# Some universal features and global systematics of superdeformed bands

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A large amount of data on superdeformed (SD) bands have been accumulated over the years [1, 2], which form the basis of a global study of superdeformed bands. The SD bands are unique in several respects. They display a behavior which seems to be simple but not easy to understand in its totality. Some of the peculiar features which we touch upon are the near rigid rotor nature of the bands, identical band phenomenon, hanging nature of the SD bands. Besides these SD bands showed weak oscillations in the angular momentum vs. gamma ray energy plots and the alignment of many SD bands had been found to be mostly negative. We have carried out a phenomenological study of SD bands to understand some of these features in more detail.

A 4-parameter formula based on the rigid rotor model of Bohr [3] has been applied to the 219 superdeformed bands spread over the whole nuclear chart to obtain the band moment of inertia $J_0$ and the nuclear softness parameter $\sigma$. Based on a classification of the SD bands into three broad categories of major to minor axes ratio ($x$), viz. 1.5:1, 1.7:1 and 2:1, the systematics of $J_0$ and $\sigma$ are presented. The SD bands are further classified into yrast and excited SD bands, which have been further sub-divided into even-even, odd-A and odd-odd nuclei to obtain a better understanding of the systematics. The measured $Q_t$ values and hence the axes ratios have been used to calculate the rigid body $J_0$ values and compare with the fitted values of $J_0$. On an average, the fitted $J_0$ values follow the expected $A^{5/3}$ trend in all the cases. In a significant finding, it is observed that more than one-third of the known SD bands have already become rigid rotors and many have actually crossed the rigid-rotor limit; the latter have been termed as "super-rigid" rotor bands [4]. Further, the softness parameter $\sigma$ is found to be strongly correlated to the nuclear shape; larger the axis ratio ($x$) or the deformation, smaller is the softness parameter $\sigma$, implying more rigidity. The spread in the $\sigma$ values also shrinks dramatically with increasing deformation. It suggests that the rigidity of the SD bands is predominantly a deformation effect.

We present for the first time many types of empirical evidence that point to the existence of preferred neutron/proton numbers for superdeformed (SD) shapes. We use a simple premise based on the pairing correlations to obtain the proposed empirical evidence. In particular, plots of $\gamma$-ray energy ratio such as $R(I) = E_\gamma(I \to I-2)/E_\gamma(I-2 \to I-4)$ vs N and Z, R(I) vs I plots, nuclear softness parameter values, and the number of SD bands for a given N and Z are used to pinpoint the N, Z numbers that are most favored as the deformed magic numbers. The proton and neutron magic numbers so obtained not only confirm the earlier theoretical predictions made for the chain of particle numbers corresponding to the SD shapes but also verify the increase in deformation with the particle number within each chain. The analysis also leads to several new predictions for the occurrence of the SD bands [5].

Two SD bands of neighboring nuclei having the same value of kinematic and dynamic moment of inertia are considered to be identical to each other [6]. This fact seems to suggest that the band moment of inertia of these bands should be the same. Identical band is the phenomenon which is still not fully under-

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stood. We propose an approach to describe the band moment of inertia of identical SD bands in A=190 mass region. We have calculated the band moment of inertia of the pair of identical SD bands by using the 4- parameter formula and have also investigated its systematics. We find that the band moment of inertia comes out to be different for two identical SD bands and same for the signature partner SD bands.

Search of the $\pm F_0$ symmetry and identical bands in SD nuclei in $72 \leq N \leq 86$ region has been done based on the concept of $N_pN_n$ product and F - spin multiplets of nuclear structure. Pairs of conjugate nuclei with the same F-spin and $F_0$ values have identical $N_pN_n$ values. The superdeformed (SD) nuclei having neutron number 72 $\leq$ N $\leq$ 86 are found to have the same boson number but different $F_0$ values except for the pair $^{130}$Ce, $^{134}$Nd, and the pair $^{144}$Gd, $^{148}$Gd. The behavior of $\gamma$-ray transition energies in bands of these pairs of SD nuclei are found to be constant. The smooth dependence of dynamic moment of inertia on rotational frequency gives the existence of identical bands in these two pairs of SD nuclei. The superdeformed band spectra of other nuclei in 72 $\leq$ N $\leq$ 86 region based on the concept of $N_pN_n$ are also discussed.

We present for the first time the study of softness parameter of SD bands of A=190 mass region with $N_pN_n$ scheme. The nuclear softness parameter values of most of the SD bands are found to be smaller than those of the normal deformed (ND) bands, implying more rigidity. The results of this work includes the variation of nuclear softness parameter against the gamma ray energy ratio R(I)=$E_\gamma(I \rightarrow (I-2))/E_\gamma((I-2) \rightarrow (I-4))$ of SD bands in A=190 mass region. The variation of R(I) and the nuclear softness parameter ($\sigma$) of these SD bands are studied with the product of valence proton and neutron numbers ($N_pN_n$). The systematics also includes the variation of $\sigma$ with the neutron number N. It is also found that the value of softness parameter of signature partner SD bands observed in A=190 mass region is also the same [7].

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