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Frustration Measure for Dipolar Spin Ice and Spin Glass

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Abstract : Usually under the frustrated magnetics, it understands such materials, in which ones the interaction between located magnetic moments or spins has competing character, and can not to be satisfied simultaneously. The most well-known and simplest example of the frustrated system is antiferromagnetic Ising model on the triangle. Physically, the existence of frustrations means, that one cannot select all three pairs of spins anti-parallel in the basic unit of the triangle. In physics of the interacting particle systems, the vector models are used, which are constructed on the base of the pair-interaction law. Each pair interaction energy between one-component vectors can take two opposite in sign values, excluding the case of zero. Mathematically, the existence of frustrations in system means that it is impossible to have all negative energies of pair interactions in the Hamiltonian even in the ground state (lowest energy). In fact, the frustration is the excitation, which leaves in system, when thermodynamics does not work, i.e. at the temperature absolute zero. The origin of the frustration is the presence at least of one ''unsatisfied'' pair of interacted spins (magnetic moments). The minimal relative quantity of these excitations (relative quantity of frustrations in ground state) can be used as parameter of frustration. If the energy of the ground state is Egs, and summary energy of all energy of pair interactions taken with a positive sign is Emax, that proposed frustration parameter pf takes values from the interval [0,1] and it is defined as pf=(Egs+Emax)/2Emax. For antiferromagnetic Ising model on the triangle pf=1/3. We calculated the parameters of frustration in thermodynamic limit for different 2D periodical structures of Ising dipoles, which were on the ribs of the lattice and interact by means of the long-range dipolar interaction. For the honeycomb lattice pf=0.3415, triangular - pf=0.2468, kagome - pf=0.1644. All dependencies of frustration parameter from 1/N obey to the linear law. The given frustration parameter allows to consider the thermodynamics of all magnetic systems from united point of view and to compare the different lattice systems of interacting particle in the frame of vector models. This parameter can be the fundamental characteristic of frustrated systems. It has no dependence from temperature and thermodynamic states, in which ones the system can be found, such as spin ice, spin glass, spin liquid or even spin snow. It shows us the minimal relative quantity of excitations, which ones can exist in system at T=0.

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