Search for patterns in dynamic moments of inertia in superdeformed bands in mass ≈ 190 region

Santosh Roy[1]*
[1] *Manipal Centre for Natural Sciences, Manipal University, Manipal 576 104, Karnataka, India*

Introduction

Superdeformation (SD) in atomic nuclei is an intriguing mode of collective excitation, at high spins. More than 300 superdeformed band have been observed over the nuclear landscape. Many experimental, and theoretical investigations have explored and characterized the underlying mechanism that leads to such a high degree of collectivity ($\beta \sim 0.6$). The stability of this structure, with the evolution of spin is due to the coherent effect of proton, and neutron single particle energy minimization (shell corrections) at high deformation. Using mean field models, such as, Woods-Saxon [1], anharmonic oscillator [2, 3], or the Skyrme-Hartree-Fock formalism [4], it is possible to account for the evolution of the SD band with rotational frequency.

Interestingly, quite a few semiclassical macroscopic models are also successful in characterizing the SD bands [5–9]. The primary reason of the applicability of the models is based on the fact that, the total moment of inertia, $\Im$, is due to the contribution of two components, rigid-core ($\Im_{rgd}$), and irrotational ($\Im_{irr}$), and is given by [7]

$$\Im = \frac{3}{4}\Im_{rgd} + \frac{1}{4}\Im_{irr} \qquad (1)$$

From this expression one can infer that, it is possible to identify a "core", which is rigid and a irrotational part in the experimental observables. The interplay of these two moment of inertia with the rotational frequency gives us some interesting insight into the overall patterns that can be observed in this domain.

Experimentally, SD bands are sometimes, sparsely populated, and their bandhead cofiguration cannot be uniquely assigned. As a result it is often convenient to characterize the moment of inertia by the first ($\Im^{(1)}$) and the second ($\Im^{(2)}$) moment of inertia.

According to the 'ab' formalism given by C. S. Wu et al., [9] the first and the second moments of inertia, are similar in functional form and can be denoted as,

$$f_n(\omega) = \Im_\circ \left[1 - \frac{(\hbar\omega)^2}{a^2 b}\right]^{(\frac{1}{2}-n)} \qquad (2)$$

where $\Im_\circ$ is the band head moment of inertia, and a and b are related with $\Im_\circ$ via, $\Im_\circ = (\hbar^2/ab)$, and can be determined by fitting the experimental data. For the kinematic, and dynamic moment of inertia, $n = 1$, and $n = 2$, respectively. In continuation of my recent work [10], here I will put forward a methodology to search for patterns in SD bands in region close to mass 190.

Phenomenological Model

The magnitude of moment of inertia of the nucleus, $\Im$, is between that of a rigid rotor and a liquid rotor ($\Im_{liquid} < \Im < \Im_{rgd}$). If we consider the experimental cases, where the dynamic moment of inertia is smooth and continuous, we can draw some conclusion using the vibration distortion plus rotation model [10].

In this model, at the highest observed rotational frequency $\omega_{\max}$ the distortion should go to zero and the SD band becomes 'rotationally pure'. The distortion effect is parametrized through, $\Im^{(2)}_{vib}$, and is coupled with the rotational core dynamic moment of inertia, $\Im^{(2)}_c$ (Eq. 3).

*Electronic address: santosh.roy@manipal.edu

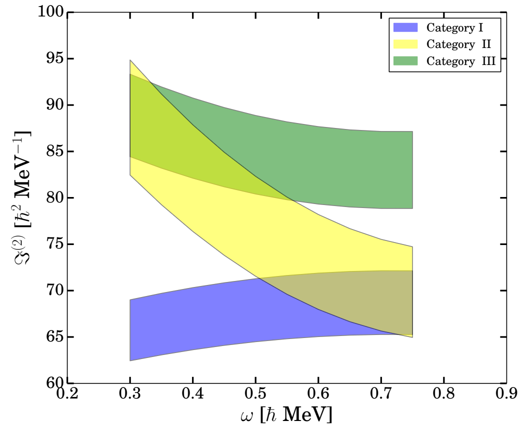

FIG. 1: The $\Im^{(2)}$ vs. ω plot shows the three regions with $\Im_c^{(2)}/\Im_{vib}^{(2)} \sim 8$ (blue), $\Im_c^{(2)}/\Im_{vib}^{(2)} \sim 5$ (green), and $\Im_c^{(2)}/\Im_{vib}^{(2)} \sim 1.5$ (yellow) for the given span of angular frequency [10].

$$\Im^{(2)} = \Im_c^{(2)} \pm \Im_{vib}^{(2)} \left[\frac{\omega_{\max} - \omega}{\omega_{\max}}\right]^2 \quad (3)$$

Here, for 23 SD bands in mass 150 region, three categories of dynamic moment of inertia were identified with ${\Im_c}^{(2)}/{\Im_{vib}}^{(2)} \sim 1.5$, 5, and 8, shown in the Fig. 1.

This observation is quite interesting. and has lead us to a search for pattern in the neighbouring mass 190 region.

Results

In mass 190 region, I have investigated smooth SD bands of ^{189,191,192,193}Tl, ^{191,193,194,195}Hg, ^{191}Au, and ^{193,194,195}Pb using the vibrational distortion plus rotation [11]. Due to a higher mass as compared to mass 150 region, we expect a higher contribution from the vibrational distortion part. In addition the core contribution should also increase. Using the prescription of the model we observe that the ratio of ${\Im_c}^{(2)}/{\Im_{vib}}^{(2)} \sim$ remains in the same ballpark, and a new region of overlap has been identified. It remains a matter of interest to investigate the variation in the quadrupole due to such an distortion effect and compare it with experimental results.

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