Spin dynamics in the triangular lattice compound α-$SrCr_2O_4$

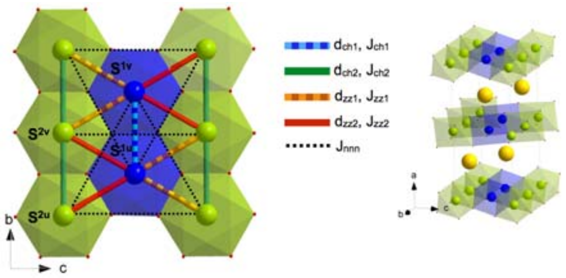
M. Songvilay[1], S. Petit[1], C. Martin[2], V. Hardy[2], F. Damay[1]

[1]Laboratoire Léon Brillouin, CEA-CNRS UMR 12, 91191 Gif-Sur-Yvette, France
[2]Laboratoire CRISMAT, CNRS UMR 6508, 6 bvd Maréchal Juin, 14050 Caen Cedex, France

Abstract

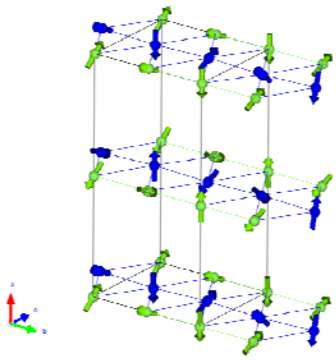
α-$SrCr_2O_4$ belongs to the same family of isostructural compounds as α-$CaCr_2O_4$ and presents a structure that comprises distorted triangular layers of magnetic chromium ions (S=3/2). This system undergoes a magnetic order below T_N ~ 43 K consisting of an incommensurate helical structure, close to the classical 120° spin structure. The spin dynamics in this triangular lattice system has been mapped out by means of inelastic neutron scattering and the spin Hamiltonian that best describes the data was determined, revealing a complex set of exchange couplings.

Structure and magnetic properties



Space group : *Pmmn*
a = 11.69 Å
b = 5.92 Å
c = 5.08 Å

Magnetization and specific heat [1][6]:
T_N ~ 43 K
θ_{CW} = -596 K



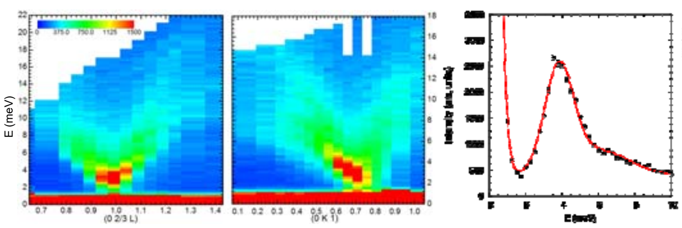
Below T_N, an incommensurate helical magnetic order sets in with **k** = (0 0.3217 0) [1]

The system displays a unique lattice distortion with 4 different nearest neighbor Cr-Cr distances but still stabilizes a structure close to the 120° structure

Spin dynamics by inelastic neutron scattering

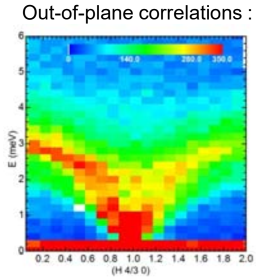
Magnetic excitations spectra measured on 2T and 4F1 at LLB-Orphée (T= 4 K)

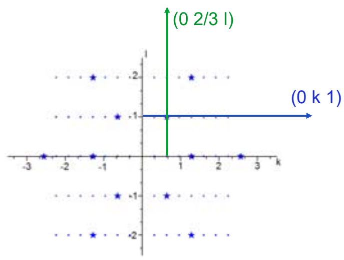
In-plane correlations :

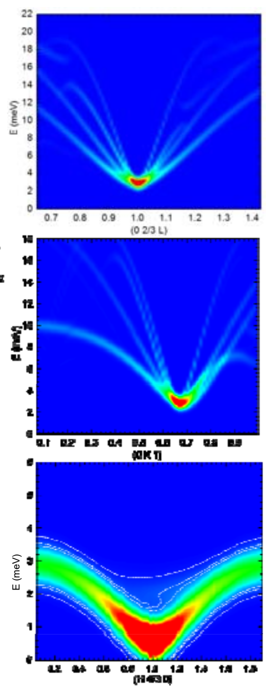


➡ Singularly broad signal
➡ The ordered magnetic moment is reduced : $2\mu_B$ ($3.87\mu_B$ for S=3/2)
➡ Quantum fluctuations ?

Out-of-plane correlations :







Spinwave calculations

The Hamiltonian used to describe the data [2] :

$$\mathcal{H} = \mathcal{H}_{nn} + \mathcal{H}_{nnn} + \mathcal{H}_{aniso}$$

$$\begin{aligned} H_{nn} = \sum_{i,j} & J_{ch1} S^{1u}_{ij} \cdot (S^{1v}_{ij} + S^{1v}_{(i-1)j}) \\ & + J_{ch2} S^{2u}_{ij} \cdot (S^{2v}_{ij} + S^{2v}_{(i-1)j}) \\ & + J_{zz1} S^{1u}_{ij} \cdot (S^{2u}_{i(j-1)} + S^{2v}_{i(j-1)}) \\ & + J_{zz1} S^{1v}_{ij} \cdot (S^{2u}_{(i+1)j} + S^{2v}_{ij}) \\ & + J_{zz2} S^{1u}_{ij} \cdot (S^{2u}_{ij} + S^{2v}_{ij}) \\ & + J_{zz2} S^{1v}_{ij} \cdot (S^{2u}_{(i+1)(j-1)} + S^{2v}_{i(j-1)}) \end{aligned}$$

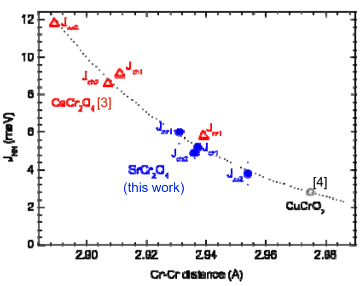
$$\begin{aligned} H_{nnn} = J_{nnn} \sum_{i,j} & S^{2u}_{ij} \cdot (S^{2u}_{(i+1)j} + S^{1u}_{(i+1)j} + S^{1u}_{(i+1)(j-1)}) \\ & + S^{2v}_{ij} \cdot (S^{2v}_{(i+1)j} + S^{1v}_{(i+1)j} + S^{1v}_{(i+1)(j-1)}) \\ & + S^{1u}_{ij} \cdot (S^{1u}_{(i+1)j} + S^{2v}_{i(j+1)} + S^{2v}_{ij}) \\ & + S^{1v}_{ij} \cdot (S^{2u}_{(i+1)j} + S^{2v}_{ij}) \\ & + S^{1v}_{ij} \cdot (S^{1v}_{(i+1)j} + S^{2u}_{(i+1)j} + S^{2u}_{(i+1)(j+1)}) \end{aligned}$$

$$H_{aniso} = \sum_i D(S_i n)^2$$

A set of exchange parameters was determined from the data; Spinwave calculations were performed using the SPINWAVE software developed at LLB [7] :

		ch1	ch2	zz1	zz2	J_{int}	J_{nnn}
α-$SrCr_2O_4$	distances (Å) (T= 3K) [1]	2.938(0)	2.936(0)	2.954(4)	2.932(4)	5.81(3)	
	J (meV) (this work)	5.2(1)	4.9(1)	3.8(2)	6.0(2)	0.020(2)	0.35(5)
α-$CaCr_2O_4$ [3]	distances (Å)	2.911	2.907	2.939	2.889	5.5	
	J (meV)	9.1	8.6	5.8	11.8	0.027	0.69

Conclusion



α-$SrCr_2O_4$	α-$CaCr_2O_4$ [2]
k=(0 0.3217 0) [1]	**k**=(0 0.3317 0) [5]
T_N = 43 K [1][6]	
θ_{CW}=-596 K [1][6]	θ_{CW}=-564 K
J_{mean} ≃ 4.9(15) meV (this work)	J_{mean} ≃ 8.8 meV [3]

- α-$SrCr_2O_4$ shows similar macroscopic magnetic properties to α-$CaCr_2O_4$ [2][3] but INS data reveal two different sets of values in terms of exchange couplings.
- Despite the triangular lattice distortion, the system stabilizes an incommensurate structure close to the classical 120° structure.
- The singularly broad signal observed by INS and the reduced magnetic moment in the ordered state could be a sign of strong quantum fluctuations affecting the ground state in this system, as was observed in α-$CaCr_2O_4$.

Références :

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