NMR spectroscopy on quantum spin liquids and solids

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NMR is useful in identifying symmetry of molecules and electrons. Electron spins in condensed matters would break time-reversal symmetry by long-range magnetic order. The exceptional case is quantum spin liquid where quantum fluctuations overcome the magnetic order. Instead of conventional order, quantum spin liquid involves nonlocal quantum order with quantum entanglement. The experimental identification has been a changing issue in condensed matter physics. The

We have focused on molecular magnets having frustrated spin lattice such as triangular lattice. Our NMR study observed no indication of magnetic ordering in triangular antiferromagnets. There are low-energy excitations from the ground state, suggesting gapless spin liquid. The spin exchange interaction between molecular dimers is tunable by applying hydrostatic pressure while leaving the system insulating [1]. The spin susceptibility against exchange coupling allows to yield the scaling function of spin liquid.

As the triangular lattice is distorted, the ground state becomes less frustrated and exhibits magnetic order or spin dimerization called valence bond solid. The spin dimer state is destabilized and transits into incommensurate magnetic order by applying strong magnetic field in contrast to the gapless spin liquid less sensitive to the field [2]. The transition can be first order following the Ginzburg-Landau-Wilson paradigm but become second order in the presence of topological degeneracy. The nature of the transition is discussed on the basis of the phase diagram obtained from NMR and magnetization measurements.

[1] Y. Shimizu *et al.,* Phys. Rev. Lett. **117**, 107203 (2016).
[2] Y. Shimizu *et al.*, Phys. Rev. Research **3**, 023145 (2021).