# Jacobi shape transition and hyperdeformation in rapidly rotating warm nuclei

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The Jacobi shape transition from non-collective oblate to hyperdeformed collective prolate or triaxial shape in nuclei is analogous to the Jacobi shape instability occurring in gravitating rotating stars. This happens at a very high spin where pairing has vanished. Thermal fluctuations do not come into play because of near zero temperature in warm nuclei. Further, Jacobian instability occurs before fission instability in light and medium mass nuclei.

Facilities like EUROBALL IV, HECTOR and EUCLIDES arrays abroad and superconducting cyclotron in India have been recently used [1] to detect the Jacobi shape transition in nuclei like $^{46}$Ti. The interest builds up by the fact that Jacobi shape transition may lead to hyperdeformation [2] which are hard to obtain. The molecular-like configurations encountered at such hyperdeformations [3] through Jacobi shape transition is also seen recently in the case $^{48}$Cr.

In the present work, the theoretical approach [4] we follow is the Nilsson-Strutinsky (NS) method extended to high spin. The total energy ($E_{TOT}$) at fixed deformation is calculated using the expression

$$E_{TOT} = E_{LDM} + \sum_{p,n} \delta E + \frac{1}{2}\omega((I_{classical} + \sum_{p,n} \delta I) \qquad (1)$$

The liquid-drop energy ($E_{LDM}$) is calculated by summing up the Coulomb and surface energies corresponding to a triaxially deformed shape defined by the deformation parameters $\beta$ and $\gamma$. The classical part of spin ($I_{Classical}$) is obtained from the rigid-body moment of inertia with surface diffuseness correction. The shell correction ($\delta E$) is the difference between the deformation energies evaluated with a discrete single-particle spectrum and by smoothening that spectrum ($\delta E = E - \tilde{E}$). Similarly the shell correction corresponding to the spin is given by ($\delta I = I - \tilde{I}$). To calculate the shell corrections for energy and spin, we use the triaxially deformed Nilsson model together with the Strutinskys prescription. The single-particle energies ($e_i$) and spin projections ($m_i$) are obtained by diagonalizing the triaxial Nilsson Hamiltonian in cylindrical representation upto first eleven major shells.

This procedure usually gives the total energy as a function of the angular velocity $\omega$. To get it as a function of spin, different methods like crude interpolation are usually used. In our method, we get those energies by **tuning** them to fixed spins. For finite temperature T, instead of the total energy the free energy is to be computed as

$$F(T, \beta, \gamma) = E - TS - \tilde{E} + E_{RLDM} \qquad (2)$$

where S is entropy and $E_{RLDM}$ is the rotating

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TABLE I: Shape transitions of $^{80}$Zr with spin at T=0 MeV (Note the Jacobi transiton at spin of 48$\hbar$ leading to hyperdeformation)

| I($\hbar$) | $\gamma$ (deg) | $\beta$ | E(MeV) |
|---|---|---|---|
| 0.00 | -180 | 0.0 | -3.99 |
| 4.00 | -180 | 0.0 | -3.28 |
| 8.00 | -180 | 0.0 | -1.16 |
| 11.99 | -180 | 0.2 | 1.82 |
| 15.99 | -180 | 0.2 | 3.76 |
| 19.99 | -180 | 0.2 | 6.95 |
| 23.99 | -180 | 0.2 | 11.23 |
| 27.99 | -180 | 0.2 | 15.86 |
| 31.99 | -180 | 0.2 | 21.55 |
| 36.00 | -180 | 0.3 | 27.51 |
| 39.99 | -180 | 0.4 | 32.56 |
| 43.99 | -180 | 0.4 | 38.51 |
| **47.99** | **-120** | **0.8** | **44.73** |

liquid drop model energy.

RLDM calculations themselves show Jacobi transitions for Zirconium isotopes but with smaller deformations while Cranked Nilsson Strutinsky calculations show Jacobi transition leading to hyperdeformation (See Tables I and II). This result may be compared with the advanced LSD calculations but without shell effects.

This work has shown that the Zirconium region is a fertile ground for harvesting Jacobi transitions leading to hyperdeformation.

TABLE II: Jacobian shape transitions in Zirconium isotopes at T=0 MeV

| Mass number | I($\hbar$) | $\gamma$ | $\beta$ |
|---|---|---|---|
| 82 | 48 | -180 | 0.4 |
| | 50 | -120 | 0.9 |
| 84 | 50 | -180 | 0.4 |
| | 52 | -120 | 0.9 |
| 86 | 52 | -180 | 0.4 |
| | 54 | -120 | 1.0 |
| 88 | 56 | -180 | 0.3 |
| | 58 | -120 | 1.0 |
| 90 | 56 | -180 | 0.2 |
| | 58 | -120 | 1.0 |

## References

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