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Competing spin-disordered phases of the spin-$1/2$ Heisenberg antiferromagnet on the kagome lattice

Despite years of intense theoretical attack from different directions, the ground state of the $S = 1/2$ kagome Heisenberg antiferromagnet has remained elusive. I will revisit this question within the framework of Gutzwiller projected fermionic wave functions studied using Variational quantum Monte Carlo technique, which implements stochastic reconfiguration optimization. Within this fermionic approach, a particular exotic algebraic spin liquid, the so called U(1) Dirac state was shown to have the best variational energy,[1] however due to its marginally stable nature there are doubts concerning its stability, and hence its possibility to occur as a real physical spin liquid. The experiments have hinted towards a gapless, algebraic spin liquid behavior.[2] We show that the U(1) Dirac spin liquid is remarkably stable (locally and globally) w.r.t dimerizing towards previously known[3] and also a new enlarged class of Valence bond crystal perturbations.[4] This stability is also preserved upon addition of a weak 2nd NN exchange coupling of both ferromagnetic and antiferromagnetic type.[3,4] However we find, that upon addition of a weak 2nd NN ferromagnetic coupling, a non-trivial valence bond crystal is stabilized, and has the lowest energy. This VBC possesses a non-trivial flux pattern and is a strong dimerization of another competing U(1) gapless spin liquid with a large spinon Fermi surface, the so called uniform RVB state.[3,4] The U(1) Dirac state and the uniform RVB state are also shown to be remarkably stable w.r.t. destabilizing into the class of $\mathbb{Z}_2$ spin liquids.[5] Thus, within the Schwinger fermion approach to the spin model, the U(1) Dirac spin liquid has the lowest variational energy for the NN and NNN (AF and ferromagnetic $J_2 > -0.09$) spin-$1/2$ kagome Heisenberg antiferromagnet.

I will also briefly touch upon my ongoing work dealing with a complete group theoretical classification of time-reversal invariant Valence bond crystals on the kagome lattice,[4] and also present some results concerning the properties of the ground state on small clusters which are extracted using the method of applying a few Lanczos steps on a given variational wave function, followed by a zero-variance extrapolation of the required observables.[6]

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[2] D. Wulferding, *et. al* : Phys. Rev. B **82**, 144412 (2010).
[3] Y. Iqbal, F. Becca, and D. Poilblanc: Phys. Rev. B **83**, 100404(R) (2011).
[4] Y. Iqbal, F. Becca, and D. Poilblanc: Manuscript in preparation.
[5] Y. Iqbal, F. Becca, and D. Poilblanc: Phys. Rev. B **84**, 020407(R) (2011).
[6] Y. Iqbal, F. Becca, S. Sorella, and D. Poilblanc: Manuscript in preparation.

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