Deconfined quantum criticality in J-Q models

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I will discuss recent quantum Monte Carlo results for the quantum phase transition between antiferromagnetic (AFM) and valence-bond solid (VBS) ground states in a class of J-Q models—the conventional two-dimensional Heisenberg model with added multi-spin interactions consisting of products of bond-singlet projectors. First, I will show unambiguous signals of first-order transitions in J-Q_n models, where $n \in \{2, \ldots, 6\}$ corresponds to the number of singlet projectors. In the case of the widely studied $n = 2$ case, the first-order discontinuities are very small but observable in long-distance correlation functions on lattices of size above $L \approx 100$. Increasing n leads to larger discontinuities, detectable in smaller systems. By combining two different Q terms, specifically the J-Q_2-Q_6 model, the transition can be tuned from weak to moderately strong first-order. The coexisting AFM and VBS order parameters on the first-order line scale with an exponent that is consistent with the scaling dimension of the relevant charge-0 operator of a recently studied tri-critical SO(5) symmetric conformal field theory (CFT). Moreover, in the near-critical J-Q_2 model, there is also an operator preserving the microscopic symmetries of the model with scaling dimension in good agreement with that of the relevant charge-2 operator in the CFT. The scaling dimension of the leading irrelevant operator perturbing the SO(5) symmetry is also well reproduced. Thus, it appears that the J-Q models can be tuned extremely close to the SO(5) DQCP, and the reason why this point cannot be reached exactly is likely that the interactions would have to be in the regime where simulations are hindered by the sign problem, i.e., negative Q_6 in the specific model studied. In addition to matching scaling dimensions of the SO(5) CFT, finite-size scaling behaviors and correlation functions in the J-Q models also show the presence of another relevant operator, which governs the AFM and VBS correlation lengths for large L before the system flows to the first-order fixed point. This operator, which is missing in the CFT, should reflect another nearby critical point, thus providing additional information on the phase diagram of the system beyond the SO(5) tri-critical point.