

## Odd – even staggering in rigid triaxial rotor model

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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  $\gamma$  – unstable rotor model [2]. In  $\gamma$  – soft rotor model of Wilets and Jean, it is assumed that the potential energy is independent of  $\gamma$  – 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  $\gamma$ . Therefore, it has always been a subject of keen interest for experimentalists and theoreticians to see whether the asymmetric nucleus under consideration is axial,  $\gamma$  – soft or  $\gamma$  – rigid.

In RTRM, the ground state band is normal rotational band while the other two bands that are  $\gamma$  and  $\gamma\gamma$  – 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  $\gamma$  and compared the odd – even staggering (OES) in  $\gamma$  and  $\gamma\gamma$  – band. The staggering indices  $S(I)$  in  $\gamma$  – band is expressed as [3]

$$S(I) = \frac{(E_I - E_{I-1}) - (E_{I-1} - E_{I-2})}{E_{2I}^{\dagger}} \quad (1)$$

McCutchen et al [4] using above equation shown that for both vibrator and  $\gamma$  – 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  $\gamma$  – 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  $\gamma$  and  $\gamma\gamma$  – band [Fig. 1(a) – (b)]. It is clear that there is a significant difference in the behavior of staggering

indices of  $\gamma$  and  $\gamma\gamma$  – 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  $\gamma\gamma$  – band. However, in  $\gamma$  – 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  $\gamma\gamma$  – band differs from  $\gamma$  – band, it is small in  $\gamma\gamma$  – band and is large in  $\gamma$  – band. The magnitude of  $S(I)$  in  $\gamma\gamma$  – band is constant and is nearly equal to 0.33 for  $\gamma = 10^0$  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  $\gamma$  upto spin  $I = 8$ , at  $\gamma = 25^0$  and then the zigzag behavior appears. However, for  $\gamma$  – 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  $\gamma$  – band as criteria to distinguish  $\gamma$  – rigid and  $\gamma$  – soft nucleus in  $\gamma\gamma$  – band. Hence, the criteria to distinguish  $\gamma$  – rigid and  $\gamma$  – soft nucleus in  $\gamma\gamma$  – 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  $\gamma\gamma$  – band with RTRM for <sup>154</sup>Gd and <sup>178</sup>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  $\gamma\gamma$  – band for <sup>154</sup>Gd. These values are similar in phase with RTRM [Fig.2 (a)]. Thus, it may be rigid triaxial nucleus.

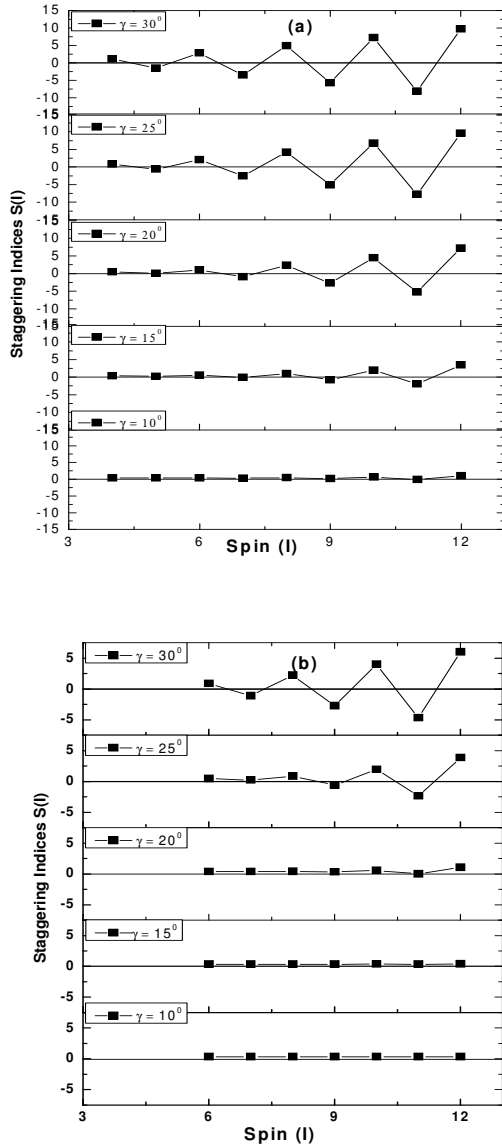


FIG. 1 (a) – (b)

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

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  $\gamma$  – soft structure of  $^{178}\text{Hf}$  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  $^{178}\text{Hf}$ .

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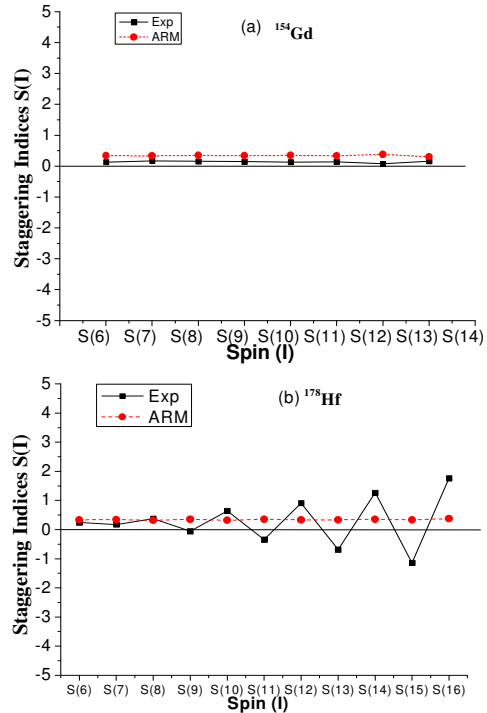


FIG. 2 (a) – (b)

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

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