# Nuclear Structure Studies of Exotic Nuclei

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## Introduction

Nuclei in the region A $\approx$ 80 are of considerable interest, since this region contains highly deformed nuclei. The interesting features in this mass region are pronounced shell structure effects, strong dependence of nuclear shapes on proton and neutron numbers as well as on the spin, termination of rotational band, shape-coexistence etc.

In this mass region, the most striking shell effect is a gap in the single-particle level sequence for prolate deformation at nucleon number 38, stabilizing very large deformations ($\beta_2$ $\approx$0.4) in Rubidium [1, 2], Strontium [3] and Zirconium [4] nuclei. Shape polarization in many odd-A nuclei in this region is expected to be highly dependent on the single-particle orbital occupied by the odd nucleon. $^{79}$Rb is of particular interest, because with N=42, it lies at the border of the well-deformed highly rotational region which includes $^{77}$Rb and the moderately deformed $\gamma$-soft region including $^{81}$Rb.

Nuclear Chirality is a manifestation of spontaneous symmetry breaking [5, 6] resulting from a orthogonal coupling of angular momentum vectors in triaxial nuclei which minimizes the total energy of the system. These perpendicular angular momenta can form two geometries of the opposite handedness and are related to each other by the chiral operator, which is a combination of time reversal and rotation by 180$^0$.

In the mass A $\sim$ 100 region, chiral partner bands were identified in the odd-odd nuclei $^{100}$Tc [7], $^{102,104,106}$Rh [8–10] and $^{106}$Ag [11] based on the $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}$ configuration and in the odd-A $^{103}$Rh [12] and $^{105}$Rh [13] nuclei based on $\pi g_{9/2}^{-1}$ configuration after the alignment of a pair of $h_{11/2}$ neutrons. The present work on $^{98}$Tc provides the first indication of chirality in this nucleus.

The present thesis pertains to the investigation of shapes changes occurring at high spin which may lead to band termination in $^{79}$Rb and the occurrence of candidate chiral doublet bands in $^{98}$Tc involving the role played by high-$j$ intruder ($h_{11/2}$ and $g_{9/2}$) orbitals.

## Spectroscopy of $^{79}$Rb at high spin

Excited states in the $^{79}$Rb were populated in the $^{63}$Cu ($^{19}$F, p2n) $^{79}$Rb reaction. Enriched $^{63}$Cu target of thickness $\sim$ 700 $\mu g/cm^2$ on a $\sim$ 8 $mg/cm^2$ thick $^{181}$Ta backing was used. $^{19}$F beam at 60 MeV energy was provided by the 15 UD Pelletron at IUAC, New Delhi. The set-up used was the Indian National Gamma Array (INGA-I) consisting of 8 Compton suppressed Clover detectors. The level scheme of $^{79}$Rb has been studied up to the $J^\pi$ = $41/2^+$ in +ve parity band while $J^\pi = 33/2^-$ in -ve parity band upto excitation energy of $E_x \cong$ 10 MeV and $E_x \cong$ 7 MeV respectively. In $^{79}$Rb nucleus, the earlier reported level scheme is confirmed from our data. In the present work, the major aim was to study experimentally the shape driving effects of $g_{9/2}$ orbital in $^{79}$Rb and the effects of quasi proton and quasi neutron alignments on the shape of this nucleus. The direct measurement of nuclear shapes was done through the measurements of lifetimes of the levels. The lifetimes have been measured upto the $J^\pi$ = $41/2^+$ level in the yrast positive-parity band and upto the $J^\pi = 33/2^-$ level in the negative-parity band using the Doppler Shift Attenuation Method (DSAM). From the knowledge of lifetimes we can directly calculate the transition matrix elements (e.g. B(E2)) and transition quadrupole moments ($Q_t$), which are the direct measure of nuclear shape. The values

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of transition quadrupole moments show decrease with increase in rotational frequency at high spins for both the favoured and unfavoured $\pi g_{9/2}$ partner bands in the yrast positive parity and $\pi p_{3/2}$ negative parity bands of $^{79}$Rb. This result signifies that the nucleus loses its collectivity at high spins and its shape changes from collective prolate to noncollective oblate, thereby indicating band termination trend.

## Spectroscopy of $^{98}$Tc at high spin

The odd-odd $^{98}$Tc nucleus was populated in the reaction $^{94}$Zr ($^{7}$Li, 3n) 98Tc. $^{7}$Li at beam energy of 32 MeV was provided by the 15 UD Pelletron at IUAC. A self-supporting $^{94}$Zr target having thickness of $\sim$ 4.4 mg/cm$^2$ was used in the experiment. The de-exciting $\gamma$ - rays were detected utilizing an array of 15 Compton suppressed Clover detectors (INGA-III). The Clover detectors were arranged in five rings *viz.* $32^0$, $57^0$, $90^0$, $123^0$ and $148^0$ with respect to the beam direction. As a result of this work we have reconfirmed the old level scheme showing a yrast band at low spins and also added many gamma transitions and levels to the existing level scheme. A total of 42 new gamma transitions and 27 new levels have been placed in the level scheme. A new chiral partner band similar to the yrast band and a number of characteristic M1/E2 interconnecting $\gamma$ - ray transitions between the yrast and the new partner band have been observed in the work. This is is the first time that candidate chiral doublet bands have been found in $^{98}$Tc, thereby extending the limit of observation of such bands to lighter mass isotope of Tc. Chirality in bands are tested with many experimental chiral signatures, like, plots of $E_x$ *vs* spin, S(I) *vs* spin and B(M1)/B(E2) *vs* spin. The trends in the plots indicate the possibility of chiral character in $^{98}$Tc. The Total Routhian Surface (TRS) calculations for $^{98}$Tc are also done in the present work. The stable value of $\gamma$ ($\gamma \sim 30^0$) for different rotational frequencies give the triaxial nature for $^{98}$Tc. This also supports the possibility of chirality in $^{98}$Tc.

In the above mentioned work, it is found that the high-j orbitals play a key role in the phenomena of loss of collectivity (band termination trends) in $^{79}$Rb nucleus and in the observation of new candidate chiral doublet bands in $^{98}$Tc nucleus.

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