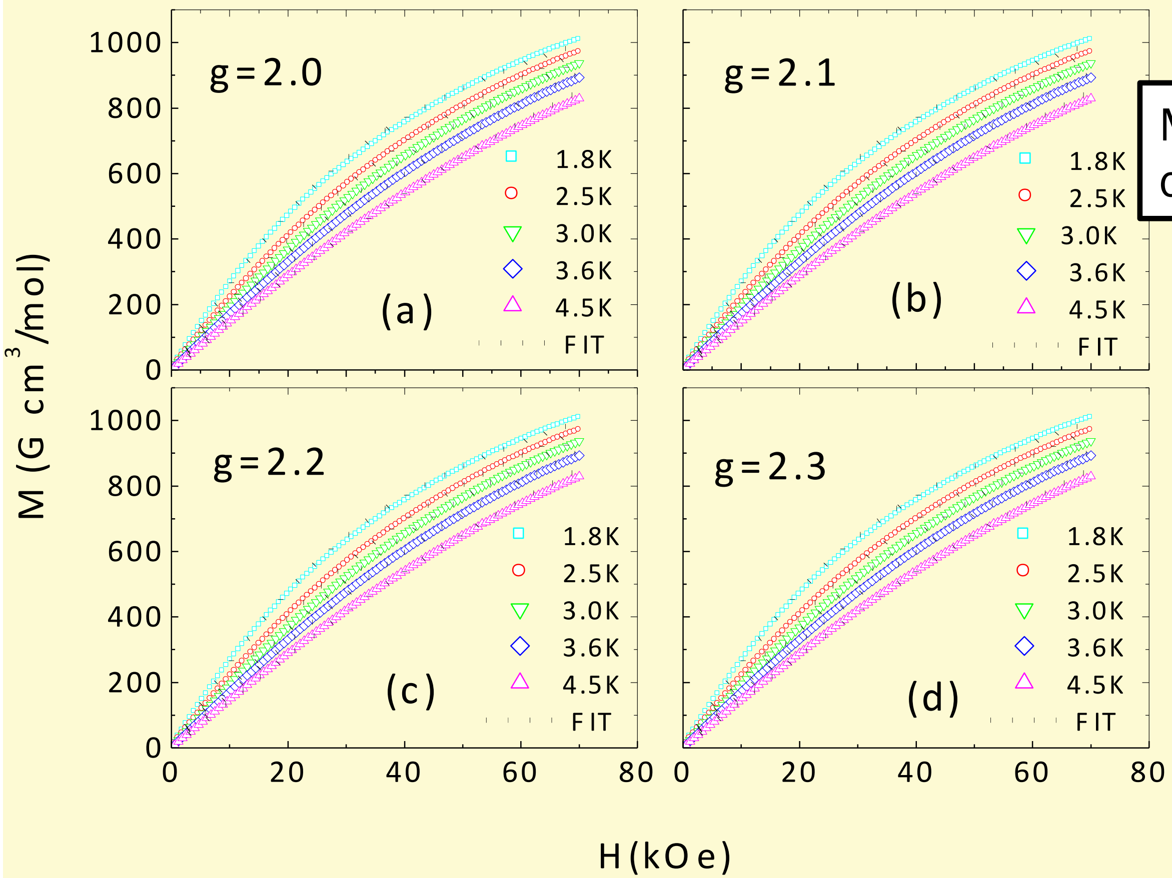


MAGNETIC SUSCEPTIBILITY



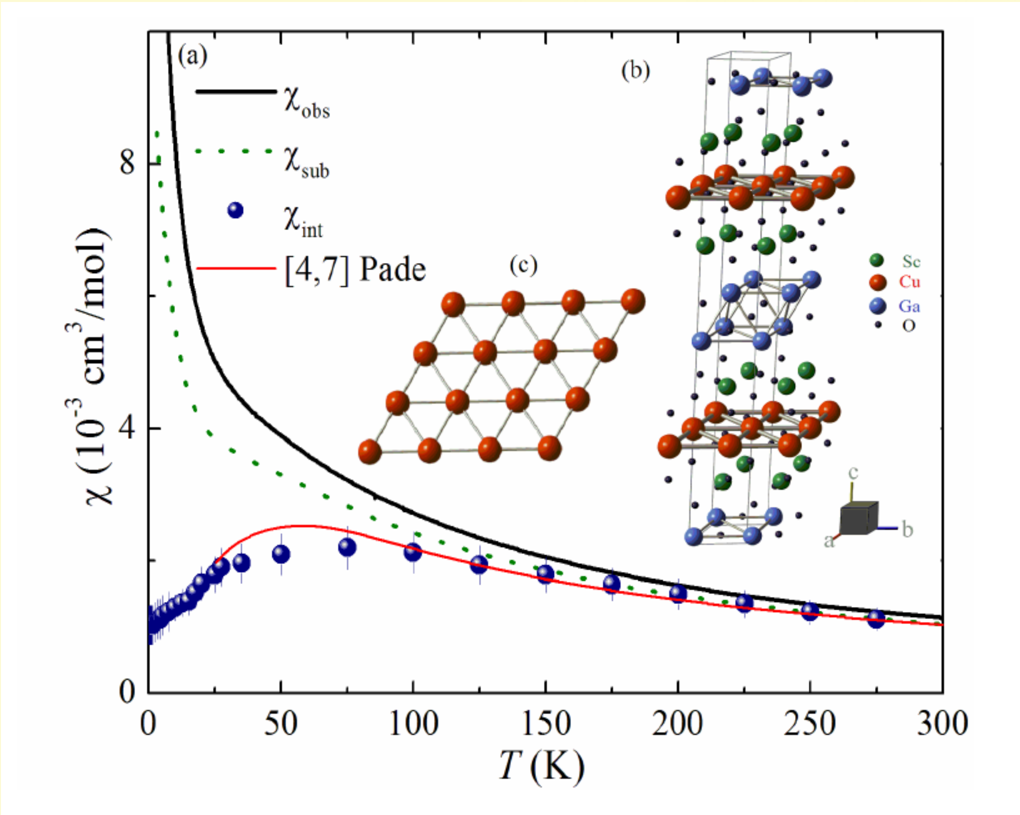
μ_{eff} = 1.79 μ_B
θ ~ -50 K
No ZFC/FC bifurcation

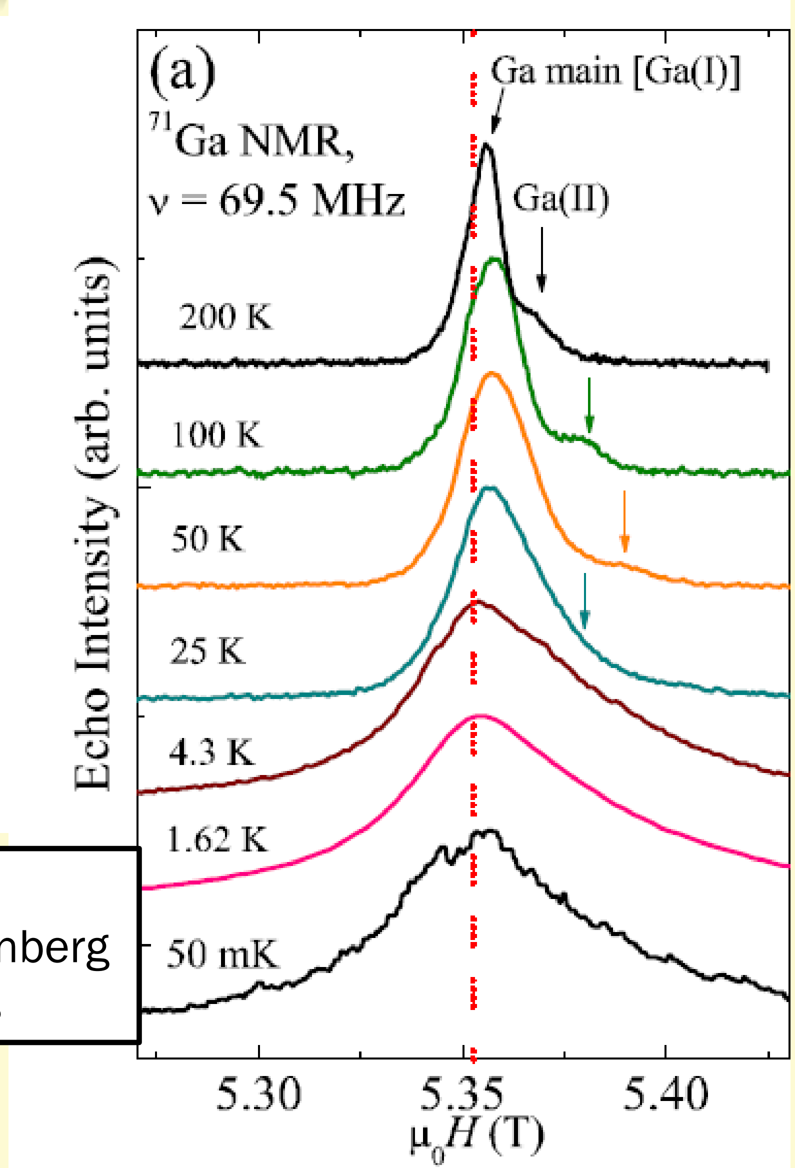
MAGNETISATION ISOTHERMS



M (H, T) = χH + Brillouin fcn
consistent with about 12% free spins

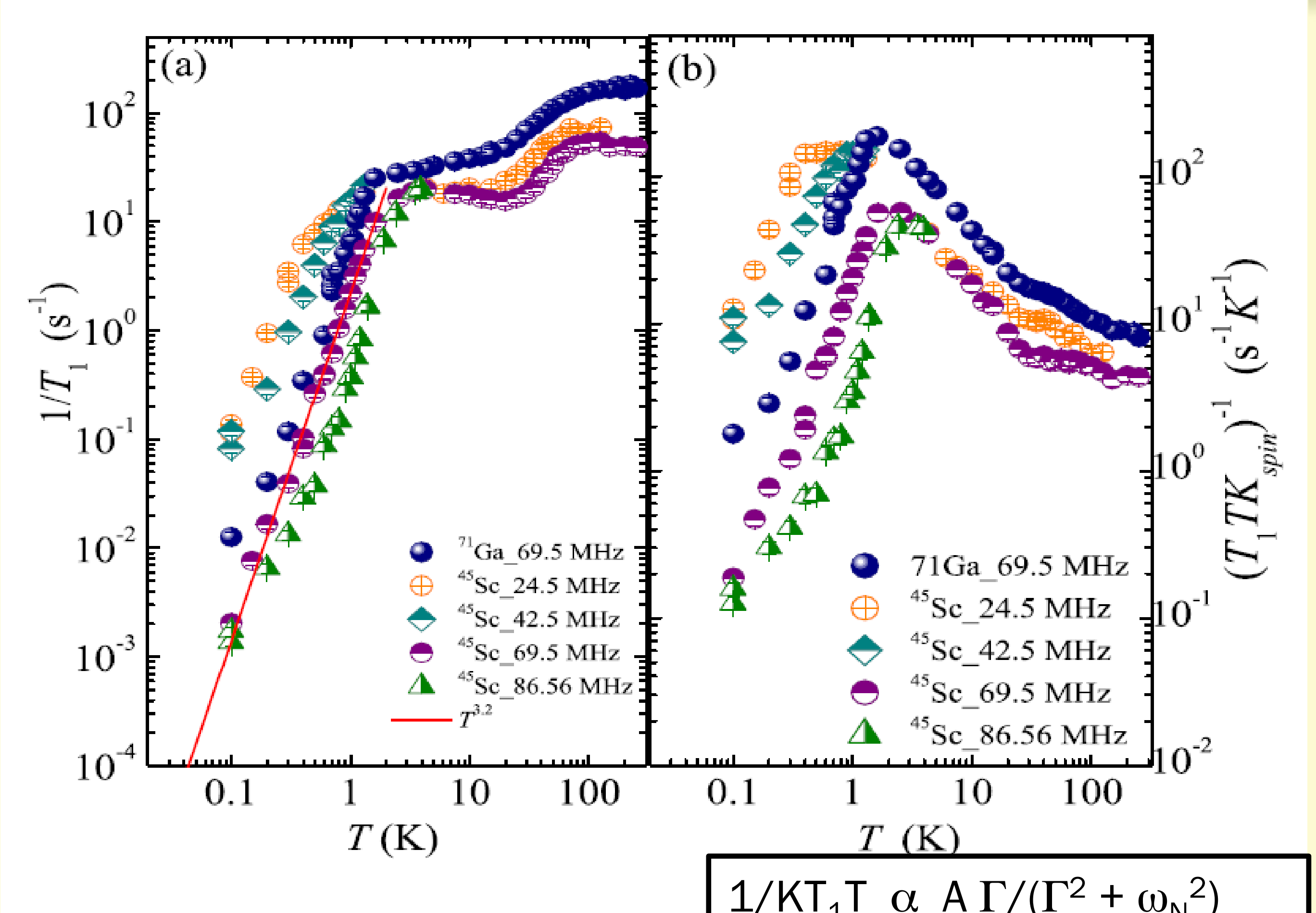
^{71}Ga NMR (AMES LAB)





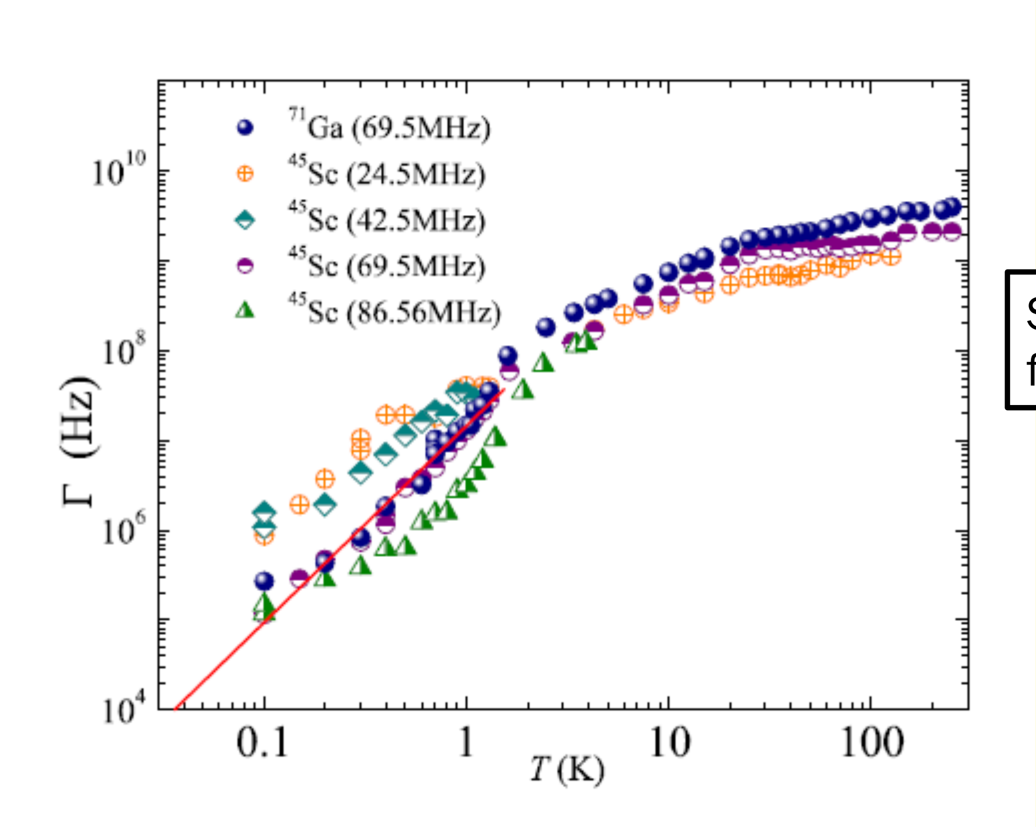
NMR susceptibility shows a broad max around 50 K
Above 30K consistent with HTSE of triangular Heisenberg
Two Ga lines originate from the Ga in the two planes

^{71}Ga AND ^{45}Sc SPIN-LATTICE RELAXATION RATE



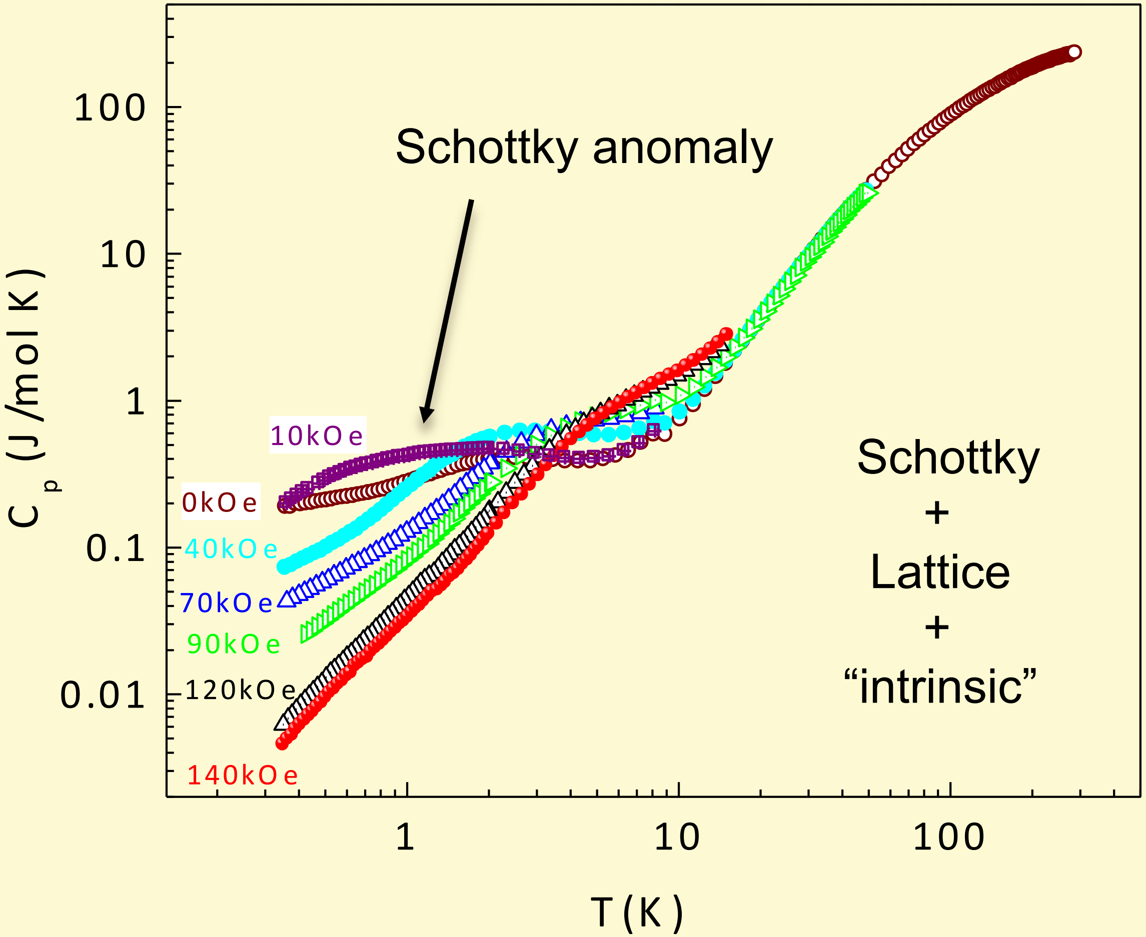
$1/KT_1T \;\alpha\; A\,\Gamma/(\Gamma^2 + \omega_N^2)$
Γ is the inverse of the correlation time of fluctuating hyperfine fields at the nucleus

$1/T_1 \;\alpha\; T^{3.2}$



Slowing down of fluctuation frequency of Cu spins

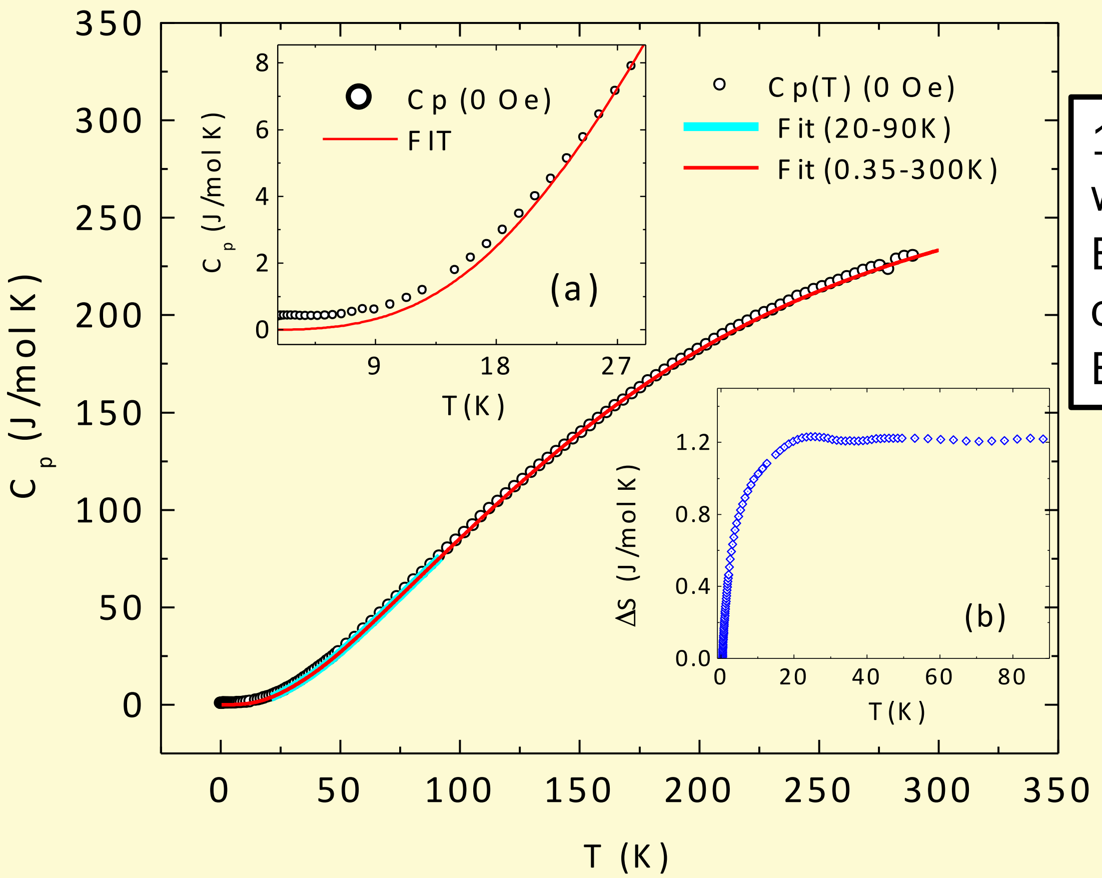
HEAT CAPACITY (MPICPfS DRESDEN)



ANALYSIS OF HEAT CAPACITY

- Subtract data at different fields from each other (removes the lattice and any field independent contribution)
- Fit such data to a combination of two Schottky terms
- Obtain (i) the Schottky gap for various fields and the (ii) fraction of spins which contribute (fixed to 10% in our case)
- Fit high-T data to a combination of Einstein and Debye terms… extrapolate to low-T
- Subtract Schottky and lattice part from the measured data to obtain the magnetic contribution C_m.

LATTICE HEAT CAPACITY

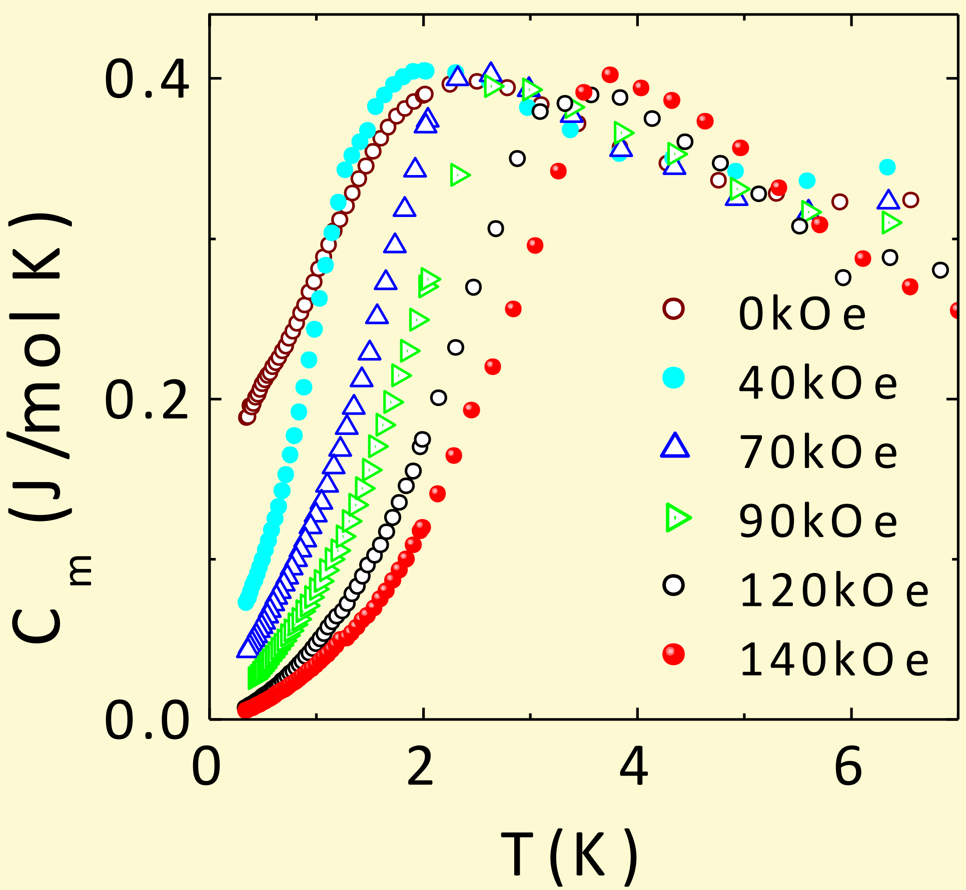


1 Debye + 3 Einstein with weights 1:1:4:6

Entropy change only about 20% of the value for ordered S = ½ system

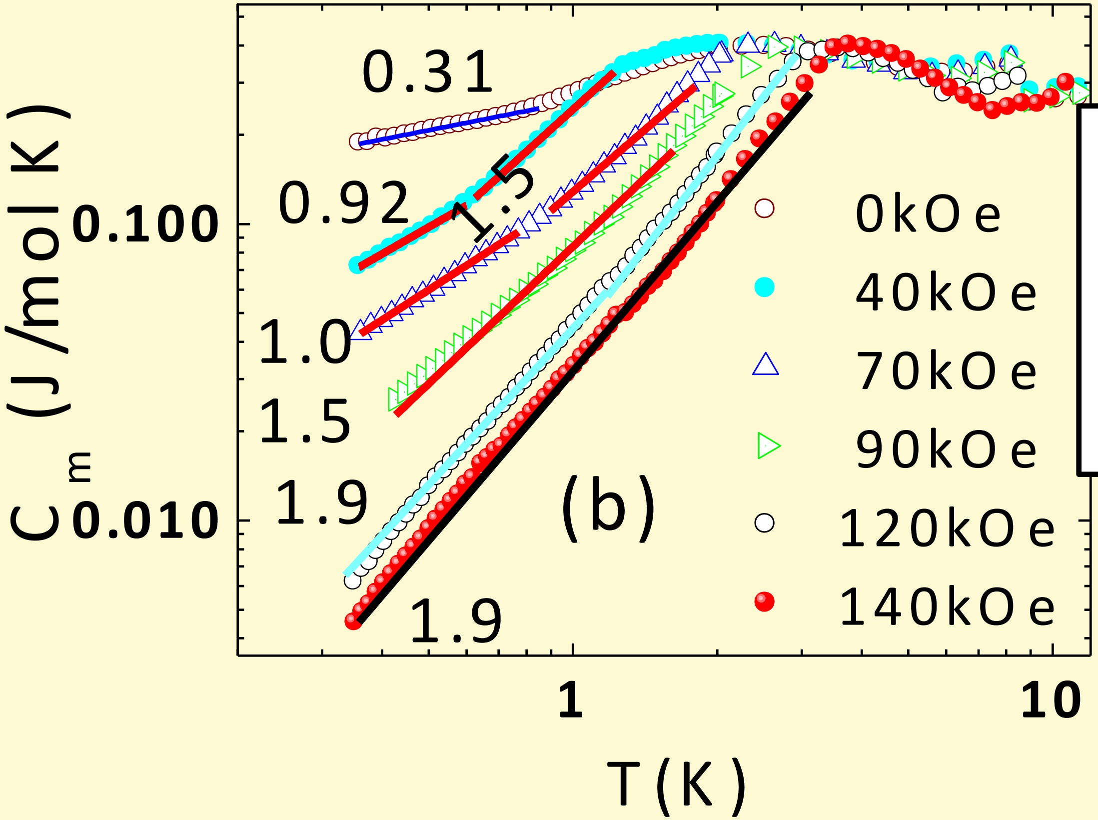
Even lower at higher fields.

MAGNETIC HEAT CAPACITY



Broad max around 2-4 K
Similar max seen in other frustrated systems $NiGa_2S_4$, $Na_4Ir_3O_8$, $Ba_3CuSb_2O_9$, $Ba_3NiSb_2O_9$

POWER LAW BEHAVIOUR



Note that in high field data below 1K There is negligible Schottky as also lattice contribution.
Exponent is more robust.
In any case, there is a field induced suppression of C_m at low-T.

Conclusion

- $Sc_2Ga_2CuO_7$ has "triangular" Cu planes with some Ga/Cu disorder
- Large Curie-Weiss θ = -50K but no ordering/freezing down to 50mK
- NMR susceptibility follows HTSE for a Heisenberg triangular system with J ~ 40 K
- Slowing down of Cu spin fluctuations below 2 K as $T^{2.2}$
- Magnetic heat capacity follows power law (T^2) at low-T for H > 90 kOe
- Field induced suppression of the magnetic excitations at low-T at lower fields
- We suggest a quantum spin liquid ground state for $Sc_2Ga_2CuO_7$

Collaboration and Funding

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