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Quantum Spin Liquids in XY models with Ring Exchange[1]

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Many promising candidate Hamiltonians have been proposed recently as harboring emergent quantum spin liquid states. Regardless, convincing examples of the state are still lacking in large-scale quantum Monte Carlo simulations of microscopic spin models, due in part to the negative sign problem which inhibits studies of antiferromagnetic spins on frustrating lattices. However, recently several unfrustrated spin models have been studied, with results that suggest that emergent spin liquid states can exist there. One of these is the square lattice $S = 1/2$ XY model with ring exchange, tractable by quantum Monte Carlo without the sign problem [1]. The basic Hamiltonian is purported to harbor an isolated spin liquid point with emergent $U(1)$ gauge symmetry and spinons [2]. Using suggestions from analytical theory, we attempt to stabilize an extended region of spin liquid around this critical point by adding terms to the Hamiltonian, and increasing the dimensionality of the lattice. However, such modifications produce no spin liquid state. We therefore explore a version of the Hamiltonian on the kagome lattice, which with a particular diagonal interaction is exactly soluble analytically, and is argued to be in a stable spin liquid state with Z_2 gauge symmetry [3]. The Monte Carlo is able to simulate directly all parameter regions of this Hamiltonian to test this claim, and in addition is able to explore the adjacent superfluid and insulating phases and respective phase transitions. [1] Sandvik, Daul, Singh and Scalapino, Phys Rev. Lett. 89 247201 (2002). [2] Senthil et al., Science 303 1490 (2004). [3] Balents, Fisher and Girvin, Phys. Rev. B 65, 224412 (2002); Sheng and Balents, cond-mat/0408639.

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