Geometry of Magnetic Rotational (MR) band-crossing in MR phenomenon

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Introduction

In nuclear landscape, a number of dipole ($\Delta I = 1$) magnetic rotational bands have been found which occur due to the anisotropic distribution of nuclear current [1]. The band-crossing phenomenon was also exhibited by such bands which is known as magnetic rotational (MR) band-crossing *i.e* the two bands have magnetic rotational behavior before and after the band-crossing. In this work, a schematic model base on semiclassical (SC) approach of Macchiavelli *et.al* [2] was proposed to explain MR band-crossing. The MR band-crossing occurs due to the alignment of a pair of valence nucleon and the shear blades re-open to built up a new shear band [3]. At the crossing region, there will be some states in which the two valence nucleon are not fully aligned. The resultant angular momentum should be more or less quantized, therefore, at these intermediate states only those angles are possible between the aligning pair which quantized the angular momentum. Due to the above interpretation of MR band-crossing, the $B(M1)$ value can be calculated when the band changes its structure during crossing. In the present paper, we report semiclassical model to calculate the B(M1) value in the MR band-crossing region.

Semiclassical model for MR band-crossing

From the geometry of MR band as given in [2], the $B(M1)$ values are proportional to the square of perpendicular component of the magnetic moment ($\mu_\perp$) and it shows decreasing behavior with the spin. In this geometry the $B(M1)$ can be calculated as

$$B(M1) = \frac{3}{4\pi}\frac{1}{2}\vec{\mu}_\perp^2 = \frac{3}{4\pi}g_{eff}^2 j_\pi^2 \frac{1}{2} sin^2\theta_\pi \quad [\mu_N^2] \tag{1}$$

The shear angle $\theta_{\nu\pi}$ is given as

$$cos\theta_{\nu\pi} = \frac{J(J+1) - J_\nu(J_\nu+1) - J_\pi(J_\pi+1)}{2\sqrt{J_\nu(J_\nu+1)J_\pi(J_\pi+1)}} \tag{2}$$

This expression has been extended in terms of the shear angle as given in [4]

$$B(M1) = \frac{3}{4\pi}\frac{(2J_\nu+1)^2(2J_\pi+1)^2}{16J(2J+1)} \tag{3}$$

$$\times (g_\nu - g_\pi)^2 sin^2\theta_{\nu\pi}$$

Assume that a shear band is built by the recoupling of two long angular momentum J_π and J_ν which are formed by the coupling of one or more protons and neutrons, respectively. This band is crossed by another band which arises due to the alignment of a pair of neutron (J_ν^1 and J_ν^2) along J_ν, coupled to form $J_\nu^{'}$. The shear will reopen with the two shear blades formed by J_π and $J_\nu^{'}$. At the crossing region, J_ν^1 and J_ν^2 are partially aligned and the effective neutron angular momentum, $J_\nu^{eff}$is formed by the coupling of J_ν and J_ν^{12} where,

$$J_\nu^{12} = \sqrt{(J_\nu^1)^2 + (J_\nu^2)^2 + 2(J_\nu^1)(J_\nu^2)cos\phi} \tag{4}$$

where, ϕ is the angle between the aligning pair. If g_ν is the neutron g-factor before crossing then, the effective neutron g-factor at the crossing region is

$$g_\nu^{eff} = g_\nu + g_\nu^{12} \tag{5}$$

where g_ν^{12} can be calculated from the g-factors of the aligning pair g_ν^1 and g_ν^2

$$g_\nu^{12} = \frac{1}{2}(g_\nu^1+g_\nu^2) + \frac{J_\nu^1(J_\nu^1+1) - J_\nu^2(J_\nu^2+1)}{2J_\nu^{12}(J_\nu^{12}+1)}(g_\nu^1 - g_\nu^2) \tag{6}$$

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From the semiclassical expression,

$$B(M1) = \frac{3}{4\pi}\frac{(2J_{\nu}^{eff}+1)^2(2J_{\pi}+1)^2}{16J(2J+1)} \times (g_{\nu}^{eff} - g_{\pi})^2 sin^2\theta_{\nu\pi} \quad (7)$$

$$cos\theta_{\nu\pi} = \frac{J(J+1) - J_{\nu}^{eff}(J_{\nu}^{eff}+1) - J_{\pi}(J_{\pi}+1)}{2\sqrt{J_{\nu}^{eff}(J_{\nu}^{eff}+1)J_{\pi}(J_{\pi}+1)}} \quad (8)$$

The same approach can be used if the aligning pair is proton.

Discussions

Calculating J^{eff} and g^{eff} for possible angle ϕ between the aligning pair a deeper understanding of MR band-crossing can be done by observing the $B(M1)$ behavior. It has been observed in shear bands that the $B(M1)$ value decreases with increasing spin and after band crossing the $B(M1)$ value suddenly jump to a higher value and then again follows the same decreasing trend. In this crossing region, the $B(M1)$ value should be of some intermediate value so that it changes from a lower value before crossing to a higher value above crossing by a step by step increment. This interpretation ables to explain this phenomenon in mass region $A \sim 100$ and $A \sim 200$, as shown in FIG 1. The calculated values for the given configuration, before crossing (BC) and after crossing (AC), as given in [5, 6] are given in TABLE 1. The g-factors are calculated from the Nilsson orbitals of the bands. An inspection in other mass region is currently under study. However, lack of experimental $B(M1)$ value in crossing region is a draw-back to test its implementation.

In summary, the present geometrical picture will help in a better perception of shear bands and their crossing and will propel the theoretical efforts in understanding the structure in these bands.

TABLE I: Calculated $B(M1)$ values of ^{108}Cd-band 1 and ^{196}Pb-band 3 at the crossing region.

^{108}Cd-Band 1					^{196}Pb-Band 3				
J	ϕ°	J_{ν}^{eff}	g_{ν}^{eff}	$B(M1)$ $[\mu_N^2]$	J	ϕ°	J_{ν}^{eff}	g_{ν}^{eff}	$B(M1)$ $[\mu_N^2]$
16.5	178	12.0	-0.13	1.07	21	134	12.0	-0.21	5.26
17.0	164	12.5	-0.20	1.34	22	106	15.0	-0.23	10.04
17.5	146	13.5	-0.25	2.16	23	74	17.0	-0.27	13.07

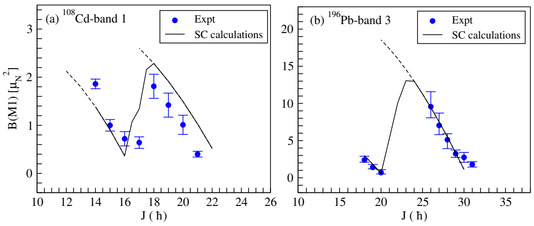

FIG. 1: Plot of $B(M1)[\mu_N^2]$ as a function of spin J ($\hbar$) for (a) ^{108}Cd-band 1 and (b) ^{196}Pb-band 3 (bands were numbered according to [5]). Solid circles were experimentally deduced values as given in [5, 6]. The doted lines were SC calculation for the given configuration BC and AC. Solid lines were SC calculations of the proposed model.

Acknowledgments

This work was done in the of Department of Physics and Astrophysics, University of Delhi, India. The authors would like to acknowledge the financial assistance at Delhi University from the University Grants Commission (UGC), India.

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