



Magnetoelastic interactions in the spin-dimer compound $\text{SrCu}_2(\text{BO}_3)_2$

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$\text{SrCu}_2(\text{BO}_3)_2$ 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. $\text{SrCu}_2(\text{BO}_3)_2$ 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, $\text{SrCu}_2(\text{BO}_3)_2$ 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.

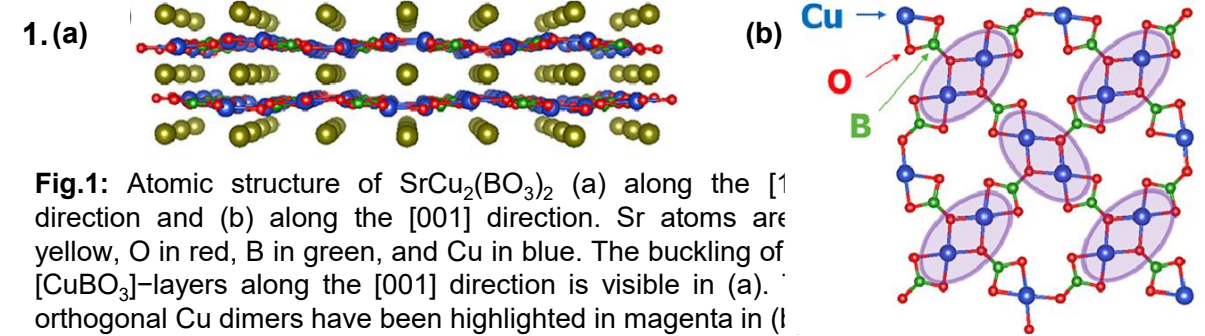


Fig.1: Atomic structure of $\text{SrCu}_2(\text{BO}_3)_2$ (a) along the $[100]$ direction and (b) along the $[001]$ direction. Sr atoms are yellow, O in red, B in green, and Cu in blue. The buckling of $[\text{CuBO}_3]$ -layers along the $[001]$ direction is visible in (a). The orthogonal Cu dimers have been highlighted in magenta in (b).

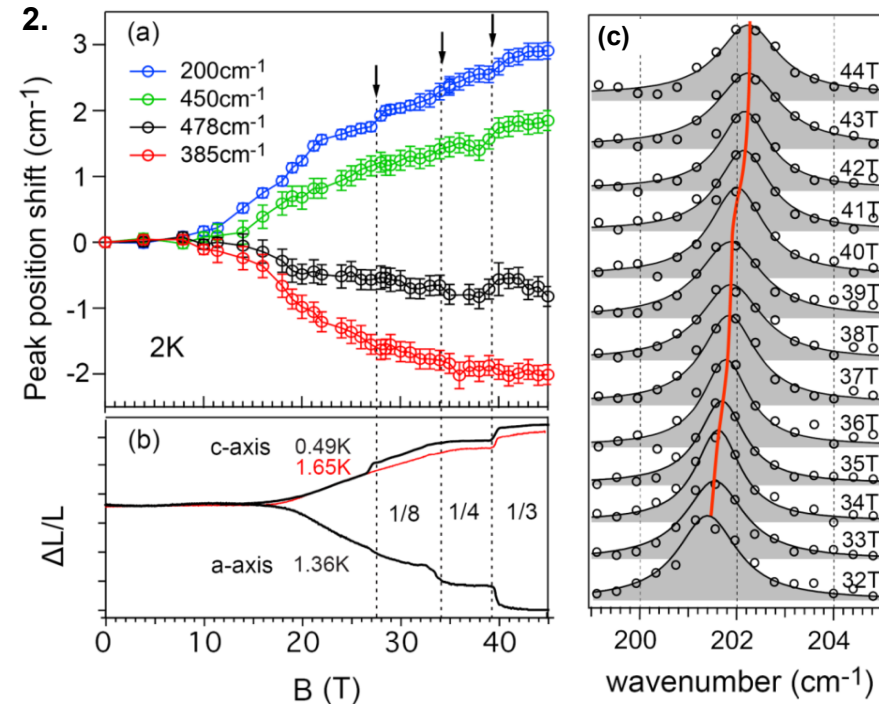


Fig.2: (a) Evolution of the energy of four Raman modes of $\text{SrCu}_2(\text{BO}_3)_2$ with applied magnetic fields up to 45T. The arrows point to the anomalies detected in 200cm^{-1} mode coinciding with $M/M_s = 1/8, 1/4$, and $1/3$ phases. (b) Magnetostriction of $\text{SrCu}_2(\text{BO}_3)_2$ along 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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