Exotic antiferromagnetic transition in deformed pyrochlore lattice $Ni_2(OH)_3Cl$ of atacamite-structure

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In recent years, we found unconventional magnetic transitions in a mineral compound clinoatacamite $Cu_2(OH)_3Cl$ and the coexistence of long-range antiferromagnetic order and spin fluctuation in clinoatacamite $Cu_2(OH)_3Cl$ [1]. It is the first example of the S = 1/2 (Cu^{2+}) Heisenberg quantum spin on a pyrochlore lattice and the mother compound for the "perfect kagome lattice" $ZnCu_3Cl_2(OH)_6$ exhibiting spin liquid behavior [2]. We further found that in another compound with a similar chemical formula $Co_2(OH)_3Cl$, a partial FM order coexists with spin fluctuation at zero-field [3], which is reminiscent of the field-induced "kagome ice" state in pyrochlore $Dy_2Ti_2O_7$.

We further found that there is a rich material series in the chemical formula of $M_2(OH)_3X$, with M = Cu, Co, Ni, Fe, Mn, and X = Cl, Br, or I [3]. Many chemical formulas have polymorphous crystal structures which can be the deformed pyrochlore lattice, two-dimensional kagome-like lattices or triangular lattice. Up to date we have extensively investigated their magnetic properties with multiple magnetic probes including magnetization, specific heat, neutron diffraction and muon spin relaxation/rotation (μSR). Exotic magnetic properties arising from geometric frustration and complicated phase transitions have been observed for many compounds. Of particular interest is a novel antiferromagnetic order in some atacamite-type-structure systems. For example, in atacamite-structure $Ni_2(OH)_3Cl$, strong geometric frustration and an antiferromagnetic transition below 5 K was found. While neutron diffraction witnessed unambiguously an antiferromagnetic long-range order, the μSR method can't "see" this order, instead, the local field detected behaved quite like a dynamically fluctuating one. This unconventional behavior cannot be explained consistently with any known magnetic order. It may be the first practical material system for a novel type of antiferromagnetic order theoretically predicted on pyrochlore lattice, i.e., the Kawamura model [4] which proposes a unconventional order where the squared Fourier amplitude orders but the amplitude itself fast fluctuating.

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