Frustration of coupled microscopic degrees of freedom in spinel compounds

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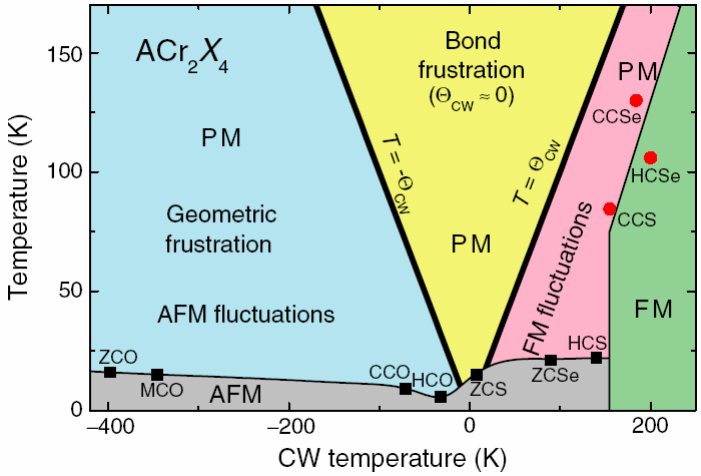
The family of normal cubic spinel systems AB_2X_4 (A = Zn, Cd, Fe, Mn ; B = Sc, Cr, Al ; X = O, S, Se) exhibit a wide range of exceptional ground state properties, depending on the appropriate choice of magnetic A- and B-site ions. Magnetic ions on the A-site form a diamond lattice and are subject to competing interactions; the B-sites form a pyrochlore sub-lattice which represents the prototype for a geometrically frustrated three-dimensional network. Thus in all compounds frustration strongly influences the complex interplay of orbital, magnetic, and structural degrees of freedom and the corresponding order phenomena, suppressing the energy scale for the correlated state from the mean-field value. In the case of magnetic A- and nonmagnetic B-sites (Sc) the different scenarios reach from a spiral spin liquid state with significant order by disorder in $MnSc_2S_4$ [1,2] to spin-orbital liquid behavior in $FeSc_2S_4$ [3]. On the other hand due to the Jahn-Teller active A-site and magnetic B-site configuration in $FeCr_2S_4$ ferromagnetic and orbitally ordered or glassy states are realized [4]. Finally, for the $CdCr_2S_4$ [5] system the absence of an orbital degree of freedom enables the structural degeneracy to be lifted by local polar distortions and multiferroic behavior, namely the coexistence of ferromagnetism and relaxor ferroelectricity. The coupling of structural and spin degrees of freedom via local exchange-striction in a bond frustrated state is nicely demonstrated via the large magneto-strictive effect in $ZnCr_2S_4$ [6].
The results are characterized by means of specific heat, magnetization, susceptibility, x-ray, and neutron measurements, as well as dielectric and optical spectroscopy.



Phase diagram of ACr_2X_4 as function of the Curie-Weiss temperature.
FM (red circles) and AFM (black squares) denote ordering temperatures [7].

[1] A. Krimmel et al., PRB 73, 014413 (2006); [2] D. Bergman et al., Nature Physics 3, 487 (2007); [3] V. Fritsch *et al.*, Phys. Rev. Lett. 92, 116401 (2003); [4] R. Fichtl *et al.*, Phys. Rev. Lett. 94, 027601 (2004); [5] J. Hemberger, et al., Nature 434, 364 (2005) and S. Weber et al., PRL 96, 157202 (2006); [6] J. Hemberger et al. Phys. Rev. Lett. 98, 147203 (2007) ;[7] T. Rudolf, et al., New Journ. Phys. 9, 76 (2007).