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

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Abstract. 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 transition in the two-dimensional(2d) classical XY model in 1973¹⁾, 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-model²⁾. Subsequently, Kawabata et al.³⁾ obtained dynamical correlations and their Fourier transforms for the 2d XY-model, using a combined MC-spin dynamics technique³⁾. Recently, the applications to systems such as Josephson-Junction arrays and high Tc superconductors have been investigated⁴⁾. 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 ;

$$H = -J \sum (S_i \cdot S_j) - m H \sum S_i \quad (1)$$

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

After developing a thermal equilibrium at a given temperature (T) by MC method⁵⁾, 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.

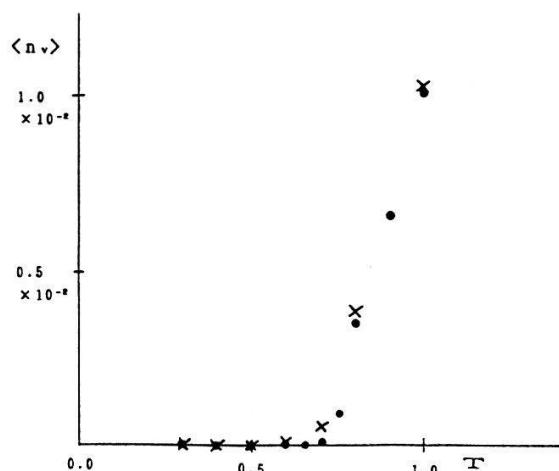


Fig.1

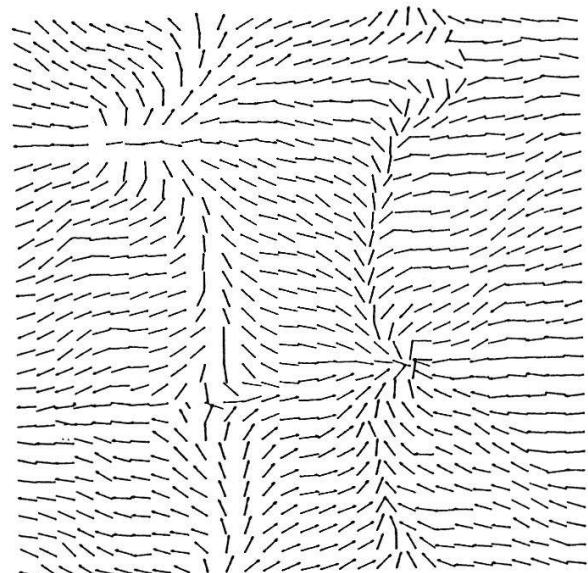


Fig.2

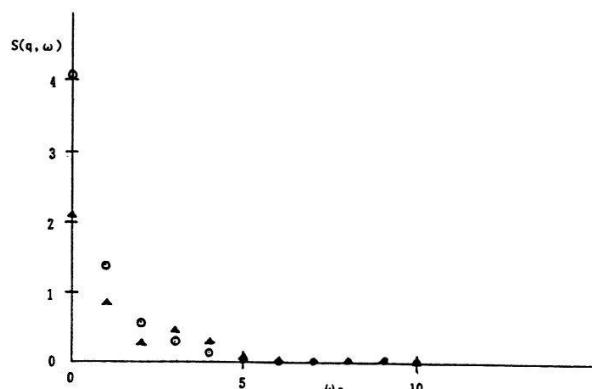


Fig.3

Fig.1

Density of free vortices (+) vs T at $mH=0.0$ for 30×30 (...) and 60×60 (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 30×30 lattice.

Fig.3

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

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