Phase behavior of a family of continuous two-dimensional n-vector models with $n = 2, 3,$ and 4

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The presence of an unusual order disorder transition in the two dimensional XY model has been known since the pioneering works of Berezinskii[1] and Kosterlitz and Thouless[2]. More generally, it has been found that similar transitions appear in lattice models of particular relevance in field theory and elementary-particle physics, such as the bidimensional RP^{n-1} (real projective space in n-dimensions).

In this work we investigate the phase behavior of a family of continuous bidimensional n-vector models (with $n = 2$, 3, and 4) using Monte Carlo simulation, in which the explicit interaction is given by a hard sphere potential of diameter σ with embedded n-dimensional spins, i.e.

$$u(r_{ij}, \omega_i, \omega_j) = u_{HS}(r_{ij}) + u_{ang}(r_{ij}, \omega_i, \omega_j), \quad (1)$$

where $u_{HS}(r)$ is a hard sphere interaction, and the angular interaction is described by

$$u_{ang}(r, \omega_i, \omega_j) = -Ku_0(r)\frac{1}{n-1}[(\hat{s}_i \cdot \hat{s}_j)^2 n - 1] \quad (2)$$

with $\hat{s}_i = (s_{i_1}, s_{i_2}, \ldots, s_{i_n})$ being a n-dimensional unit vector describing the orientation of the spin in particle i. In Eq. (2) the spin coupling is defined by

$$u_0(r) = \frac{e^{-\kappa(r-\sigma)}}{r/\sigma} - \frac{e^{-\kappa(R-\sigma)}}{R/\sigma}, \text{ for } \sigma < r < R, \quad (3)$$

$$= 0, \text{ for } r > R. \quad (4)$$

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Here we have used both cluster algorithms in the line of Swendsen and Wang method[3] with the aim of studying the orrder-disorder transtion. First order phase changes (vapour-liquid equilibrium) has been studied using an algoritm based on Wang-Landau's method[4]. In all cases we detect the presence of a defect mediated order-disorder transition of the Berezinskii-Kosterlitz-Thouless type with critical temperatures that decrease with the spin dimensionality. Coupled with the order-disorder transition a gas-liquid equilibrium is found at low temperatures. Here one observes that the stability region of the liquid phase shrinks with the growing spin dimensionality, in parallel with a decrease in magnitude of the angular averaged spin-spin interaction.

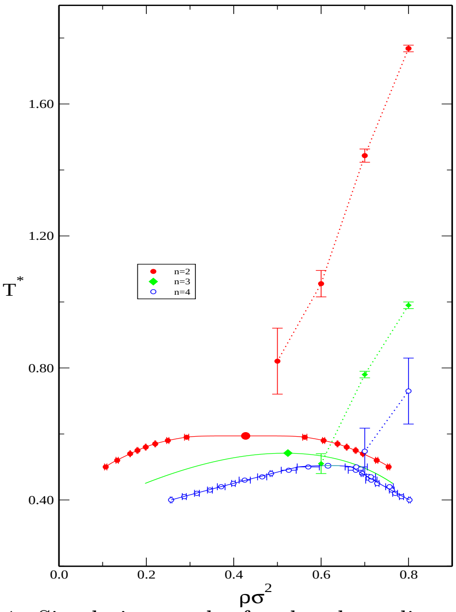

Figura 1. Simulation results for the phase diagram of the planar RP^{n-1} spin fluid for $n = 2$, 3, and 4. Symbols joined with dotted lines correspond to the states at which the BKT transition takes place and the line separates orientationally disordered states (lower densities) from states with quasi-long range order (higher density, quasi nematic states).

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