Non-Coriolis Band Mixing in Deformed Nuclei

P C Sood and R. Gowrishankar*
Department of Physics, Sri Sathya Sai Institute of Higher Learning, Prasanthinilayam, A.P., 515134 INDIA
** email: rgowrishankar@sssihl.edu.in*

In the rotor-particle model for an axially symmetric nucleus, the rotational band quantum number K defined as K=I_3 based on the vector relation $\vec{I} = \vec{R} + \vec{j}$. In this formalism [1], the total Hamiltonian includes a Rotation-Particle Coupling (RPC), namely $(\vec{I} \cdot \vec{j})$ term. When treated as a perturbation, it gives rise to coupling (henceforth termed Coriolis Band Mixing (CBM)) between different rotational bands with ΔK=±1. Mixing between bands with ΔK>1 is thence described through stepwise CBM application. Presently we focus on the somewhat less discussed ΔK=0 Non-Coriolis Band Mixing (NCBM). Such a situation arises, since, $I^{\pi}K$ does not uniquely define a nuclear state, which is more appropriately described using the Nilsson model asymptotic quantum numbers [$Nn_3\Lambda\Sigma$]. In our study we use the current databases while discussing specific level schemes.

While discussing this question in the context of β-decay [3] we pointed to an early remark of Mottleson and Nilsson that '*a selection rule associated with N should be somewhat stronger than the rules connected with other asymptotic quantum numbers*'. Since parity is a good quantum number, the lowest order NCBM is expected to be significant for closely spaced ΔN=2 bands. An examination of Nilsson level diagrams (vide Fig 5.3 of ref.1) reveals that the sharply down-sloping of 1/2[660] and also 3/2[651] neutron orbitals occur very close in energy respectively with the sharply up-sloping 1/2[400] and 3/2[402] orbitals for δ ~0.3 (normal for well deformed nuclei). A survey of corresponding experimentally observed energy levels indeed shows that NCBM occurs in almost every known case of N=89(2)97 isotones. The current data tables [2] explicitly record that in each case the 1/2[660] level has a significant 1/2[400] component and vice-versa. The same observation holds for each known pair of $3/2^+$ levels. Illustrative instances of such cases are listed in Table.1 for odd-A nuclei. This feature is also seen for even-A, both the even-even and odd-odd, nuclei of the region as seen evident in the following illustrative experimental data [2,4]:

$^{156}_{64}Gd_{92}$: 2138 keV 7^-
{nn:11/2[505]⊗3/2[651] & 3/2[402]}

$^{164}_{67}Ho_{97}$: 833 keV $4^-(K_T)$ and 925 keV $3^-(K_S)$
{p:7/2[523] ⊗ n:1/2[660] & 1/2[400]}

Direct experimental evidence for band mixing comes from various reaction processes, population and decay modes, and intraband-vs-interband transition rates. In particular, particle transfer studies provide quantitative estimates for this feature in 2qp bands in even-A nuclei as discussed in our earlier report for the odd-odd nucleus ^{176}Lu [5]. Presently we report on side-by-side examination of 2qp bands in extensively studied even-even ^{168}Er and odd-odd ^{166}Ho [2].

Table 1: Illustrative instances of experimental [2] bandhead energies (in keV) of ΔN=2 mixed ΔK=0 pairs of $K^{\pi}=1/2^+$ and also $K^{\pi}=3/2^+$ bands in lighter odd-A rare earth nuclei.

N	$^{A}_{Z}X$	$E_x: 1/2^+\{[660]$ & $1/2^+[400]\}$		$E_x: 3/2^+\{[651]$ & $3/2^+[402]\}$	
89	$^{153}_{64}Gd$	95	328	508	212
91	$^{153}_{62}Sm$	415	735	0	321
93	$^{155}_{62}Sm$	903	1282	618	866
95	$^{161}_{66}Dy$	608	773	550	678
97	$^{163}_{66}Dy$	738	884	859	1148

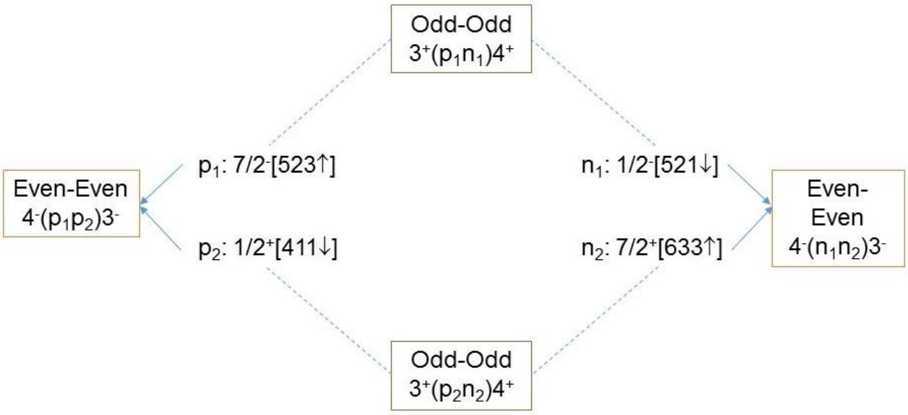

Fig. 1: Block diagram of pairs of 'Analogous Doublets' expected in an odd-odd nucleus and in an even-even neighbour constituted from a given pair each of p and n orbitals.

Table 2: Experimentally observed [2] bandhead energies (in keV) of the even-even $^{168}_{68}Er_{100}$ and odd-odd $^{166}_{67}Ho_{99}$ nuclei corresponding to the 'Analogous Doublets' bands indicated in Fig. 1.

^A_ZX	K^π	E_x (keV)	Configuration
$^{168}_{68}Er_{100}$	4_1^- (K↓↑)	1094	n_1:1/2⁻[521↓] ⊗ n_2:7/2⁺[633↑]
	3_1^- (K↑↑)	1541	
	4_2^- (K↓↑)	1905	p_1:7/2⁻[523↑] ⊗ p_2:1/2⁺[411↓]
	3_2^- (K↑↑)	1999	
$^{166}_{67}Ho_{99}$	3_1^+ (K_T)	191	p_1:7/2⁻[523↑] ⊗ n_1:1/2⁻[521↓]
	4_1^+ (K_S)	372	
	3_2^+ (K_T)	592	p_2:1/2⁺[411↓] ⊗ n_2:7/2⁺[633↑]
	4_2^+ (K_S)	719	

In this study we have focused on a highly NCBM pair of $K^\pi=4^-$ levels composed of ($n_1 \otimes n_2$) and ($p_1 \otimes p_2$) orbital pairs as shown in Fig.1, and experimentally observed [6] in ^{168}Er spectra as listed in Table 2. A series of particle transfer reaction studies by Burke *et al*. [6] concluded that the 1094 keV 4_1^- level NCBM configuration is {70%(n_1n_2)+25%(p_1p_2)} whereas the 1905 keV 4_2^- level is {60%(p_1p_2)+32%(n_1n_2)}. The 3_1^- and 3_2^- counterpart of this pair of doublets has <10% NCBM components. Our comparative study of e-e and o-o neighbours establish that the same pairs of nn and pp orbitals constitute pair of GM doublets bands (Fig.1) experimentally identified in the o-o neighbour ^{166}Ho, as listed in Table 2. We term this occurrence as 'Analogous Doublets in odd-odd and even-even Nuclei'. Detailed analysis of the scope and characteristics of this feature are under investigation.

References

[1] A Bohr and B R Mottelson, 'Nuclear Structure', Vol II (Benjamin, 1975).

[2] ENSDF and XUNDL continuously updated data files at NNDC (July 2017 Version).

[3] P. C. Sood, Rajkumar Jain and OSKS Sastri, Phys. Rev. **C69** (2004) 057303.

[4] D M Headley *et al.*, At. Data Nucl. Data Tables, **69** (1998) 239.

[5] P. C Sood *et al.*, Proc. DAE-BRNS Symp. Nucl. Phys. **60** (2015) 120.

[6] D G Burke *et al.*, Nucl. Phys. **A445** (1985) 70.