Quantum Phase Transitions in a Quasi-one-dimensional Ising Quantum Magnet

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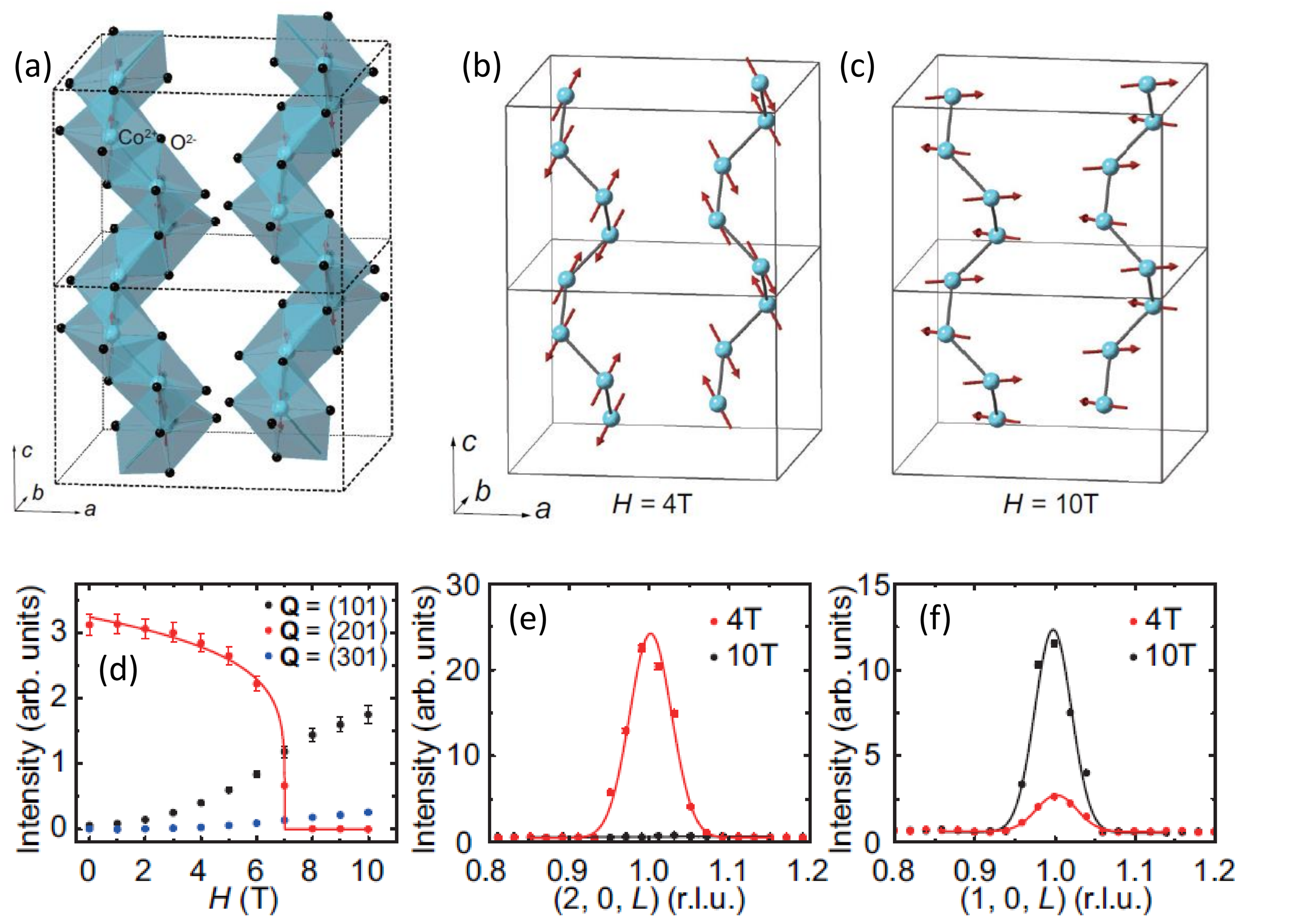
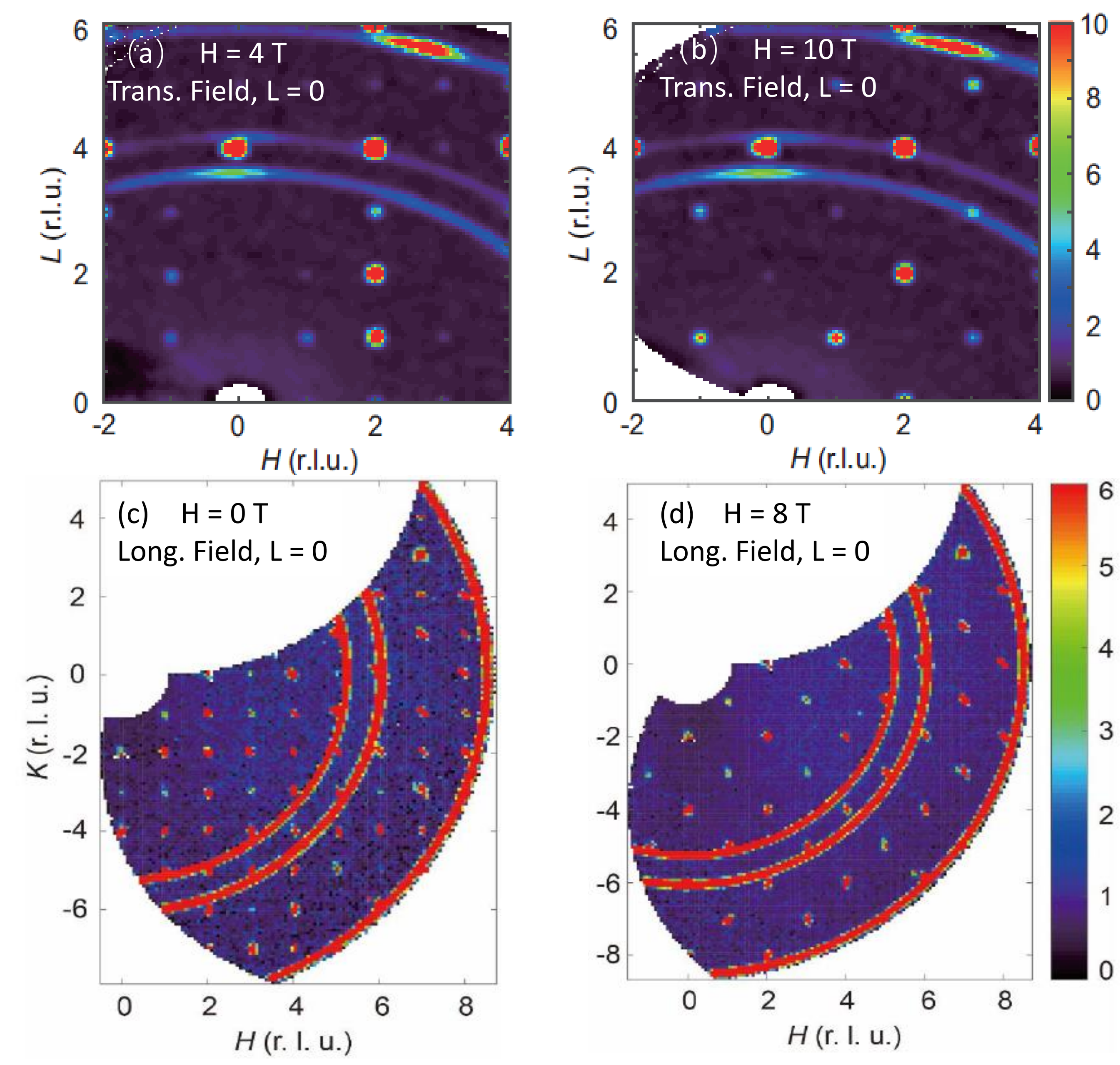
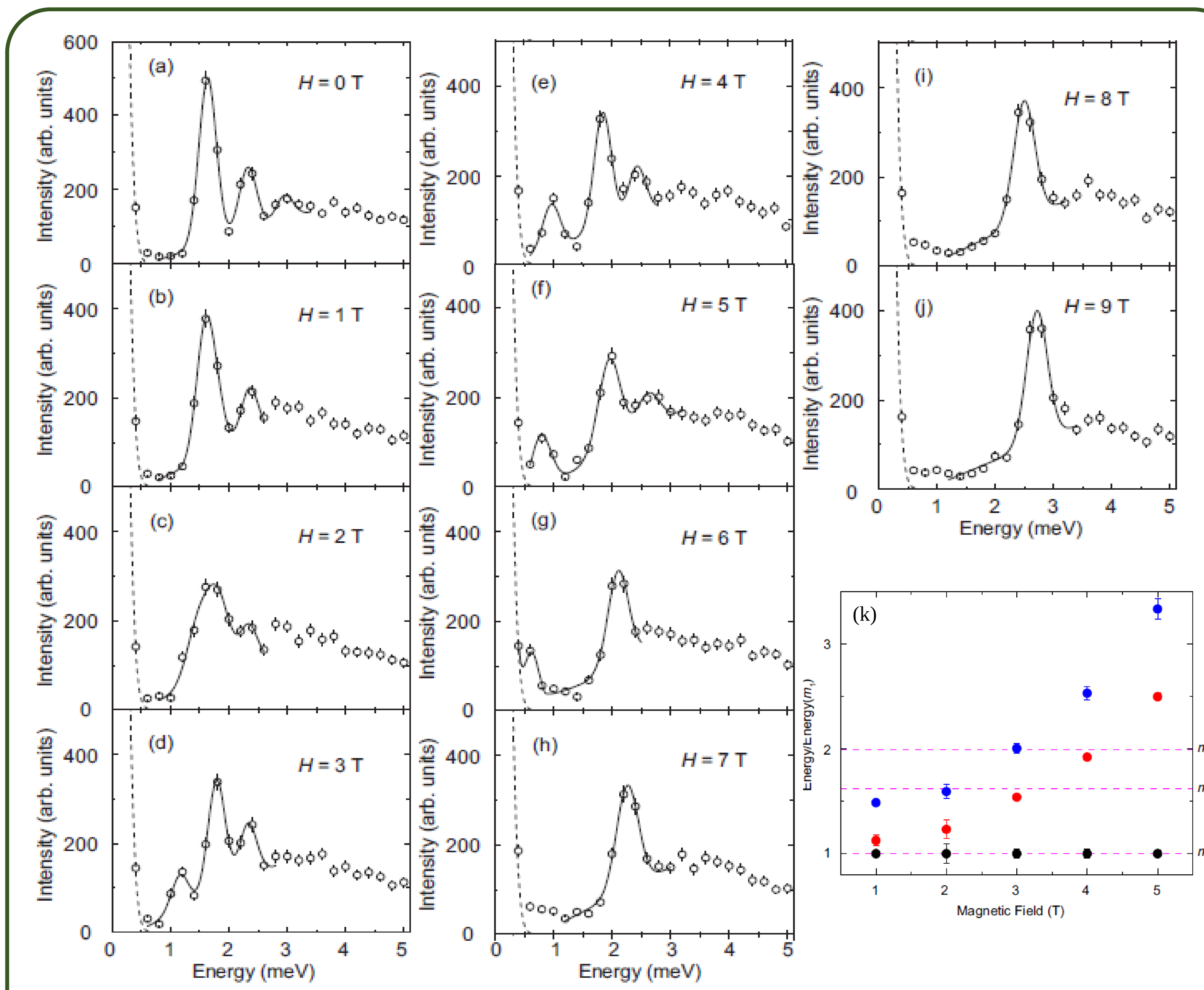
Abstract We report neutron scattering measurements of the quasi-one-dimensional Ising magnet $SrCo_2V_2O_8$ under transverse fields along the tetragonal *a/b* direction and longitudinal fields along the c direction. Our experiments reveal a Neel-type magnetic order in zero field, which successively changes into a coplanar antiferromagnetic order in applied transverse fields while longitudinal fields will not induce new magnetic phase. Moreover, a series of gapped discrete confined-spinon modes are observed in zero field. With increasing transverse field, the spin gap progressively softens, reaching a minimum value at ~7 T where the Neel-type magnetic ordering moment is completely suppressed. This corresponds to the three-dimensional quantum critical point (QCP). For longitudinal field case, incommensurate peaks which could probably be explained by TLL theory are observed, accompanied by the splitting of the highest energy modes in the spectrum splits into two modes. The implications for multiple QCPs in this class of materials are discussed.



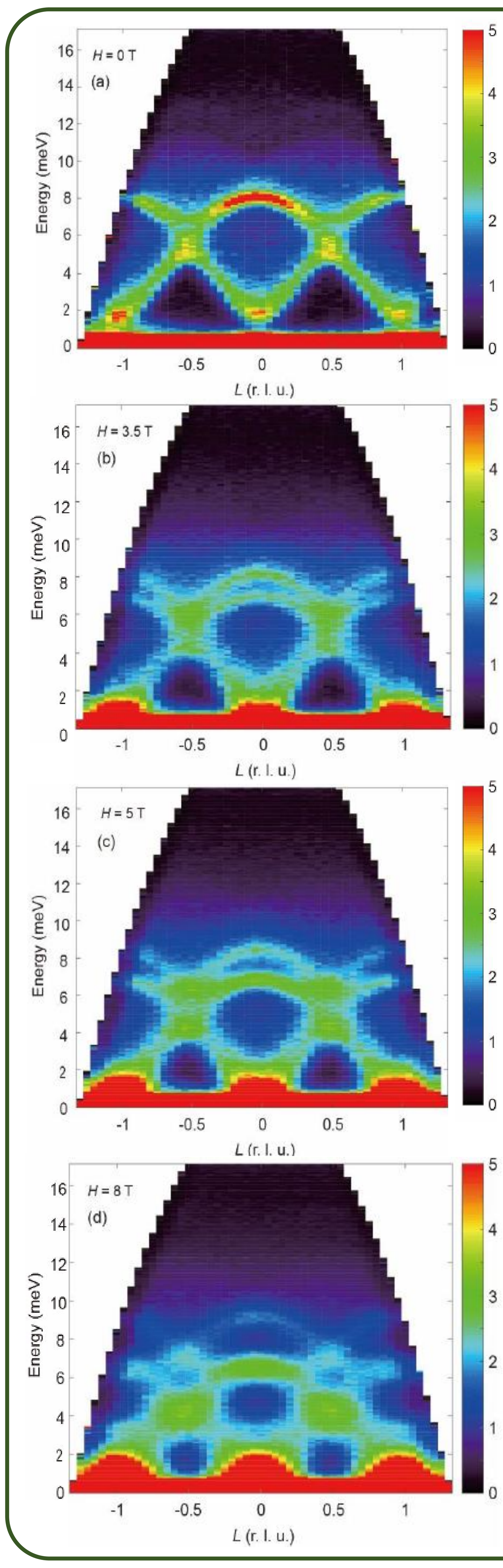
Magnetic structure of $SrCo_2V_2O_8$ under transverse field. | (a-c) Schematic of the lattice and magnetic structure for $SrCo_2V_2O_8$ at a transverse field of H = 0, H = 4 T and H = 10 T. Magnetic moments gradually reorients when the magnetic field increases. (d) Field dependence of the neutron diffraction intensity at the indicated **Q** positions at 1.5 K which indicates the change of k-vector from **k** = (1 0 0) at zero field to **k** = (0 0 0) at high field. Elastic **Q**-cuts across (2, 0, 1) (e) and (1 0 1) (f) along the *L* direction at 4 and 10 T are shown as well.

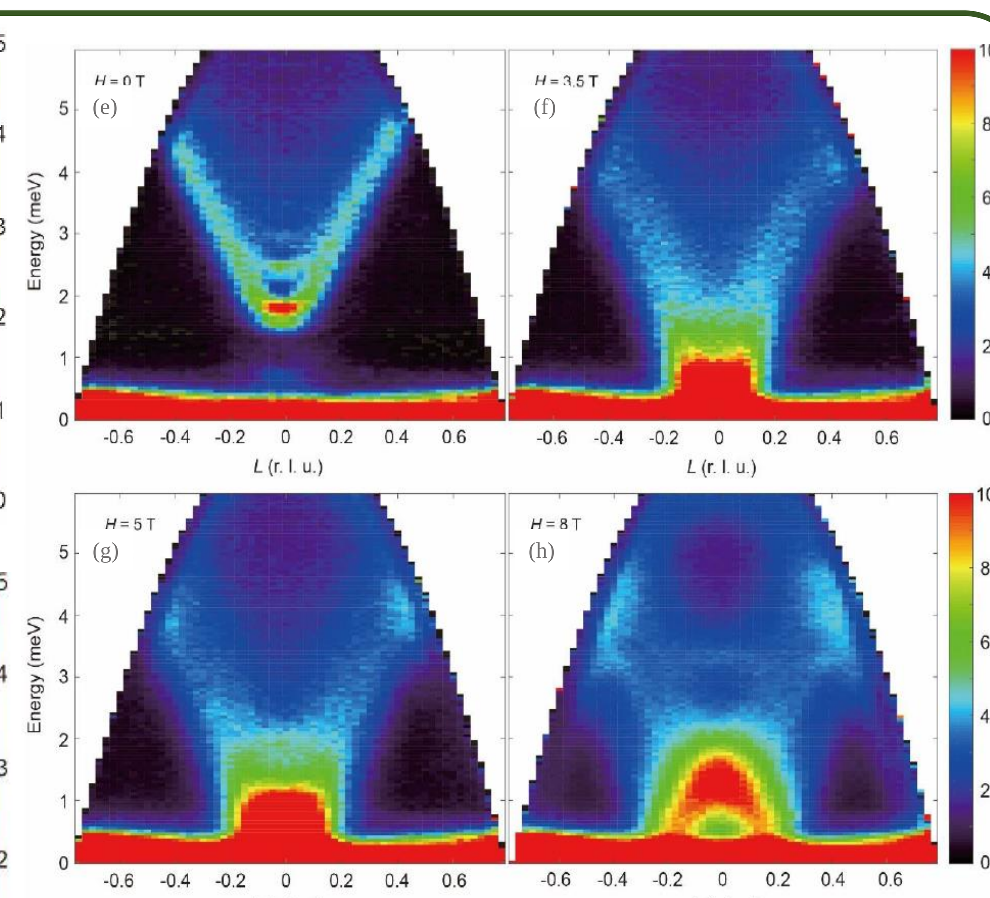


Elastic slices of neutron scattering under transverse field and longitudinal Field. | (a-b) Elastic constant-energy slice obtained at 1.5 K under transverse field of 4 T and 10 T, respectively. The Bragg peaks at positions where (h + k + l) gets odd number disappear under high field while the intensity of the remaining peaks increase. (c-d) Elastic constant-energy slice obtained at 2 K under longitudinal field of 0 and 8 T, respectively. What's worth mentioning, for longitudinal field case, there's no new magnetic structure emerged after the Neel state is killed by a longitudinal magnetic field of 4 T.



Inelastic Neutron Scattering under Transverse Field. | (a-j) Energy scans of the spin excitations in $SrCo_2V_2O_8$ at indicated transverse fields at **Q** = (0, 0, 2) and 1.5 K. The solid lines are the Gaussian fits of the data. A series of discrete modes could be seen in the zero field data which could be interpreted as spinon excitation confined by inter-chain interaction. For non-zero transverse field, the discrete mode still survive but are strongly modulated. The lower energy mode splits into two modes at H = 2 T. The lowest energy mode gradually goes to lower energy and reaches minimum at H = 7 T, indicating the appearance of the 3D QCP where Neel order is suppressed by external transverse field. (k) The energy ratios of high energy excitation modes with respect to the lowest energy mode in $SrCo_2V_2O_8$. The black, red, and blue dots indicate the energy ratios of the first, second, and third peaks fitted from the energy scan measured at each field, respectively. The dashed lines indicate the theoretically expected ratios for the E8 excitations which indicates that H = 3T might be a 1D QCP.





Inelastic Neutron Scattering under Longitudinal Field. | (a-d) Spin excitation of $SrCo_2V_2O_8$ measured under longitudinal field. The incident energy of the neutron beam is E_i = 20.1 meV. Clear splitting of the upper branch could be observed under non-zero field and the intensity of the highest branch drops under higher field. (e-h) Low energy part of spin excitation measured with neutron beam of E_i = 7.0 meV under longitudinal field. For zero field, clear discrete energy levels of confined spinon excitation could be seen near L = 0. When the field gets higher, incommensurate peaks which could probably be explained by TLL theory are observed. A flat band near 3.2 meV could be seen when the magnetic field is up to 8T, which possibly comes from Bethe string excitation.