Thermodynamcis of highly frustrated quantum magnets: Kagome vs. Square-Kagome

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Highly frustrated quantum spin systems are in the focus of theoretical and experimental studies due their unconventional properties such as highly entangled spin-liquid ground states and fractionalized excitations. The most prominent example is the s=1/2 kagome Heisenberg antiferromagnet (HAFM). Very recently the square-kagome HAFM has come into the focus as another promising candidate of a quantum spin-liquid material [1-3]. So far the theoretical studies of the s=1/2 kagome as well as square-kagome HAFM are focussed on ground state properties, whereas much less is known on thermodynamics. We fill this gap by large scale numerical simulations of both models using the finite-temperature Lanczos method for system sizes of $N = 18, 24, 30, 36, 42, 48$, and 54 [4-8]. We find a striking similarity of the temperature profiles of the basic thermodynamic properties of the square-kagome and the kagome HAFM down to very low temperatures T. The specific heat exhibits a low-temperature shoulder below the major maximum which can be attributed to low-lying singlet excitations filling the singlet-triplet gap, which is significantly larger than the singlet-singlet gap. This observation is further supported by the behavior of the entropy $S(T)$, where a change in curvature is present just at about $T/J = 0.2$, the same temperature where the shoulder in C sets in. For the susceptibility the low-lying singlet excitations are irrelevant, and the singlet-triplet gap leads to an exponentially activated low-temperature behavior. The maximum in $\chi(T)$ is found at a pretty low temperature $T_{\max}/J = 0.146$ compared to $T_{\max}/J = 0.935$ for the unfrustrated square-lattice HAFM signaling the crucial role of frustration also for the susceptibility. The magnetization process featuring plateaus and jumps and the field dependence of the specific heat that exhibits characteristic peculiarities attributed to the existence of a flat one-magnon band are as well discussed.

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