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Effects of Dzyaloshinsky-Moriya Interaction on Planar Rotator Model on Triangular Lattice

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Abstract. The thermodynamic properties and some critical properties of the planar rotator model with chiral Dzyaloshinsky-Moriya (DM) interaction on triangular lattice are analyzed using a hybrid Monte Carlo method. It has been shown that there is a XY-like Berezinskii-Kosterlitz-Thouless (BKT) phase transition in this model. The ground state of this spiral system and the effects of size mismatch are also discussed.

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Key words: Critical temperature, Dzyaloshinsky-Moriya interaction, Monte-Carlo simulation, vortex.

1 Introduction

The study of the anisotropic effects on critical behaviors in spin system has attracted much interest. One of the important anisotropies is the so-called Dzyaloshinsky-Moriya (DM) interaction, arising from a mixture of super-exchange and spin-orbit coupling under distorted lattices [1, 2]. It has been shown the DM interaction is responsible for the understanding of the weak ferromagnetism of the low-temperature orthorhombic phase and magnetic structure in copper oxide compound, such as La_2CuO_4 and some Fe and Cr jarosites [3–8]. The DM interactions play an important role in the study of spin glasses as well as the explanation of some neutron scattering measurements [9, 10]. Due to the

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lack of centrosymmetry of the lattice, the DM interaction can induce a helical chiral magnetic order [11–15]. Recently, it is found that DM interaction is the primary source of anisotropy and plays an important role for understanding of the magnetization and spin structure in antiferromagnetic materials [16]. The effects of DM interactions on low energy magnetic excitations have also investigated extensively by spin wave analysis and direct numeric simulations [17–19]. The study of classical and quantum XY model with DM interactions on a triangular lattice by real space renormalization group method and spin molecular dynamics simulations indicated that the Berezinskii-Kosterlitz-Thouless (BKT) phase could appear at low temperatures [20]. Wilson renormalization group results showed that adding DM interactions on the classical ferromagnetic Heisenberg model, there exists a XY-like phase transition [21]. In addition, Monte-Carlo (MC) simulations and self-consistent harmonic approximation theory were also used to calculate the BKT transition for the two-dimensional classical Heisenberg model with DM interaction [22, 23]. To the best of our knowledge, the most of numeric simulations have been focused on the study of strong DM interactions for antiferromagnetic spin models. On appearance of anisotropic interactions, however, the spin system may display complex thermodynamic and magnetic characteristics due to the competition between spin coupling and DM interactions. In this work, we adopt a hybrid Monte-Carlo method to study the effects of the DM term on planar rotator model on triangular lattices.

2 Model and simulation method

The Hamiltonian of the classical spin planar rotator model with a DM interaction term between spins can be written as [20, 24, 25]

$$H=-J\sum_{\langle ij\rangle}\vec{S}_i\cdot\vec{S}_j-\sum_{\langle ij\rangle}\vec{D}\cdot(\vec{S}_i\times\vec{S}_j). \tag{2.1}$$

Here $J=1$ is the reduced ferromagnetic coupling constant, θ_i are the angular coordinates of two-component spins $\vec{S}_i=(S_i^x,S_i^y)=(\cos\theta_i,\sin\theta_i)$ and i, j indicate the nearest neighbor sites of a triangular lattice. For the application of a cluster algorithm, Eq. (2.1) can be simplified into

$$H=-\tilde{J}\sum_{\langle ij\rangle}\cos(\theta_i-\theta_j-\varphi). \tag{2.2}$$

By considering the direction of DM interaction vector $\vec{D}=D\hat{z}$ along the positive z-axial direction. For simplicity, $\tilde{J}=J\sqrt{1+d^2}$, $d=D/J$ and $\varphi=\tan^{-1}(J/\tilde{J})$. Note that when $d=\sqrt{3}$, namely $\varphi=\pi/3$, this model coincides with the fully frustrated XY model if the sum of φ along an elementary triangular cell is equal to π [26, 27].

In order to prevent critical slowing down and correlations for different configurations, we use a hybrid MC method, including cluster and single spin updates to calculate the thermodynamic quantities for the model Hamiltonian Eq. (2.2). The simulations consist