Magnetoelastic interactions in the spin-dimer compound $SrCu_2(BO_3)_2$

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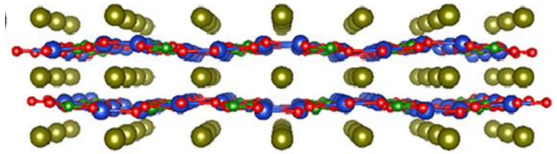
$SrCu_2(BO_3)_2$ is a Mott-Hubbard insulator that hosts an orthogonal spin-dimer system, with a tetragonal unit cell that accommodates spin $S = 1/2$ Cu^{2+} dimers arranged in copper-oxygen-boron planes separated by strontium spacer layers. *$SrCu_2(BO_3)_2$ is also a physical realization of the exactly-solvable two-dimensional Shastry-Sutherland model proposed more than four decades ago*. The combination of geometrical frustration, exchange interactions that are sensitive to the Cu-O-Cu angle, and proximity to a quantum critical point make this a fascinating compound, very rich in magnetic phases stabilized with tuning parameters such as temperature, external magnetic fields, applied pressures, and disorder induced by chemical substitutions. *Thus, $SrCu_2(BO_3)_2$ is a unique system that provides numerous practical routes to tune exotic states such as spin stripe phases, spin supersolids, spin plaquettes, and quantum spin liquids.*

In an effort to understand the extent of the exchange interaction's dependency on the Cu-O-Cu angle, the user collaboration performed technically difficult magneto-Raman scattering experiments in magnetic fields up to 45T, the highest continuous magnetic field in the world, and coupled these results with first principles calculations. *The research team is a diverse group of scientists from Europe and the USA, with the lead author being physics professor at a minority-serving institution who maintains her research laboratory at the MagLab*.

The experimental and theoretical work presented here provides a direct correlation between the magnetic interaction and the Cu-O-Cu angle and identifies the phonons that facilitate this interaction between the Cu ions. As such, this work is a milestone in the understanding quantum materials with novel magnetic properties. *A clear understanding of the exchange mechanism in these materials is crucial for developing future applications that rely on controllable quantum phenomena*.

1. (a)



(b)

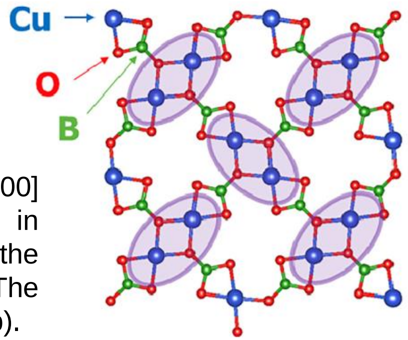


Fig.1: Atomic structure of $SrCu_2(BO_3)_2$ (a) along the [100] direction and (b) along the [001] direction. Sr atoms are in yellow, O in red, B in green, and Cu in blue. The buckling of the $[CuBO_3]$−layers along the [001] direction is visible in (a). The orthogonal Cu dimers have been highlighted in magenta in (b).

2.

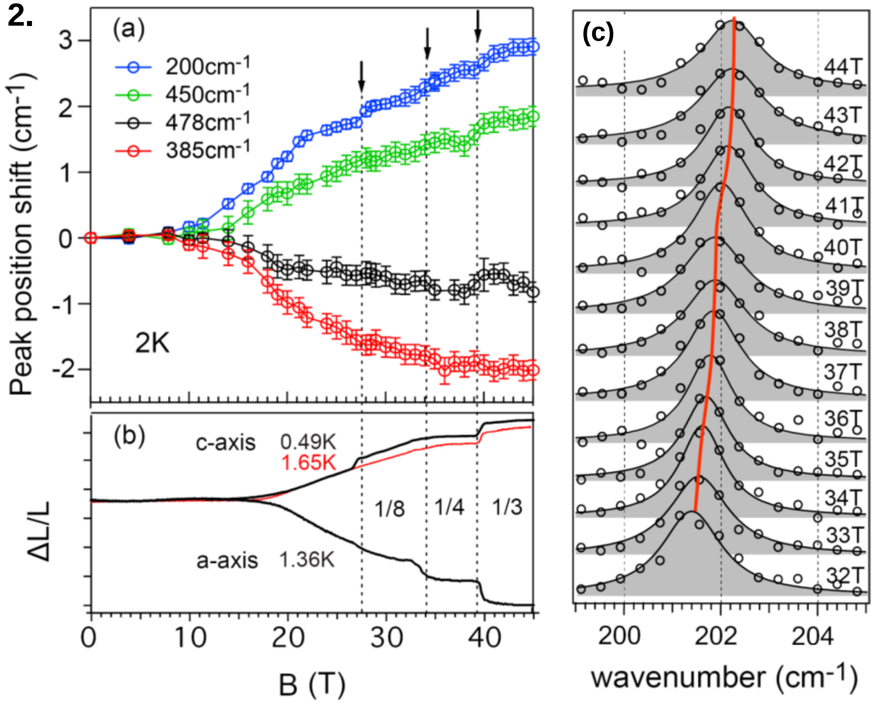


Fig.2: (a) Evolution of the energy of four Raman modes of $SrCu_2(BO_3)_2$ with applied magnetic fields up to 45T. The arrows point to the anomalies detected in 200cm⁻¹ mode coinciding with M/Ms = 1/8, 1/4, and 1/3 phases. (b) Magnetostriction of $SrCu_2(BO_3)_2$ along a and c axes measured at magnetic fields up to 45T. (c) and (d) Evolution of the 200cm−1 pantograph phonon mode with respect to increasing magnetic fields in the range 24-44T. The data points are shown as open circles and the solid lines are the Lorentzian fit of the data.

Facilities and instrumentation used: 45T hybrid magnet system and 31T resistive magnet.

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