Odd – even staggering in rigid triaxial rotor model

*M. Singh[1], Y. Singh[2], Devendra Singh[3], A. K. Varshney[4], K. K. Gupta[5]

[1]*Department of Physics, Greater Noida Institute of Technology, Greater Noida - 201306, INDIA*
[2]*Department of Physics, Govt. PG College, Dharamshala – 176215 (H.P.), India*
[3]*Department of Physics, Gurukula Kangri University, Haridwar – 249404 (U.K.), India*
[4]*Department of Physics, Govt. College, Palampur – 176061 (H.P.), India*
[5]*Department of Physics, Govt. PG College, Dhaliara – 177103 (H.P.), India*

*email: singh.moti@gmail.com

In geometrical approach, the triaxial nuclear properties are usually interpreted in terms of two basic models, the rigid triaxial rotor model (RTRM) [1] and the γ – unstable rotor model [2]. In γ – soft rotor model of Wilets and Jean, it is assumed that the potential energy is independent of γ – degree of freedom to describe the deviations from axial symmetry while the rigid triaxial rotor model considers the rigid shape of nucleus having harmonic oscillator potential with a minimum of finite value of asymmetric parameter γ. Therefore, it has always been a subject of keen interest for experimentalists and theoreticians to see whether the asymmetric nucleus under consideration is axial, γ - soft or γ – rigid.

In RTRM, the ground state band is normal rotational band while the other two bands that are γ and γγ – bands are anomalous rotational bands. We shall evaluate the values of energy levels of observed spectrum within the framework of rigid triaxial rotor model at different asymmetry parameter γ and compared the odd – even staggering (OES) in γ and γγ – band. The staggering indices S (I) in γ – band is expressed as [3]

$$S(I) = \frac{(E_I - E_{I-1}) - (E_{I-1} - E_{I-2})}{E2_1^+} \qquad (1)$$

McCutchen et al [4] using above equation shown that for both vibrator and γ – soft limits the S (I) is negative for even spins and positive for odd spins. For rigid triaxial nucleus, the values of S (I) again oscillating but opposite in phase namely, positive for even spins and negative for odd spins. For axially symmetric deformed rotor that is for harmonic oscillator potential with minimum at $\gamma = 0^0$, the S (I) values are small, positive and constant with increasing spin. The OES in γ – band using RTRM have been studied earlier for some even – even nuclei [5 - 7].

We have plotted the staggering indices S (I) calculated in RTRM with spin up to I = 12 for both γ and γγ – band [Fig. 1(a) – (b)]. It is clear that there is a significant difference in the behavior of staggering indices of γ and γγ – band in RTRM. The zigzag behavior that is the alternate positive values at even spin (positive phase) and the negative values at odd spins (negative phase) of staggering indices S (I) in RTRM initiates from spin I = 8 at $\gamma = 25^0$ and continues up to $\gamma = 30^0$ in γγ – band. However, in γ – band this zigzag behavior is seen from spin I = 10 at $\gamma = 10^0$, S (8) at $\gamma = 15^0$ and S (6) at $\gamma = 20^0$ and before these spins the values of all S (I) are small, positive, and constant. Although, the sign of S (I) at all spins are same in both the bands showing alternate positive and negative phase. The magnitude of S (I) in γγ - band differs from γ - band, it is small in γγ – band and is large in γ – band. The magnitude of S (I) in γγ – band is constant and is nearly equal to 0.33for $\gamma = 10^0$ and $\gamma = 15^0$ at all spins. This constant value continues upto spin I = 8 at $\gamma = 20^0$ and at higher spins the magnitude initiates to deviate from this constant value. The value of S (I) increases for even spins and decreases for odd spins from the constant value 0.33. The deviation increases with the increase of spins and asymmetric parameter γ upto spin I = 8, at $\gamma = 25^0$ and then the zigzag behavior appears. However, for γ – band the S (I) values are constant and nearly equal to 0.33 only upto spin I = 8 at $\gamma = 10^0$. The deviation in the value of S (I) increases and zigzag nature of S (I) appears beyond I = 10 at $\gamma = 10^0$. Therefore, it is not justified to take zigzag behavior similar to γ – band as criteria to distinguish γ – rigid and γ – soft nucleus in γγ – band. Hence, the criteria to distinguish γ – rigid and γ – soft nucleus in γγ – band should be the similarity of experimental S (I) with RTRM, not the zigzag behavior.

Thus, in the present work we have compared the experimental energy staggering indices of γγ – band with RTRM for ^{154}Gd and ^{178}Hf. The values of S (I) in experiment are very small and positive at all spin that is from S (6) to S (13) in γγ – band for ^{154}Gd. These values are similar in phase with RTRM [Fig.2 (a)]. Thus, it may be rigid triaxial nucleus.

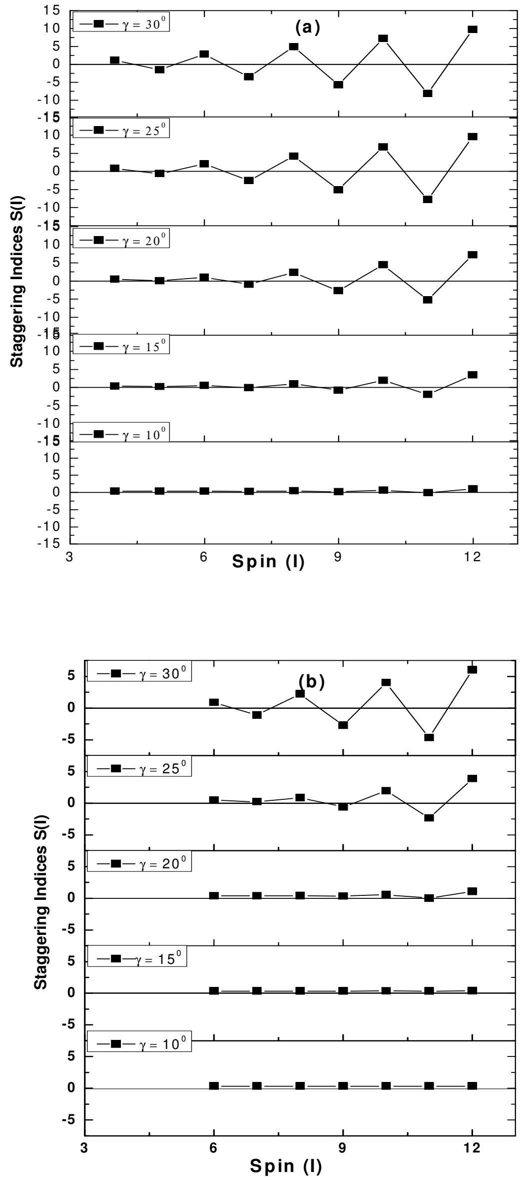

FIG. 1 (a) – (b)

Staggering of level energies in rigid triaxial rotor model for (a) K = 2, γ – band and (b) K = 4, γγ – band plotted with spin (I) at different asymmetry parameter γ

The S (I) values do not tally with RTRM in phase [Fig.2 (b)]. The phase of S (I) is opposite to RTRM and hints the γ – soft structure of ^{178}Hf nucleus. The detailed study for some other even nuclei has been communicated for publication [9]. The staggering indices S (6) to S (16) in experiment alternatively changed the phase and magnitude with spin in ^{178}Hf.

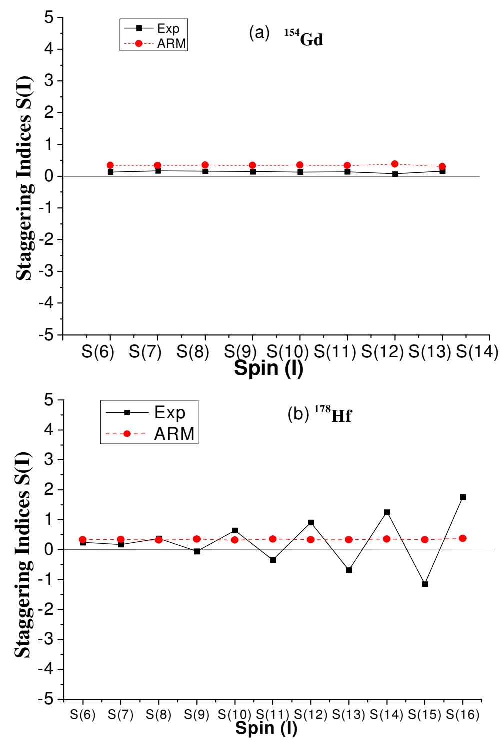

FIG. 2 (a) – (b)

The plots of staggering indices S (I) versus spin (I) in experiment and rigid triaxial rotor model for K = 2, γ – band and K = 4, γγ – band for ^{154}Gd and ^{178}Hf nuclei. The experimental data for calculating S(I) in taken from ref. 8.

Acknowledgement:

The authors are grateful for constant encouragement from J. B. Gupta, Delhi University, Delhi. One of the authors namely, M. Singh is thankful to the Chairman, Greater Noida Institute of Technology, Greater Noida, for their kind cooperation and providing working facilities.

References:

1. A. S. Davydov and G. F. Filippov, Nucl. Phys. A 8, 237 (1958).
2. J. Wilets and M. Jean; Phys. Rev. 102, 788 (1956).
3. N. V. Zamfir and R. F. Casten; Phys. Lett. B 260, 265(1991).
4. E. A. McCutchen, D. Bonatsos, N.V. Zamfir and R. F. Casten; Phys. Rev. C 76, 024306 (2007).
5. M. Singh, Chhail Bihari, Y. Singh, Deepti Gupta, A. K. Varshney, K. K. Gupta and D. K. Gupta; Can. J. Phys 85, 899 (2007).
6. M. Singh, Y. Singh, Chhail Bihari, A. K. Varshney, K. K. Gupta and D. K. Gupta; Adv. Studies Theor. Phys 3, 251 (2009).
7. Mani Varshney, C. Bihari, Y. Singh, M. Singh, A. K. Varshney, K. K. Gupta and D. K. Gupta; Phys. Scr. 75, 451 (2007).
8. nndc.bnl.gov.in
9. Communicated for publications (2019).