Variational Monte Carlo Study of the Spin Liquid State with One-dimensionalization

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Spin liquid states in frustrated lattices have been attracting considerable attention. Among them, recent experiments showed that the spin liquid phases observed in κ-$(ET)_2Cu_2(CN)_3$ and $EtMe_3Sb[Pd(dmit)_2]_2$ have anomalously small spin gaps[1,2]. Its physical origin has not been understood yet.

With these facts in mind, we study the S=1/2 Heisenberg model on an anisotropic triangular lattice using a variational Monte Carlo method. We take an approach from the one-dimensional (1D) chains (with interaction J) coupled with the frustrating zigzag bonds of J' as shown in the left panel of the figure below. We consider that the small gap observed in the experiments descends from the gapless excitations of 1D spin system. As a result of our calculation using resonating-valence-bond (RVB) variational wavefunctions, we find a strong "one-dimensionalization" in the singlet pairing function, even though the system is almost isotropic (J'/J~0.98). This indicates the strong suppression of the spin excitation gap according to our previous work of RVB mean-field analysis[3].

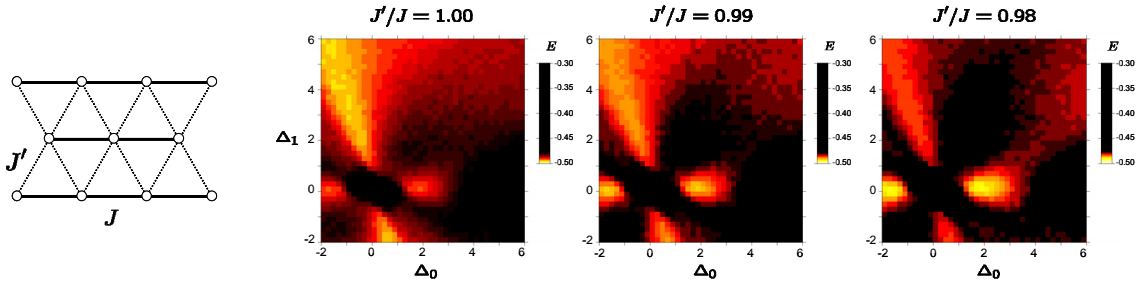

Figure: Model Hamiltonian (left), and the energy map (right) obtained in the Monte Carlo method as a function of singlet pairing amplitude Δ_0 (intrachain) and Δ_1 (interchain). Brightest areas show the parameter space with low energies. Although the energy minimum is located in the area $\Delta_1>0$ when J'/J=1.00, it moves to Δ_1~0 and Δ_0~2 when J'/J=0.98, which indicates "one-dimensionalization" of singlet pairing function.

[1] Y. Shimizu *et al.*, Phys. Rev. Lett. **91** (2003) 107001.
[2] T. Itou *et al.*, Phys. Rev. B **77** (2008) 104413.
[3] Y. Hayashi and M. Ogata, J. Phys. Soc. Jpn. **76** (2007) 053705.