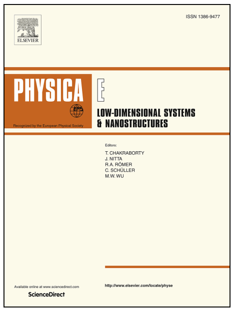
Accepted Manuscript



Thermodynamics of anisotropic antiferromagnetic Heisenberg chain in the presence of longitudinal magnetic field

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PII: S1386-9477(17)31979-3

DOI: 10.1016/j.physe.2018.04.010

Reference: PHYSE 13104

To appear in: *Physica E: Low-dimensional Systems and Nanostructures*

Received Date: 26 December 2017

Revised Date: 14 March 2018

Accepted Date: 8 April 2018

Thermodynamics of anisotropic antiferromagnetic Heisenberg chain in the presence of longitudinal magnetic field

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(Dated: April 11, 2018)

We have addressed the specific heat and magnetization of one dimensional spin-1/2 anisotropic antiferromagnetic Heisenberg chain at finite magnetic field. We have investigated the thermodynamic properties by means of excitation spectrum in terms of a hard core Bosonic representation. The effect of in-plane anisotropy thermodynamic properties has also been studied via the Bosonic model by Green's function approach. This anisotropy is considered for exchange constants that couple spin components perpendicular to magnetic field direction. We have found the temperature dependence of the specific heat and longitudinal magnetization in the gapped field induced spin-polarized phase for various magnetic fields and anisotropy parameters. Furthermore we have studied the magnetic field dependence of specific heat and magnetization for various anisotropy parameters. Our results show temperature dependence of specific heat includes a peak so that its temperature position goes to higher temperature with increase of magnetic field. We have found the magnetic field dependence of specific heat shows a monotonic decreasing behavior for various magnetic fields due to increase of energy gap in the excitation spectrum. Also we have studied the temperature dependence of magnetization for different magnetic fields and various anisotropy parameters.

PACS numbers: codes 75.10.Pq,75.40.Gb, 66.70.-f, 44. 10.+i

Keywords: Heisenberg chain; Thermodynamics; anisotropic

I. INTRODUCTION

The seminal model for correlated quantum many-body systems is the well known Heisenberg model. Low-dimensional quantum magnets realize an antiferromagnetic (AF) Heisenberg chain. This structure is an important model to describe real materials and at the same time is the most important paradigm of low-dimensional quantum magnetism[1]. Low-dimensional quantum models have, for many years, been the subject of considerable research, analytical as well as experimental, due to both, the unconventional physics of theses models, and the quantum field theoretical methods used in the analysis of the problem[2]. Particularly, a great deal of attention has been devoted to the study of spin models that can lead to a better understanding of the behavior of compounds like $SrCu_2O_3$, $VO_2P_2O_7$, and $CuGeO_3$ where a spin gap occurs. The theoretical work have shown that several mechanisms can be responsible for creating a gap in the energy spectrum, including, for example, competing interactions and quantum fluctuations. Bethe ansatz, exact diagonalization, the density matrix renormalization group and quantum monte carlo have been employed to study the ground-state of low dimensional spin systems on the theoretical side[1,3,4]. Antiferromagnetic Heisenberg chain opens the field for rich physics such as, gapless Luttinger liquid[5], the Kosterlitz-Thouless phase transition[6], gapped and gapless excitation continua. In the presence of external magnetic fields, finite temperature high resolution spectroscopies such as inelastic neutron scattering[7] and magnetic transport[8] have theoretically been calculated by dynamical correlation functions of the Heisenberg chain. Specially, field induced effects on the dynamical spin correlation function in low dimensional quantum spin models have been attracting much interest from theoretical and experimental point of view in recent years[9–11]. Heisenberg chain in the presence of axial anisotropy at finite non zero values for magnetic field is a solvable model. Its ground state properties have been investigated within Bethe-Ansatz[12,13]. Specific heat and magnetization, as thermodynamic quantities have been investigated by several theoretical methods such as Bethe ansatz, Quantum Monte Carlo and Density matrix renormalization group[14–16]. The field has been studied by numerical and theoretical methods. Based on quantum Monte Carlo and maximum-Entropy methods, spin structure factors of antiferromagnetic Heisenberg chain with longitudinal anisotropy and applied magnetic field have been evaluated[17]. The spin-1/2 antiferromagnetic Heisenberg chain in both perpendicular uniform and staggered magnetic fields has been studied using the density-matrix renormalization group method[18]. In this study, low energy properties, magnetization and spin correlation functions are found at very high magnetic fields. In the other theoretical work, the thermodynamic properties of the spin 1/2 XXZ chain in the presence of a transverse magnetic field have been studied within finite temperature Lanczos method[19]. In this work, the specific heat and correlation functions for chains up to 20 sites have been calculated.

In the general case, the spin model Hamiltonian can include spatial anisotropies in the exchange coupling between nearest-neighbor spins. This property arises from the existence of easy axis magnetization due to crystalline electric