"Topological Phase" of J-J' Model on Square Lattice

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We revisit the two-dimensional $J - J'$ dimerized quantum spin model on the square lattice [1] by solving the ground state wave function with the translational invariant tensor product states (TPS) ansatz. In the anti-ferromagnetic regime, i.e., $J' > 0$ (with $J = 1$), this model is known to undergo a second order phase transition around $J'/J \simeq 2.56$ from Neel phase to a finite-gap quantum disordered phase. However, it is not sure if this quantum critical point belongs to the $O(3)$ universality class [2, 3]. On the other hand, in the ferromagnetic regime, $J' < 0$, the model is frustrated [4, 5] and a spin liquid phase could exist J'/J is negative enough. We try to answer the second issues by using the the infinite time-evolving block decimation (iTEBD) method [6] to find the ground states numerically. We then read the entanglement spectra [7] from the TPS, and evaluate the energy expectation value, Neel order and dimer order [8] by the method of tensor renormalization group (TRG) [10, 11]. Our results show that for $J'/J < -0.4$ both the Neel and dimer order are consistently zero, and the entanglement spectra become doubly degenerate. It indicates the existence of topologically nontrivial spin liquid phase. Especially, the double degeneracy of entanglement spectra is related to the recent observation in [9] of using it to characterize the Haldane phase of one-dimensional spin chain.

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