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Antiferromagnets in 2 + ε Dimensions

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ABSTRACT. Using a perturbative approach with a modified Wick theorem for a spin 1/2 antiferromagnet we find the excitation spectra, an effective exchange interaction and the staggered magnetization for the square lattice at T = 0. In the framework of the non- linear sigma model we discuss the dimension shift, the influence of anisotropic and helical terms. Anisotropy leads always to a reduction of the quantum disordered fixed point. The results of large n expansion complete the conclusions of a renormalization group approach.

Introduction

The discovery of high temperature superconductors has led to renew efforts to understand quantum antiferromagnets /1/. The behaviour of an antiferromagnet depends on the value of the underlying spin. Since there is no general theory which covers the whole region between s = 1/2 and large spin we consider the two limiting cases in detail using a perturbative approach for the s = 1/2 system and the renormalization group approach for a continuum model which seems to be valid only for large spin /2/.

Perturbation theory for spin 1/2

The Heisenberg Hamiltonian can be expressed in terms of Pauli-operators

$$H = J(0) \sum_i b_i^+ b_i + J(0) \sum_j a_j^+ a_j + \sum_{i,j} J_{ij} \left(b_i a_j + a_j^+ b_i^+ - 2\, b_i^+ b_i a_j^+ a_j \right) \qquad (1)$$

The operators a and b act in different sublattices. They obey the commutation relation

$$[b_i , b_j^+] = \delta_{ij} \left(1 - 2\, b_i^+ b_i \right) \qquad (2)$$

which prevent the application of the conventional Wick theorem. We have applied a modified Wick theorem /3/ to calculate the temperature Green's function

$$G_{lm}(\tau_l-\tau_m) = -\begin{pmatrix} \langle T_\tau (b_l b_m^+)\rangle & \langle T_\tau (b_l a_m)\rangle \\ \langle T_\tau (a_l^+ b_m^+)\rangle & \langle T_\tau (a_l a_m^+)\rangle \end{pmatrix} \qquad (3)$$

The non- diagonal part gives rise to a renormalized interaction $J_{eff}(\underline{k})$ summing up a whole class of diagrams. J_{eff} diverges for d=1 and T=0 whereas for finite temperatures the divergency appears for $d \leq 2$.
The commutation rule (2) leads also to additional diagrams (kinematic inter - action) which contribute to the staggered magnetization M_s . We get M_s= 0.381 (perturbational approach, second order) or M_s = 0.359 (self-consistent summation) for d = 2 and at T = 0 in agreement with recent results /1/.

NON-LINEAR SIGMA MODEL

In the large spin limit one may start with a Lagrangian in terms of a unit vector field $\underline{n}$ the average of which is related to the staggered magnetization. Alternatively we derive the Lagrangian using the semi- macroscopic equation of motion for the two relevant variables $\underline{n}$ and $\underline{l}$ related to the generator for spin rotations. It results /2/

$$S = \rho_s / 2\hbar \int d\tau\, d^d x \left\{ (\nabla \underline{n})^2 + w^{-2} \dot{\underline{n}}^2 \right\} \qquad \underline{n}^2 = 1 \qquad (4)$$

Using Polyakov's renormalization group procedure/4/ we find the flow equations for the parameters y = g coth x , x= g/2t with t= T/ ρ_s and g= h w/ ρ_s, and additional to /2/ also for the magnetization, the correlation length and the correlation function. Ford =2 there occur a fixed point g^*above it quantum fluctuations destroy the conventional Neèl order. If the action (4) is completed by an anisotropic term the quantum disordered fixed point is reduced. We have also considered the influence of a term proportional to $\underline{n}$ curl $\underline{n}$ which favours a helical order. The value of the fixed point g^* increases. The restriction $\underline{n}^2$ = 1 can be lifted by introducing a Lagrange multiplier. Such an approach can be used in a 1/n expansion (n number of components).

REFERENCES

/1/ E. Manousakis, Rev. Mod. Phys. 63 , 1 , 1991.
/2/ S. Chakravarty, B.Halperin, D. Nelson, Phys. Rev. Lett. 60 , 1057, 1988.
/3/ A. Kühnel, J. Phys. C 2 , 704 , 1969 .
/4/ A. M. Polyakov, Phys. Lett. B 59 , 79 , 1975.