Random dilution effects in 1D spin system $CaCr_{2-x}Sc_xO4$

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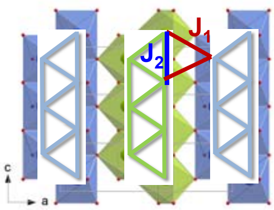
Introduction

β-$CaCr_2O_4$ is a compound in which magnetic chromium ions (S = 3/2) form parallel weakly coupled triangular ladders. A long-range magnetic order sets in below T_N = 21 K. This topology allows to combine both magnetic frustration and low dimensionality. In order to study the impact of random dilution on the magnetic properties and the 1D character of this compound, a series of substituted compounds $CaCr_{2-x}Sc_xO_4$ (0 ≤ x ≤ 1) was investigated by neutron scattering and magnetization measurements.

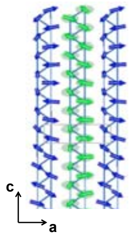
β-$CaCr_2O_4$

Structure

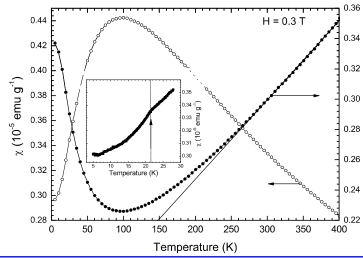


Pbnm a = 10.6203(3) Å [1]
b = 9.0801(3) Å
c = 2.9681(1) Å

- Cycloidal incommensurate structure : **k** = (0 0 q), q = 0.47 [1]
- In the mean-field approximation : [2] $\cos(\pi q) = \frac{J_1}{4J_2}$, $\frac{J_2}{J_1} = 3.3$



Magnetization Measurements

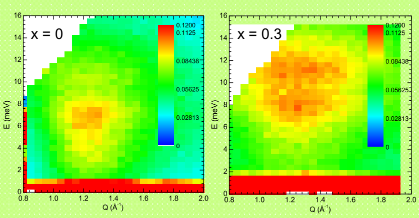


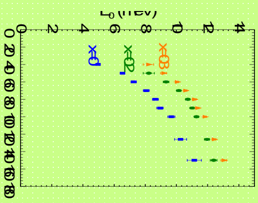
For x = 0 : [1]

- θ_{CW} = -239 ± 5 K
- μ_{eff} = 3.89 μ_B (μ_{th} = 3.87 μ_B, S = 3/2)
- T_N = 21 K
- f = $|\theta_{CW}|/T_N$ ~11

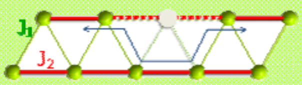
β-$CaCr_{2-x}Sc_xO4$

Inelastic neutron scattering measurements (T = 90 K)

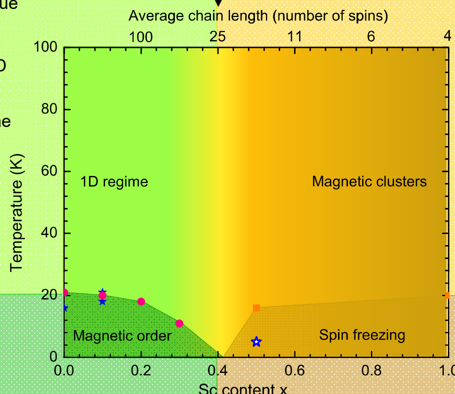




- Above TN, the spectra shows a pseudo-gapped excitation attributed to the onset of 1D quantum effects, which persists up to x = 0.3 and which can be seen over a large temperature range
- The characteristic frequency E_0 of the excitation increases with both temperature and substitution (« blue shift » [3])
- Progressive confinement of the 1D excitation within shorter chains
- Crucial role of J_2 in propagating the 1D excitation

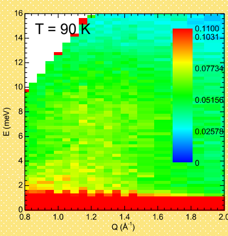


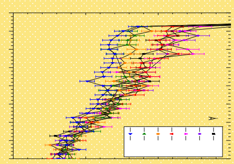
Threshold (~25 spins)



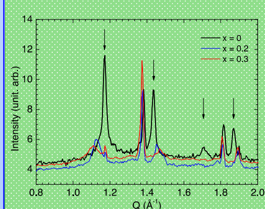
- The system breaks apart into a set of disconnected 3D clusters

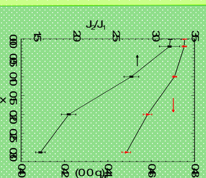
Inelastic neutron scattering measurements (x = 0.5)

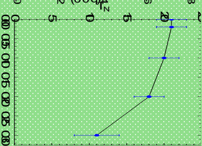




Neutron diffraction (T = 1.5 K)

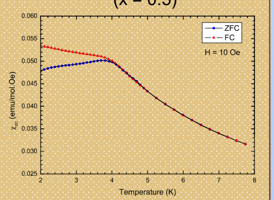






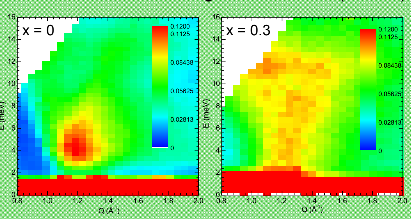
- Broadening of the magnetic Bragg peaks and significant decrease in the ordered magnetic moment
- Decrease in the magnetic correlation length (80 Å for x = 0.3) and in the component q of the propagation vector **k** = (0 0 q) with substitution

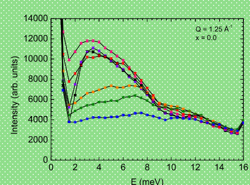
Susceptibility measurements (x = 0.5)

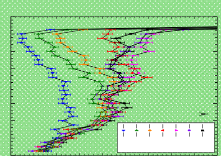


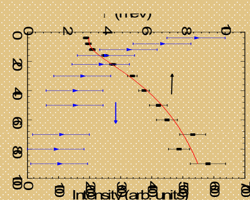
- Above x = 0.5 : disordered system with a spin glass transition below 4 K

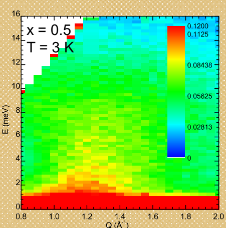
Inelastic neutron scattering measurements (T = 3 K)











Références :

[1] F. Damay *et al., Zigzag ladders with staggered magnetic chirality in the S = 3/2 compound β-$CaCr_2O_4$*, Phys. Rev. B 81, 214405 (2010)
[2] F. Damay *et al., Quantum gapped spin excitations in the S = 3/2 zigzag ladder compound β-$CaCr_2O_4$*, Phys. Rev. B 84, 020402 (2011)
[3] I. A. Zaliznyak *et al., Neutron-scattering study of the dynamic spin correlations in $CsNiCl_3$ above Néel ordering*, Phys Rev B 55(21), 15824 (1994)