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Advances in Applied Science Research, 2010, 1 (1): 96-100

External magnetic field effect on the two particles spins system using Dzyaloshinskii-Moriya Method

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ABSTRACT

This work on base of a theoretical study on the system which is consist of two spin-1 particles, which have spin degree of freedom. With implementing Dzyaloshinskii-Moriya(DM) interaction between these particles, we exactly calculated the ground state energy and configuration of system and also we check its magnetic order at zero temperature.

Keywords: two spin-1 Dimmer system, DM interaction, Hamiltonian, eigen –states.

INTRODUCTION

This work on base of a theoretical study on the In recent decade, people have spent a lot of attention on the external field effect on the spin systems. The especially topic is the effect of the field-induced quantum fluctuation in the spin systems. In quantum phase transition these quantum fluctuations are the only responsible of destroying, which is directly related to the Heisenberg exclusion principle. The effects of quantum fluctuation which can destroy the long-range order at zero temperature _ are completely different from thermal fluctuations that are responsible of the finite temperature phase transition In this section we take an special model, which consist of two particles systems that are completely independent without any interaction. This is applicable to the two-leg spin ladder systems [1] and also alternating AF-F spin chains [2].

In these cases the behavior of the system, obtain with checking a dimmer of spins.

Vector Field

The model has been considered here as:

$$\hat{H} = \sum_{j=1}^{N} [J\vec{S}_j.\vec{S}_{j+1} - HS_j^x]$$

Where J > 0 is the coupling exchange and H is the magnetic field. S_j^α Shows α-th component of the spin operator at jth site. For investigating the anisotropy effect on the ground state behavior of the system, we add the DM interaction to the Hamiltonian [3,4]

$$\hat{H} = \sum_{j=1}^{N}[J\vec{S}_j.\vec{S}_{j+1} + \vec{D}.(\vec{S}_j \times \vec{S}_{j+1}) - HS_j^x]$$

Where $\vec{D}$ is known as the DM vector and we choose it in y direction, $\vec{D}=(0,D,0)$. From experimental point of view, in most cases , the observed results are different from the obtained theoretical results by Hamiltonian(the first equation) [5,6,7,8,9,10,11,12]. Because the DM interaction destroys the fundamental S (second equation of Hamiltonian) symmetry in Heisenberg model, so one can obtain very better results with adding the term of DM interaction.

It is necessary to mention that the most researches have just be done on Heisenberg model and less attentions go toward DM interaction. In this work we will check the effects of the DM interaction on the zero-temperature behavior of a two spin-1 particles system.

In each system, particles are interacting via anti-ferromagnetic exchange constant

$$H = J(\overrightarrow{S_1}.\overrightarrow{S_2}) + D(\overrightarrow{S_1} \times \overrightarrow{S_2}) - h(S_1^x + S_2^x)$$

For two reasons this model has been elected. Firstly, it is exactly solvable and secondly, the above phenomena could be happened on spin chains and study of such model will help us to get better understand of unsolvable real interaction.

For treat the problem, firstly , we choose the Hilbert spaces basis as eigen -states of $S_1^z\, S_2^z$ operator, after diagonalization for ground states of system, and

$$\begin{aligned}|GS\rangle &= a_1|11\rangle + a_2|10\rangle + a_3|1-1\rangle + a_4|01\rangle + a_5|0-1\rangle \\ &+ a_6|-11\rangle + a_7|-10\rangle + a_8|-10\rangle + a_9|-1-1\rangle\end{aligned}$$

Where a_j is coefficient expansion. In order to determine the properties of the ground state of the dimmer system in the various subspaces of ground state phase diagram, at first we calculate magnetic order parameters such as conventional magnetization $M^{x,y,z}$ and staggered magnetization $M_{st}^{x,y,z}$ defined as

$$M^{x,y,z} = \langle GS|\frac{1}{N}\sum_n S_n^{x,y,z}|GS\rangle$$

$$M_{st}^{x,y,z} = \langle GS|\frac{1}{N}\sum_n (-1)^n S_n^{x,y,z}|GS\rangle$$

where the average was taken on the ground state. In Fig1, we have plotted the magnetization as a function of the applied field direction for some values of the DM vectors. It is clean that for small value of D=0.1 for small field the magnetization will remain zero , with increasing field and for h$> h_c$, magnetization will become saturated, which is that the quantum fluctuation built in presence of the D vector. There isn't any sharp phase transition in the saturation point. For enough big value of D, immediately after applying field magnetization starts to increase. For this case, the saturation will occur for very high fields. With staggered magnetization definition we can get:

$$M_{st}^z = \frac{1}{2}\langle GS|S_1^Z - S_2^Z|GS\rangle = \frac{1}{2}(AC + CA) = AC$$

In figure 2 the staggered magnetization was plotted via applied field h for various vector D=0.1 , 0.5 , 1.0 .From this figure we can see with applying a uniform field h, wheel order will have been made up that shows long-range order spin flop. And there is a maximum value for staggered magnetization about 0.3.[13]

On the other hand Nersesyan and his colleagues [14] show that in one dimension spin model with next nearest neighbor interactions will make a new phase which it produces as result of parity broken symmetry. This phase is well-known as chiral and its order parameter definition is :

$$\chi^{\alpha} = \langle GS \,|(\overrightarrow{S_1} \times \overrightarrow{S_2})^{\alpha}|\, GS\rangle$$

Where α has the x, y, z directions in space. So far, two kind of chiral phases have been detected, gap and gapless chiral phases [15,16,17] . For clarity in the ground state phase diagram of a dimmer system in external field and DM interaction, we consider the above order parameter as :

$$\chi^{y} = \langle GS|(S_1 \times S_2)^{y}|GS\rangle = \langle GS|S_1^z S_2^x - S_1^x S_2^z|GS\rangle = \sqrt{2}AB$$

In Fig.3 the chiral order parameter was plotted via applied field h for various values of the DM vector D=0.1,0.5,1.0.

As it is clearly seen, in the absence of the DM interaction, there isn't the chiral ordering in the ground state. But in the presence of a DM interaction, by applying an external magnetic field the chiral phase in ground state has been appeared and increasing with increasing field. But with much increasing external field the chiral phase decreases until it disappears at high field. This state that system lives in saturated magnetization along the magnetic field phase.

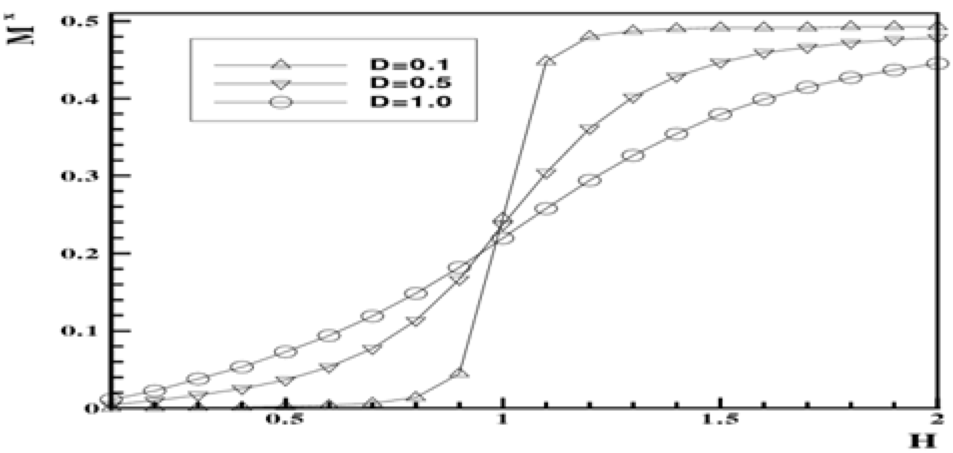

Fig1: Magnetization in field direction as a function of external field h with exchange J=1 and various value of DM parameters D=0.1, 0.5 , 1.0 .

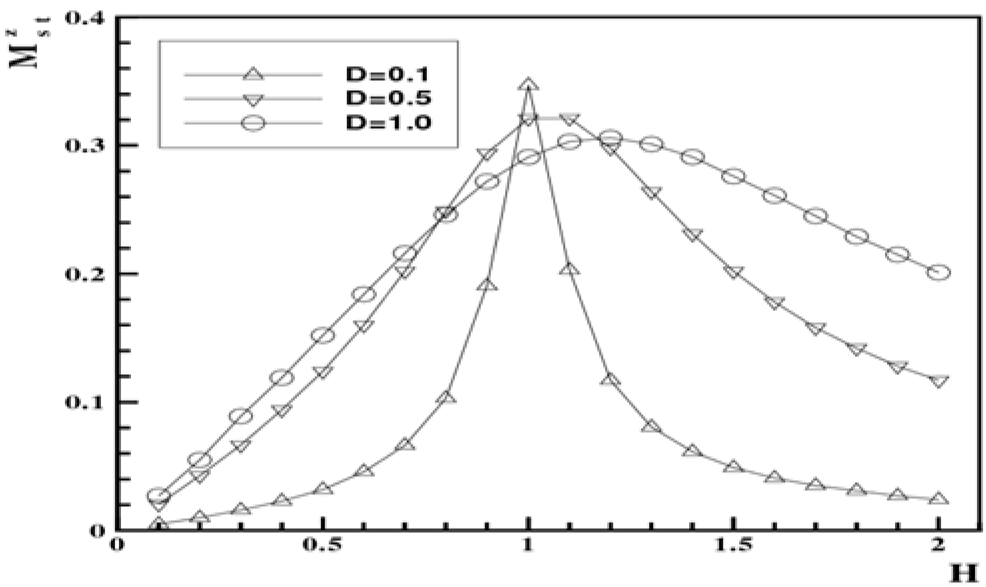

Fig2:staggered magnetization perpendicular to h and DM vector . M^z_{st} Was plotted as function of external field h with exchange J=1 and various value of DM interaction D=0.1, 0.5 , 1.0 .

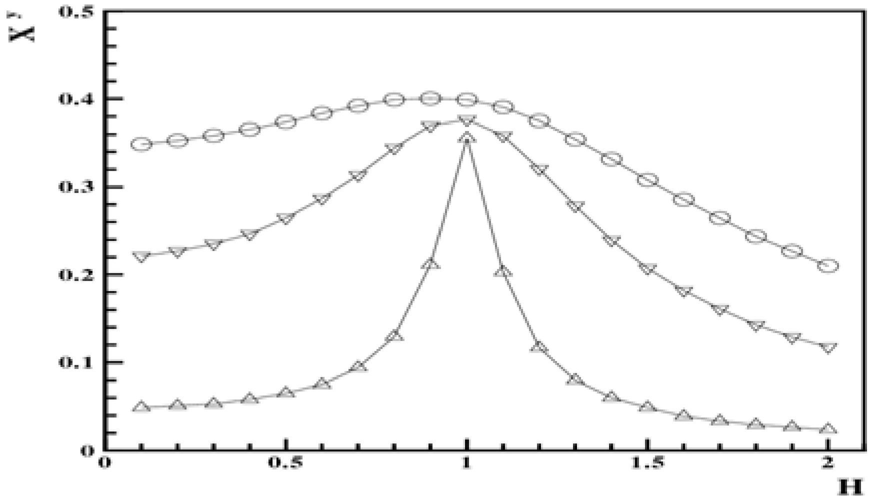

Fig3: Chiral order parameter in y direction as function of external field with exchange J=1 for various value of DM interaction D=0.1, 0.5, 1.0 .

RESULT AND DISCUSSION

We have investigated the XXZ model with DM interaction in the presence of transverse magnetic field for two particle spin-1 systems. In this model we have found out that for weak DM interaction, the magnetization of systems will stay near zero with weak fields, on other hand, not only for strength fields $h > h_c$ magnetization of system will be saturated, but also for high DM interaction with non-zero fields it happens. With calculation of staggered magnetization in the z-direction the Neel order will appear which its maximum value is 0.3. We have also investigated the phase of the system in the absence of DM interaction which there is Chiral order in the ground state of the system that with implying DM interaction and magnetic transverse field this order will destroy and for high field the system will be in saturated phase.

CONCLUSION

In this paper, we have investigated the ground state orderings of a dimmer of two spin-1 particles in the presence of a uniform external field and DM interaction. We have exactly calculated the ground state expectation values for chiral, magnetization and staggered magnetization quantities .We have shown that the DM interaction has effects on these quantities and makes quantum fluctuations. Interesting results is that, in the presence of a DM interaction, the spin flop phase will appear.

Acknowledgement
This work was supported by Shahed University Research Center.

REFERENCES

[1] Dagotto, E. and T. M. Rice, *Science*, **1996**, 271,618-623.
[2] Hida, K., *J. Phys. Soc. Jpn.*, **1993**, 62, 439-442.
[3] Moriya, T. *Phys. Rev.*, **1960**, 12, 91-99.
[4] Dender,D. C. *Phys. Rev. Lett.***1997,**79, 1750-1753.
[5] Sirker, J. and A. Weiße and O. P. Sushkov, *J. Phys. Soc. Jpn.*, **2005**, 74 ,129-134
[6] Sakai,T. and H. Shiba, *J. Phys. Soc.Jpn.*,**1994,** 63, 867-871.
[7] Chaboussant, G . and Julien, M. H. and Fagot- Revurat, Y. and Hanson, M. E. and Levy, L.P. and Berthier, C. and Horvatic, M. and Piovesana, O. *Eur. Phys. J. B.*,**1998**, 62,167-181.
[8] Kageyama, H. and K. Yoshimura, and R. Stern, and N. V. Mushnikov, and K. Onizuka, and M. Kato, and K. Kosuge, and C. P. Slichter, and T. Goto, and Y. Ueda, *Phys. Rev. .Lett.***1999**, 82, 3168-3171.
[9] Cepas, O. and K. Kakurai and L. P. Regnault, and T. Ziman, and J. P. Boucer, and N. Aso, and M. Nishi, H. Kageyama and Y. Ueda, *Phys. Rev. Lett.***2001**, 87, 167205-167208.
[10] N Kazuma, and G. A. Jorge, and R. Stern, and I. Heinmaa, and S. A. Zvyagin, and Y. Sasago, and K. Uchinokura, *Phys. Rev. Lett.***2004,** 93, 087203-087206
[11] Oshikawa, M. and I. Affleck, *Phys. Rev. Lett.* **1997,** 79: 2883-2886.
[12] Dagotto, E. and T. M. Rice, *Science*, **1996,** 271,618-623.
[13] Hida, K., *J. Phys. Soc. Jpn*.,**1993**, 62:439-442.
[14] Alcaraz, F. C. and W. F. Wreszinski, *J. Stat. Phys.***1990,** 58: 45-56.
[15] Nersesyan, A. A. and A. Luther, doi:10.1103/*PhysRevB.***1994**,50.309.
[16] Kaburagi, K. and H. Kawamura and T. Hikihara, *J. Phys. Soc. Jpn.*,**1999**, 68, 3185-3188.
[17] T Hikihara,T. and M. Kaburagi, and H. Kawamura and T. Tonegawa, *J. Phys. Soc. Jpn.*, **2000**, 69: 259-266.