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Vortex and Domain Wall Dynamics of 2d-XY Model with in-Plane Magnetic Field

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Absract. Using a combined Monte Carlo-spin dynamics technique, we have studied vortex and domain wall excitations on square 30x30 and 60x60 lattices for the classical XY model with an in-plane magnetic field. We have isolated and followed the dynamics of vortices and domain walls. We have obtained the density of free vortices and the dynamical structure factor S(q,w) at various temperatures.

Introduction

Since Kosterlitz and Thouless (KT) proposed the vortex-antivortex unbinding topological phase transitiion in the two-dimensional(2d) classical XY model in 1973[1), many scientists have focussed on studying the KT-transition and its applications. In 1977, Kawabata and Binder gave evidence for KT vortex formation in Monte Carlo(MC) studies of the 2d XY-model[2)]. Subsequently, Kawabata et al.[3)] obtained dynamical correlations and their Fourier transforms for the 2d XY-model, using a combined MC-spin dynamics technique[3)] . Recently, the applications to systems such as Josephson-Junction arrays and high Tc superconductors have been investigated[4)]. Here, we report computer experiment on the 2d XY-model for 30x30 and 60x60 spin square lattices,using the combined MC-spin dynamics technique. We have applied a technique to isolate the elementary collective spin structures (vortices and walls) and follow their evolution. We have animated and video-taped this data for better understanding of the dynamics.

Simulation and Discussion

We have treated 2d 30x30 and 60x60 square lattices with periodic boundary condition. The spin Hamiltonian studied is ;

$$H = -J\Sigma(\ S_i\ \ S_j\ )-mH\Sigma\ S_i \qquad (1)$$

where J(>0) is the exchange constant; S_i is a unit vector at the lattice site i and m is the magnetic mpment; H is an external magnetic field.

After developing a thermal equilibrium at a given temperature (T) by MC method[5)] ,the 2d XY-model was evolved with Landau-Lifshitz dynamics. We obtained the location of KT vortices (+,-)[6)] and the density of free vortices(+) at various temperatures is shown in Fig.1. Next,we studied the interaction between vortices and domain walls as illustrated in Fig.2. We have calculated dynamical structure factors S(q,w) as in Fig.3. Interpretation of S(q,w) in terms of walls and vortices will be described elsewhere.

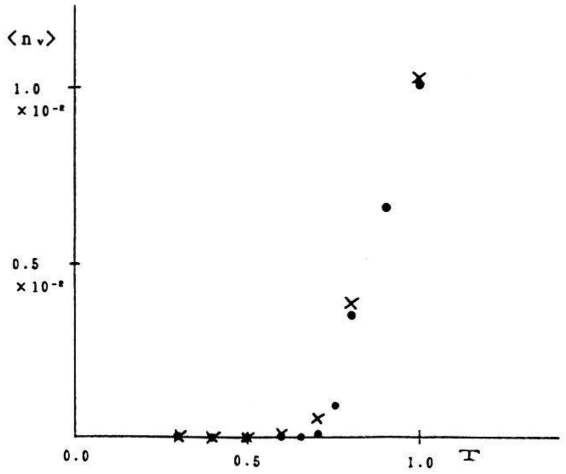

Fig.1

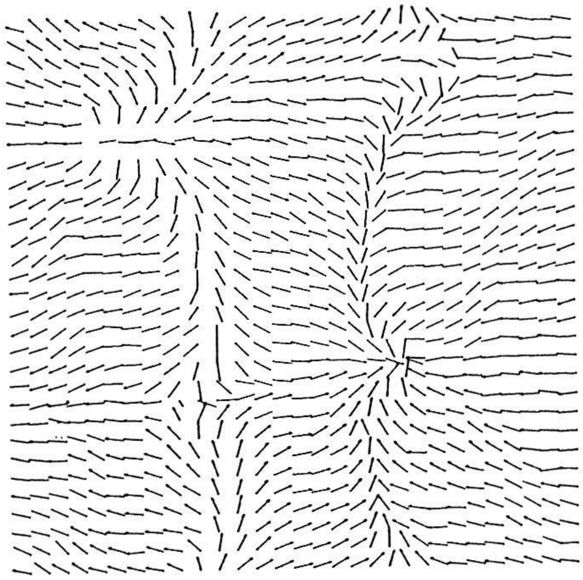

Fig.2

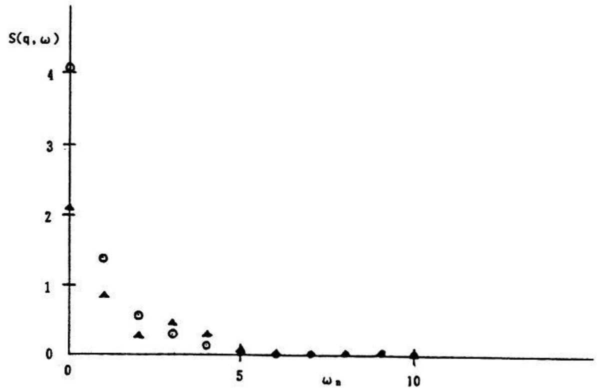

Fig.3

Fig.1

Density of free vortices(+) vs T at mH=0.0 for 30x30 (...) and 60x60 (xxx)lattices.

Fig.2

Typical pattern of domain walls at T=0.05 and mH_x =0.1 for 127 time step of spin dynamics on 30x30 lattice.

Fig.3

Dynamical structure factors S_{xx} (q,w) for q_r (0.06,0.06),T=0.2 (a) and T=0.9 (b), at mH_x =0.2.

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