Study of superdeformed bands in $^{80-83}$Sr by using two-parameter formulae

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With rapid advancements in the experimental facilities, particularly the detector systems and data acquisition systems, superdeformed (SD) shapes at high spins and associated rotational bands were discovered in the last decade of 20th century [1]. The work on SD bands peaked around 1995-2000. First compilation of the SD bands due to Singh et al. [2] was published in 2002. It contained information on 242 SD bands spread all over the periodic table. The excitation energy and firm assignment of spin-parity are not known for most SD bands because the linking transitions have not been observed in most of the cases. The phenomenon of identical bands and other features of SD bands are still not understood.

Despite numerous attempts, the searches for SD shapes in the lighter region (A~ 80) have been hampered for many years primarily because of experimental difficulties. SD bands have now been established in $^{80-83}$Sr, $^{82-84}$Y, ^{83,84}Zr and ^{86}Zr. Multiple bands are known in many of these nuclei, and many of these bands have been shown to be highly deformed by lifetime measurements. A detailed understanding of the structure of SD bands in this mass region is still emerging. Most of the SD bands in this region have been interpreted as prolate shaped due to their highly collective nature, large moments of inertia, and in some cases measured average transition quadrupole moments. However, it has been suggested that a large variety of shapes is possible in the high and intermediate spin range in these nuclei, including both prolate and triaxial collective structures.

With these issues in mind, a study of the evolution of the SD bands of $^{80–83}$Sr nuclei has been undertaken by employing variable moment of inertia models using three types of two-parameter formulae namely the *AB* formula, the *ab* formula and the power law formula.

Bohr and Mottelson pointed out that the rotational energy of axially symmetric deformed nucleus in $K = 0$ band can be written as

$$E(J) = A\big(J(J+1)\big) + B\big(J(J+1)\big)^2$$

It is obtained as first order approximation to centrifugal stretching. Holmberg and Lipas [3] noted that the moment of inertia of deformed nuclei varies approximately linearly with level energy and they obtained the phenomenological two-parameter *ab* formula

$$E(J) = a\left[\sqrt{1+bJ(J+1)} - 1\right]$$

The linear relation between moment of inertia *I* and the level energy *E* is not obeyed well by many rotational spectra for low as well as very high spins. In other words, *ab* formula overstresses the centrifugal stretching effect. Gupta et al. [4] suggested a single-term expression for ground state band, level energies of a soft rotor. They replaced the concept of the arithmetic mean of the two terms used in the Bohr-Mottelson expression by the geometric mean and introduced a two-parameter formula called the power law:

$$E(J) = a\,J^b$$

where *a* and *b* are two parameters.

In table 1, comparison of experimental energy levels for SD-1 and SD-2 bands of ^{81}Sr with theoretical energies obtained by using power law, *ab* and *AB* formulae is presented.

A comparative study of the theoretical calculations with the observed energies of SD bands in $^{80-83}$Sr nuclei indicates that the results obtained by using power law, *ab* and *AB* formulae are in satisfactory agreement with the experimental results. For most of the SD bands in these nuclei, theoretical results obtained by using the power law formula are better than those predicted by the other two formulae.

Table 1: Comparison of experimental energy spectra for (a) SD-1 and (b) SD-2 bands of ^{81}Sr with theoretical energies obtained by using power law, *ab* and *AB* formulae.

(a)

Spin (J)	Energy $E(J)$ (in MeV)			
	Experimental	Power Law	*ab*	*AB*
27/2	x	x	x	x
31/2	1.214 + x	1.214 + x	1.214 + x	1.214 + x
35/2	2.584 + x	2.584 + x	2.584 + x	2.584 + x
39/2	4.102 + x	4.1088 + x	4.1079 + x	4.1078 + x
43/2	5.780 + x	5.7873 + x	5.7834 + x	5.7829 + x
47/2	7.619 + x	7.6185 + x	7.6081 + x	7.6067 + x
51/2	9.605 + x	9.6016 + x	9.5792 + x	9.5761 + x
55/2	11.743 + x	11.7357 + x	11.6941 + x	11.6879 + x
59/2	14.035 + x	14.0202 + x	13.9498 + x	13.9387 + x
63/2	16.474 + x	16.4543 + x	16.3434 + x	16.3246 + x
67/2	19.036 + x	19.0374 + x	18.8718 + x	18.8416 + x
71/2	21.694 + x	21.7690 + x	21.5317 + x	21.4856 + x
75/2	24.442 + x	24.6484 + x	24.3200 + x	24.2519 + x

(b)

Spin (J)	Energy $E(J)$ (in MeV)			
	Experimental	Power Law	*ab*	*AB*
31/2	y	y	y	y
35/2	1.773 + y	1.773 + y	1.773 + y	1.773 + y
39/2	3.697 + y	3.697 + y	3.697 + y	3.697 + y
43/2	5.780 + y	5.7674 + y	5.7589 + y	5.7528 + y
47/2	8.018 + y	7.9801 + y	7.9464 + y	7.9192 + y
51/2	10.413 + y	10.3316 + y	10.2478 + y	10.1729 + y
55/2	12.950 + y	12.8187 + y	12.6524 + y	12.4888 + y
59/2	-	15.4385 + y	15.1505 + y	14.8394 + y

References

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