論 文 の 内 容 の 要 旨

論文題目　Numerical Study of Strongly Correlated Electron Systems with Geometrical Frustration
（幾何学的フラストレーションを有する強相関電子系の数値的研究）

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For the purpose of clarifying the nature of quantum spin liquid phases and exploring possible emergence of novel quantum phases, we investigate how next-nearest-neighbor interaction and charge fluctuations affect the ground state properties of the triangular lattice systems. To investigate how pure geometrical frustrations affect the ground state even in the absence of charge fluctuations, we study the ground states of the spin 1/2 triangular Heisenberg model with the next-nearest-neighbor exchange interaction by using the many-variable variational Monte Carlo method. We find a spin liquid in the parameter region $0.10(1)<\alpha<0.135(5)$, sandwiched by the antiferromagnetic phase with three sublattices aligning in coplanar 120° directions each other (120° order) and a collinear stripe-type antiferromagnetic phase. Here α denotes the ratio of nearest and the next-nearest-neighbor interaction amplitudes. The transition between the 120°-order and the spin-liquid phase is continuous, while that between the stripe-order and the spin-liquid phase is of the first order. By using the quantum-number projection scheme, we find that the spin liquid state is characterized by gapless singlet-singlet and singlet-triple excitations. At the critical

point $J_2/J_1=0.1$ and even deeply in the spin liquid phase, both gaps $\Delta$ obey the scaling $\Delta$□$1/L^z$ ($z=1$) with L being a square root of the system size, suggesting the whole spin liquid region may belong to the critical phase with the dynamical exponent $z=1$. Besides, the total momentum dependences of the lowest energy for singlet and triplet sectors are shown to be unusual with flat dispersion, suggesting the presence of a large spinon Fermi surface. We also investigate the ground-state phase diagram of the triangular Hubbard model with the next-nearest-neighbor hopping by using the many-variable variational Monte Carlo method. Sandwiched by the paramagnetic metallic state for small Coulomb interaction and the antiferromagnetic insulating states with 120° or stripe spin structure for large Coulomb interaction, we find two possible insulating ground states in the intermediate range of Coulomb interaction: One is a spin liquid state, where broad spin structure peaks appear as a diffusive peak instead of the Bragg one. The other is an insulating state characterized by the ``up-up-down-down'' spin structure that has unusual characters and shares many common properties. Both states are close in energy, and they become more stable as increasing the negative next-nearest-neighbor hopping. By using the total momentum projection scheme, we find that the spin liquid state is characterized by nearly spin gapless excitations in extended total momenta of the peak momenta of the spin structure factor. However, the spin triplet excitation at the Γ point shows unusual nonzero gap commonly with the ``up-up-down-down'' structure. Although both spin liquid states found in the presence and absence of charge fluctuations are characterized by the gapless singlet-singlet and singlet-triplet excitations, their excitations show clear difference in the momentum dependence, and they seem to be disconnected in the ground-state phase diagram. Finally, possible relevances of previously proposed spin liquid states on triangular systems are examined.