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Quantum kagome spin liquids: a local view

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The antiferromagnetic kagome lattice decorated with quantum spins has been considered since the late 90's as the best candidate for stabilizing a quantum spin liquid in dimension higher than one. From a theoretical point of view, the simple Heisenberg case remains a standing problem, not solved yet. Experimental realizations have remained scarce for long until the discovery of Herbertsmithite $ZnCu_3(OH)_6Cl_2$ in 2005. It features a perfect kagome geometry and was first in this geometry not to show any freezing at any temperature [1]. It was coined as the "end to the drought of spin liquids" [2,3]. It has triggered an intense activity on new kagome materials and related theories for the ground state of the quantum kagome Heisenberg antiferromagnet which I'll briefly summarize.

The crucial problem for experimentalists is the presence of quasi-free Cu^{2+} on Zn^{2+} sites separating the kagome layers which mask the signature of the kagome physics at low-T in most experimental techniques, typically $T<J/10$. These difficulties can be circumvented by using local techniques such as NMR. Indeed, one can take advantage of the strong coupling of O to the kagome Cu's –this is the exchange path- to track this physics through ^{17}O NMR. However, one cannot get rid completely of the Cu/Zn defects signature in NMR spectra, but the different spectral signatures from Cu spins on the kagome lattice and those on Zn site have opened the way to the discussion of the gapped character of the ground-state [4]. We will present our ^{17}O NMR study on high quality crystals. The defects contribution at low-T is clearly singled out and has been studied in great detail. Our shift and T_1 relaxation measurements will be presented and discussed in the light of the recent findings from the Mac Master's group [5]. From our study we claim that no gap opens down to 1.2 K, ie 0.007 J. Insights on the defect physics is also gained from recent high field ESR [6] measurements on our samples.

Given the difficulty in solving the theoretical problem of the kagome Heisenberg antiferromagnet, an alternative route for the study of quantum spin liquids was opened with a modified version of the kagome lattice, the *trimerized*, or more recently coined *breathing* kagome lattice [7] after the breathing pyrochlores [8]. It also consists of corner sharing equilateral triangles and thus importantly it retains the full degeneracy of the kagome lattice at the classical level. However a dissymmetry is allowed in between the interactions on the triangles pointing up J_Δ and those pointing down J_∇ (see Fig 1, inset) which defines a large class of highly frustrated systems encompassing the kagome one ($J_\Delta = J_\nabla$). The recently discovered vanadium V^{4+} ($3d^1$, S =1/2) oxyfluoride compound $(NH_4)_2[C_7H_{14}N][V_7O_6F_{18}]$ (DQVOF) [9] features such a breathing kagome lattice. Through our ^{17}O NMR study of DQVOF [10], we can isolate the local susceptibility of the breathing kagome network. A fit to series expansion yields the ratio of the interactions within the breathing kagome plane, $J_\Delta / J_\nabla = 0.55(4)$, and the mean antiferromagnetic interaction J = 60(7) K. Spin lattice, T_1, measurements reveal an essentially gapless excitation spectrum with a maximum gap $\Delta/J = 0.007(7)$, if any.

Whether the gapless spin liquid behavior displayed by DQVOF is intrinsic to its breathing kagome lattice or whether it is due to perturbations to this model, such as a residual coupling of the V^{4+} ions in the breathing kagome planes to the interlayer V^{3+} (S = 1) spins remains an avenue for future research.

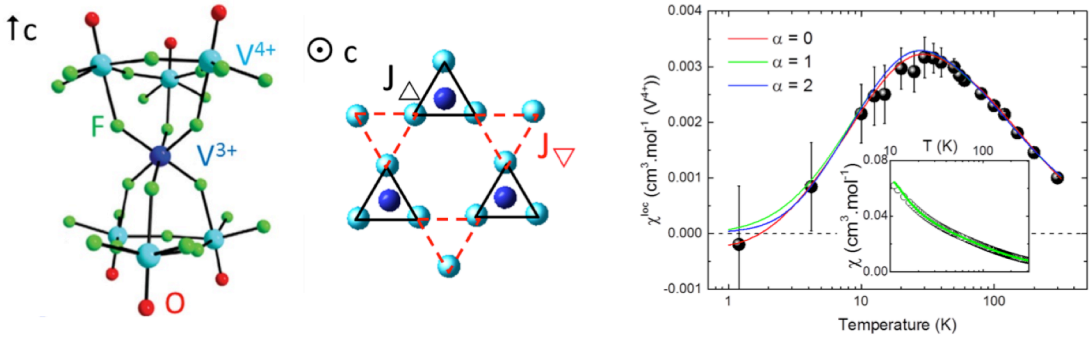

Fig. 1 Left: Local environment of V^{4+} S=1/2 kagome and V^{3+} S=1 interlayer ions in DQVOF. Middle: Top view of the magnetic lattice with V^{4+} light blue and V^{3+} dark blue ions. Right: Local NMR susceptibility of the kagome layers in DQVOF. Inset: SQUID macroscopic susceptibility (circles) and fit (line) to a combination of the kagome V^{4+} (S=1/2) and a paramagnetic contribution from the other V^{3+} (S=1) interkagome weakly coupled site .

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