2D non-Heisenberg ferromagnetic with complex exchange interactions

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We investigated the 2D magnetic system with anisotropic exchange interactions, which limiting cases are the 2D XY-model with biquadratic exchange interaction and the isotropic 2D non-Heisenberg ferromagnetic. The Hamiltonian of such a ferromagnetic system is given by

$$\mathcal{H} = -\frac{1}{2}\sum_{n,\acute{n}} J_{n,\acute{n}}(S_n^x S_{\acute{n}}^x + S_n^y S_{\acute{n}}^y + \Delta S_n^z S_{\acute{n}}^z) - \frac{1}{2}\sum_{n,\acute{n}} K_{n,\acute{n}}[\frac{\Delta}{3} O_{2n}^0 O_{2\acute{n}}^0 + \\ + O_{2n}^2 O_{2\acute{n}}^2 + O_{2n}^{xy} O_{2\acute{n}}^{xy} + \Delta(O_{2n}^{xz} O_{2\acute{n}}^{xz} + O_{2n}^{yz} O_{2\acute{n}}^{yz})] - \frac{1}{2}\sum_{n,\acute{n},i,j} V_{n\acute{n}}^{ij} S_n^i S_{\acute{n}}^j + \\ + \lambda \sum_n [u_{xx}(n) S_n^{x\,2} + u_{yy}(n) S_n^{y\,2} + u_{xy}(n) O_{2n}^{xy}] + \frac{E}{2(1-\sigma^2)} \sum_n [u_{xx}^2(n) + \\ + u_{yy}^2(n) + 2\sigma u_{xx}(n) u_{yy}(n) + (1-\sigma) u_{xy}^2(n)]. \quad (1)$$

Here we introduce the following notations: $J > 0, K > 0$ are the constants of the bilinear and the biquadratic exchange interactions, respectively; O_{2n}^p are the Stevens operators related with the spin operators as follows: $O_{2n}^0 = 3S_n^{z\,2} - S(S+1)$, $O_{2n}^2 = S_n^{x\,2} - S_n^{y\,2}$, $O_{2n}^{ij} = S_n^i S_n^j + S_n^l S_n^i$; S_n^i is the ith component of the spin operator at the nth site; $u_{ij}(n)$ are the components of the elastic deformations tensor; λ is the constant of the magnetoelastic interaction; E is Young's modulus; σ is Poisson's ratio; $V_{n\acute{n}}^{ij}$ are the components of the magnetic dipole interaction tensor.

The results obtained show that the account of the exchange interactions anisotropy essentially changes the phase diagram of non-Heisenberg ferromagnetic. First of all, this is exhibited in the impossibility of the ferromagnetic ordering at $\Delta \longrightarrow 0$ (in this case the quadrupolar order is stabilized). The account of the magnetic dipole interaction leads to the realization of a spatially inhomogeneous QU-phase. Its inhomogenity is connected not with the spatial distribution of the magnetization, but with the change of the quadrupolar order parameters, which in their turn are related to the orientation of the main axes of the quadrupolar moments tensor. This result is predictive. As far as we know, an inhomogeneous quadrupolar phase has not yet been observed experimentally.