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Negative Doublet Bands with Different Shape in the ^{107}Ag Nucleus

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ABSTRACT

The existence of chirality in the negative high spin states in the ^{107}Ag nucleus has been confirmed by the Interacting Boson-Fermion Model (IBFM). IBFM excited states and electromagnetic properties are in good agreement with the available experimental data. According to IBFM analysis, the negative parity doublet bands (3) and (4) in the ^{107}Ag nucleus were interpreted as triaxial and axial shap respectively.

1. Introduction:

Different deformations in the high spin states in the mass region A ~ 110 such as signature inversion[1], shape evolution and coexistence[2], magnetic rotation[3], and chiral doublet bands[4,5] had been reported. Chiral doublet bands in mass region A ~ 100, has been reported in odd-odd nuclei and in odd-A ^{103}Rh[6] and ^{105}Rh[7], due to the valence $h_{11/2}$ neutrons and $g_{9/2}$ protons. For $43 \leq Z \leq 49$ in A ~ 105 mass region, the location of Fermi surface near high-Ω $1g_{7/2}$, $d_{5/2}$, and $h_{11/2}$ orbitals, which manifest some exciting form demanded shears bands[8-12], and chiral doublet bands[13-17]. Chiral bands in the transitional nuclei in this mass region might exist.

Chiral symmetry breaking has been found in triaxial deformed odd-odd nuclei, such as in ^{106,108}Ag[18] and ^{104}Rh[19]. The experimental fingerprints[19] of the doublets bands in these nuclei for chirality such as (i) The energies of ΔI bands with the same spin are nearly degenerate.(ii) The signatures are independent of spin. (iii) Both bands have the same characteristic staggering of the B(M1;I→I-1) /B(E2; I→I-2) ratios for in-band transitions. Moreover, these doublet bands should display a nearly similar kinematic moment of inertia(MOI) and quasi-particle alignment[20,21].

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The proton Fermi level in odd-A nucleus ^{107}Ag with Z=47 and N=60, lies near $g_{9/2}$, while the neutron Fermi level lies at the $h_{11/2}$, $g_{7/2}$, $g_{5/2}$ or $d_{3/2}$ subshells. Different shapes may form in odd-A nucleus ^{107}Ag due to different quasiparticle configurations or due to a shape transformation. The best examples of the chiral nucleus in the A ~ 100 mass region are ^{106}Rh [22,23], and ^{106}Ag [24] . The ^{107}Ag nucleus has two protons more than ^{106}Rh nucleus and one neutron more than ^{106}Ag nucleus.

The (E(I) – E(I-1)) plot in the positive parity bands of the Ag isotopes (^{105,107,109}Ag) shows an analogy more like staircase type graph[25]. This property is indicating a mechanism which an admixture of collective rotation of the Principal Axis Rotation (PAR) and Magnetic Rotation (MR).

High spin states in ^{107}Ag had been studied experimentally[26], a new level scheme was presented including two newly negative bands (labeled 3 and 4) and assigned to be chiral doublet bands. The configurations for these bands had been suggested as $\pi g_{9/2} \otimes \upsilon h_{11/2}$ $(g_{7/2}, d_{5/2})$. However, there is a leakage in the experimental electromagnetic transitions data.

The purpose of this study is to investigate the negative parity chiral doublet bands suggested experimentally and labeled as band 3 and band 4 in the ^{107}Ag nucleus with the aid of the IBFM electromagnetic transition results.

2. Results and Discussion:

In this work, the (IBFM) has applied to this nucleus ^{107}Ag. The IBFM has been described in details in reference[27]. The π = 28-50 shell contains the three active negative parity orbits, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ and one, $1g_{7/2}$, with positive parity. The $^{107}Ag_{60}$ nucleus is considered as resulting from coupling a proton hole to the even-even $^{106}Pd_{60}$ nucleus. The Interacting Boson Approximation (IBA-1) parameters of the even-even core have been taken from ref.[28]. The three negative parity orbits in the π = 28-50 region ($2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$) have been included in the calculations. The BCS (Barden-Cooper-Schrieffer) parameters required as input for the IBFM calculations for the orbits included in the calculation are listed in Table 1.

Table 1. **BCS parameters used in the analysis for negative parity states in the ^{107}Ag nucleus.**

	ε_j (MeV)	ϑ_j^2
$2p_{1/2}$	1.4555	0.7690
$2p_{3/2}$	2.0761	0.9423
$1f_{5/2}$	2.2016	0.9550

The standard program ODDA[29] was used to diagonalize the IBFM Hamiltonian. The IBFM parameters used in the analysis of the negative-parity states in ^{107}Ag was adjusted to the experimental excited states. These parameters are, BFQ=0.1069 MeV, BFE= 0.1183 MeV and BFM= -0.3102 MeV. The boson core parameters chosen in this work are those reported in ref.[28].

This set of parameters produced an excited state in good agreement with the experimental excited states and confirm the spin assignments for some experimental states. The average percentage deviation between the experimental excitation energy and the IBFM prediction has been found to be nearly 3% only for both bands (3 and 4). The IBFM energy separation between the doublet bands is approximately 200 Kev and shown in figure 1. The S(I)= 1/ J_1= [E(I) – E(I-1)] / 2I, where J_1 is the kinematic moment of inertia (MOI), versus spin for band 3 and 4 is shown in figure 2. Energy- staggering function is not completely smooth especially for band 4. The reversed phase for the two bands 3 and 4 mean inversion occurred.

The doublet band in ^{107}Ag cross each other twice around spins 27/2 and 31/2 (figure 2), due to the change in the sign of the γ deformation imposing a change of the rotational axis, from the x-axis to the y-axis. The different signature was proposed[30], band 3 may have a positive signature from the $1g_{7/2}$ or $2d_{5/2}$ neutron orbitals, whereas in band 4 it has a negative signature.

The different values of MOI (J_1=S(I)$^{-1}$) suggest triaxial shape for band 3 while the energy staggered of band 4 suggests it contains a planar axial shape. Also in ^{108}Ag nucleus different shape has been suggested[24]. Shape transformation from triaxial to planar axial shape may be attributed to the chiral vibrations resulting from a large degree of γ softness in the nucleus or due to the change in the sign of the γ deformation.

Another fingerprint of the chirality in atomic nuclei is the electromagnetic transitions in doublet bands which becomes a hot topic in identifying the chiral bands. The wave function obtained by diagonalization of the IBFM Hamiltonian by the code ODDA has been used by the code PBEM to calculate the reduced transition probabilities for E2 and M1. The only experimental data values available to compare with are those reported in ref. [31].

To be more confident about the IBFM results, the boson and fermion effective charges and g-factors used in the calculation of the electromagnetic M1 and E2 transitions are normalized in order to get agreement between calculated and experimental magnetic moments for the 1/2$^-$ state. The parameter used in this calculations are: e_B =0.12 eb, e_F =0.12 eb, g_l = 1 μ_N, g_s = 0.77(g_s free) μ_N and g_d = -0.5μ_N. The IBFM moment results are compared with the available data and shown in table 2.

Table2. **A calculated moment in comparison with available data in the ^{107}Ag.**

J $^-$	μ_J(nm) (Exp.)[31]	μ_J(nm) (Theo.)	Q_J (b.)
1/2	0.11357(2)	0.111	
3/2	0.9(2) 0.94(14) 1.05(14)	0.98	0.697
5/2	1.0(2) 0.93(15) 1.13(15)	0.825	1.03

The good agreement between calculated and reported magnetic moments encouraging us to be more confident about the theoretical electromagnetic transition results.

The calculated B(E2) intraband values (see figure 3) for the two bands shows that band 4 crossover with band 3 at two spins 27/2 and 31/2, which indicate that the deformation in the doublet bands is not same. Moreover, the calculated intraband B(E2) values in band 3 are greater than these in band 4 which means that the deformation in band 4 is smaller than that in band 3. It has been found that the interband B(E2) values are much smaller than the intraband ones (see figure 3). The similarity of B(E2) values behavior for the doublet bands(3&4) (figure 3) confirms that they originate from the same configuration. There is a direct relation between $B(E2)_{out}$ / $B(E2)_{in}$ and the triaxiality parameter γ.

The staggering in the calculated interband B(M1)(see figure 4) values for the doublet bands are not similar in phase and values. The B(M1) / B(E2) and the $B(M1)_{in}$ / $B(M1)_{out}$ ratios(see figure 4) show in phase staggering and smaller for band 3 compared with that for band 4. The staggering obvious in band 4 while it is very small in band 3 which means there is a deviation from triaxial deformation in this band in agreement with S(I) suggestion. The B(M1) staggering as well as the obtained B(M1) / B(E2) and $B(M1)_{in}$ / $B(M1)_{out}$ staggering are sensitive to the triaxiality parameter γ . Same behavior had been reported in the ^{106}Ag[32] and ^{108}Ag[33] nuclei.

In the IBFM, the Boson - Fermion Exchange interaction strength parameter BFE makes the same effect as the sign of the triaxial deformation parameters γ. The B(E2; I → I-1) / B(E2; I → I-2) is very sensitive to the γ and whether effects of γ deformation sign results in constructive or destructive in the B(E2) values. Hence, in order to see the effects of the sign of γ on triaxiality, the sign of the BFE has been changed to a negative sign with the same value. Similar behavior has been noticed for interband B(E2), B(M1) and B(M1)/B(E2) with smaller values. The only change has been noticed on the B(E2; I → I-1) and consequently on the B(E2; I → I-1) / B(E2; I → I-2) behavior as shown in figure 5. This change can be attributed to destructive coherence in B(E2) values in band 3 as the sign of γ in this band is coincide with the negative sign of the BFE. This situation confirms that the two bands have different γ sign which causes a change in the rotational axis, and probably different parameterization value as well.

3. Conclusions:

The IBFM calculations results confirmed the existence of chiral doublet bands with negative parity in the ^{107}Ag nucleus. The stability of the chiral geometry in ^{107}Ag is in fact destroyed due to a strong influence of the γ-softness. The excited band (band 3) possesses properties of a triaxial nuclear shape, while for the band 4 the nucleus has an axial shape. Different shapes formed in odd-A nucleus ^{107}Ag due to the different signs of the deformation parameters γ rather than due to different quasiparticle configurations.

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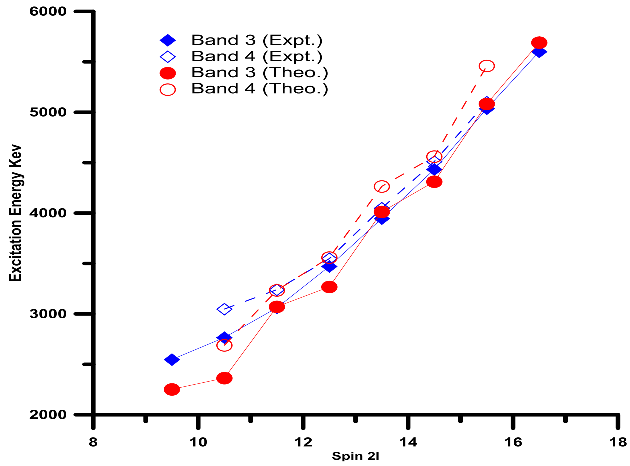

Fig.1: Experimental and IBFM energy levels versus spin(2I) for negative parity bands 3 and 4 in ^{107}Ag.

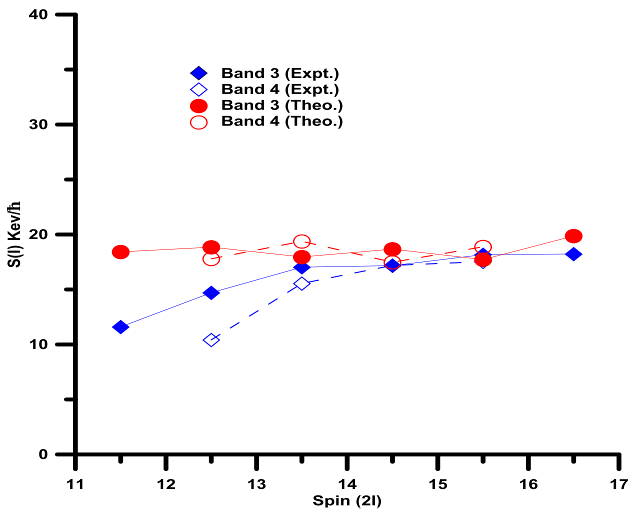

Fig.2: S(I) parameter as a function of spin for bands 3 and 4 in ^{107}Ag.

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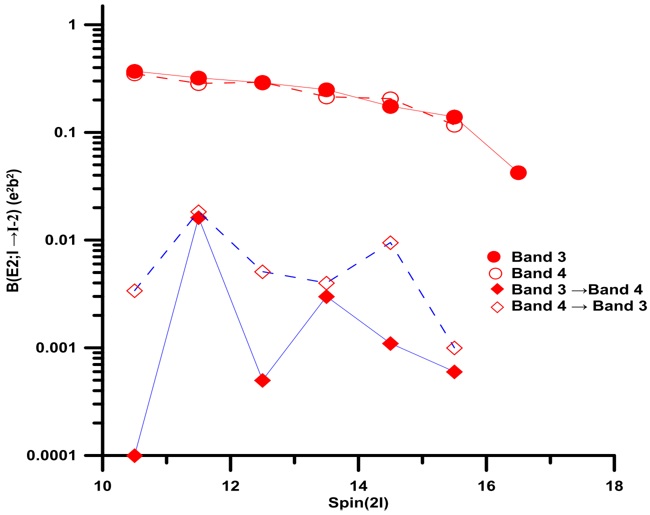

Fig.3: Intra and inter band B(E2) values calculated for bands 3 and 4 in ^{107}Ag.

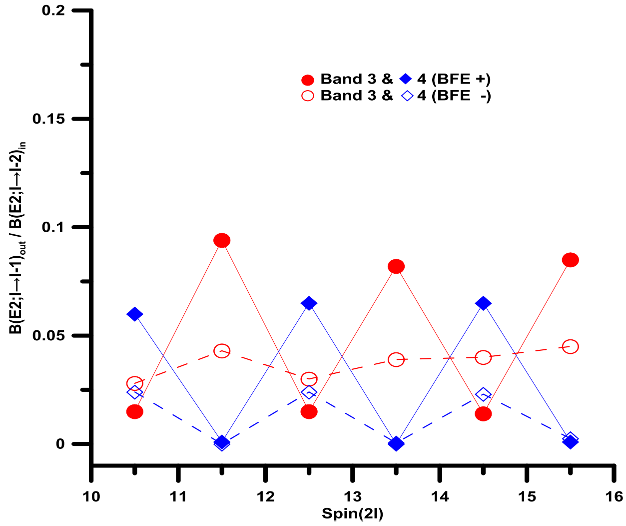

Fig.5: The B(E2;I→I-1)$_{out}$ / B(E2;I→I-2)$_{in}$ ratios for bands 3 and 4 with different sign of the Boson-Fermion exchange interaction strength parameter (BFE) as a function of spin in ^{107}Ag.

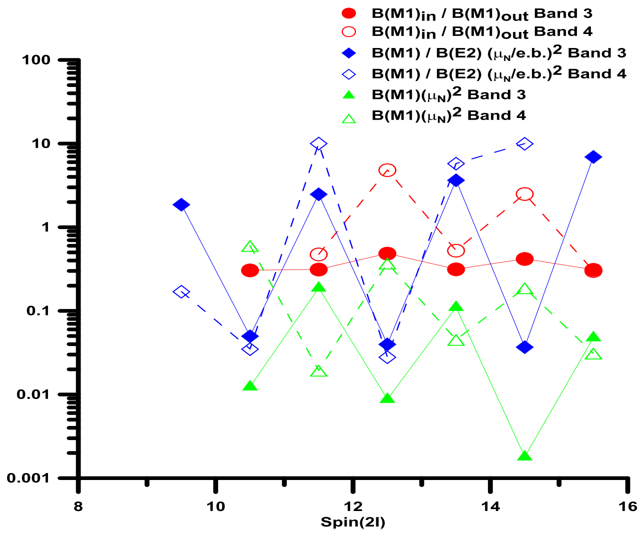

Fig.4: B(M1)in/B(M1)out and B(M1)/BE2) ratios for bands 3 and 4 as well as the intra B(M1) values calculated for bands 3 and 4 in ^{107}Ag.

الحزم المزدوجة السالبة ذات الشكل المختلف في نواة ^{107}Ag

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الخلاصة

وجود التناظر اليدوي في مستويات ذات التماثل السالب لنواة ^{107}Ag تم تأكيده باستخدام نظام تفاعل البوزون- فرميون. المستويات المتهيجة لتفاعل البوزون – فرميون والخواص الكهرومغناطيسية وجدت متوافقة بصورة جيدة مع القيم العملية المتوفرة. حسب تحليل نظام البوزون – فرميون ، فأن الحزم المزدوجة ذات التماثل السالب (3) و (4) في نواة ^{107}Ag فسرت على انها ثلاثية وأحادية المحاور على التوالي.