Magnetism of frustrated A-site Spinels $(Mn, Fe, Co)Al_2O_4$

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The three compounds crystallize in the $(A)[B_2]O_4$ spinel structure. The magnetic A-site sublattice forms a diamond lattice with tetrahedral coordination. Together with competing AFM nn- and FM nnn-interactions this leads to strong frustration which tends to suppress long-range magnetic order (LRO) in favor of short-range ordered (SRO) magnetic ground states. Also spin fluctuations are enhanced and often persistent in the $T \to 0$ limit. Detailed data on bulk magnetic properties are available [1]. Susceptibility reveals that $MnAl_2O_4$ becomes an antiferromagnet at $T_N = 40\,\mathrm{K}$. The other two materials show no evidence for entering into a LRO state, but exhibit at low temperatures ($\sim$10 K) susceptibility cusps. Field cooled vs. zero field cooled behavior suggest a spin-glass-like ground state. Neutron diffraction [2] reveals in the Mn compound a collinear simple AFM state coexistent with a paramagnetic fraction below T_N. In the Co and Fe spinels magnetic Bragg peaks are absent and a liquid-like magnetic structure factor is seen. The μSR spectra of the compounds consisted of two signals at all temperatures. One signal shows fast ("f"), the other slow ("s") relaxation. In $MnAl_2O_4$ the relative intensities of the two signals are temperature independent (A_f /$A_s = 0.75/0.25$), in the other two alloys A_f rises from $\sim$0.2 at high temperatures ($T \ll T_{cusp}$) to $\sim$0.8 on approaching T_{cusp} and then remain constant. The origin of the two signals is not understood. The differences in signal intensities and temperature dependences between the compounds renders two muon stopping sites unlikely. The fast relaxing fraction in $MnAl_2O_4$ forms the LRO state at $T < T_N$. Its signal largely vanishes in the instrument dead time, indicating that static spin disorder as well as spin fluctuations are substantial. The slow relaxing signal shows dynamic Lorentzian Kubo-Toyabe shape, meaning that a dynamic SRO spin state is formed. The coexistence of LRO and SRO is confirmed. In $CoAl_2O_4$ and $FeAl_2O_4$ the fast relaxation rates both rise sharply on approach to T_{cusp}, then stay constant for $T < T_{cusp}$ keeping exponential shape. A longitudinal field of 0.3 T has no influence on λ. At T_{cusp} strong spin-spin correlations set in with persistent spin fluctuations. The magnetic ground state is not a true glassy state, rather a highly dynamic SRO spin structure.

[1] A. Tristan et al., Phys. Rev. B 72 (2005) 174404.
[2] A. Krimmel et al., Physica B 378 - 380 (2006) 583