Gapless Spin Excitations in the Kagome- and Triangular-Lattice Antiferromagnets

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The S=1/2 kagome-lattice antiferromagnet is one of interesting frustrated quantum spin systems. The systems exhibit the quantum spin liquid behavior, which was proposed as an origin of the high-Tc superconductivity. The spin gap is an important physical quantity to characterize the spin liquid behavior. Whether the S=1/2 kagome-lattice antiferromagnet is gapless or has a finite spin gap, is still unsolved issue. Because any recently developped numerical calculation methods are not enough to determine it in the thermodynamic limit. Our large-scale numerical diazonalization up to 42-spin clusters and a finite-size scaling analysis indicated that the S=1/2 kagome-lattice antiferromagnet is gapless in the thremodynamic limit[1]. It is consistent with the U(1) Dirac spin liquid theory of the kagome-lattice antiferromagnet[2,3]. On the other hand, some density matrix renormalization group (DMRG) calculations supported the gapped Z2 topological spin liquid theory[4,5]. Our recent numerical diagonalization analysis on the magnetization process of a distorted kagome-lattice antiferromagnet indicated that the perfect kagome-lattice system is just on a quantum critical point[6]. It would be a possible reason why it is difficult to determine whether the perfect kagome-lattice antiferromagnet is gapless or gapped.

We propose one of better methods to determine whether the spin excitation is gapless or gapped, based on the finite-size scaling analysis of the spin susceptibility calculated by the numerical diagonalization. The present analysis indicates that the kagome-lattice antiferromagnet is gapless. In order to justify the validity of the method, we try a demonstration for the triangular-lattice antiferromagnet. It confirms the gapless behavior of the triangular-lattice antiferromagnet, as already well known. It suggests that the present method is useful even for such frustrated systems.

The magnetization process of the kagome- and triangular-lattice antiferromagnets will be also discussed[7,8].

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