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Two Plaquette-Singlet Phases and Emergent $SO(5)$ Deconfined Quantum Criticality in $SrCu_2(BO_3)_2$

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The deconfined quantum critical point (DQCP) has become a central open concept in the physics of quantum matter. The theoretical proposal of a DQCP at the plaquette-singlet-to-antiferromagnet (PS-AFM) transition in the Shastry-Sutherland model was followed by experimental evidence for a minimal DQCP scenario induced by an applied magnetic field in $SrCu_2(BO_3)_2$. However, the nature of the PS phase in $SrCu_2(BO_3)_2$ remains unresolved, and with it the identification of the possible DQCP.

Here we perform detailed high-pressure ^{11}B NMR studies in the PS phase between 1.8 and 2.7 GPa to reveal the presence of both the full-plaquette (FP) and empty-plaquette (EP) phases of $SrCu_2(BO_3)_2$, which coexist at a first-order, pressure-driven transition with a volume-fraction effect. Finding the field-driven EP-AFM transition complements our previous observations of the FP-AFM transition, although the temperature-dependence of the spin-lattice relaxation rate around the EP-AFM transition, $1/T_1 \propto T^{0.6}$, implies an anomalous scaling exponent $\eta \approx 0.6$ that is different from the FP-AFM value of $\eta \approx 0.2$, indicating that the critical fluctuations are governed by DQCPs of different universality classes.

A conventional field-driven PS-AFM transition should be a Bose-Einstein condensation of plaquette triplons with no anomalous features, and hence we deduce that the role of the field is to suppress the EP/FP and AFM order parameters that arise from additional interactions in $SrCu_2(BO_3)_2$ (meaning beyond the Shastry-Sutherland model), thereby revealing the critical properties of the underlying proximate DQCP. A DQCP is characterized by exotic and fractional excitations that emerge during the complete rearrangement of spin correlations, and the PS-AFM DQCP can be formulated as an $O(4)$ field theory with monopole defects. The EP-FP phase-coexistence we discover implies line-like domain walls with spinon excitations, whose combination with monopoles requires that the DQCP symmetry is raised to $SO(5)$. Hence our results take an important step towards a complete understanding of deconfined quantum criticality in $SrCu_2(BO_3)_2$ and challenge theory to provide a definitive determination of the anomalous scaling exponents for each universality class.

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