Evaluation of the Wobbling Motion in Even-Even Nuclei Within a Simple Rotor Model

Robert POENARU[1,2]

[1]Doctoral School of Physics @ UB
Bucharest, Romania

[2]Dept. of Th. Phys. @ IFIN-HH
Magurele, Romania

International Conference on Nuclear Structure Properties
June 27, 2022

Table of Contents

Nuclear Deformation

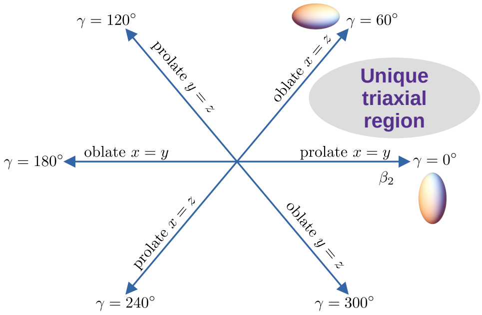
- Most of the nuclei are either *spherical* or *axially symmetric* in their ground-state.
- Deformation parameter β (*Bohr, 1969*): preserves axial symmetry

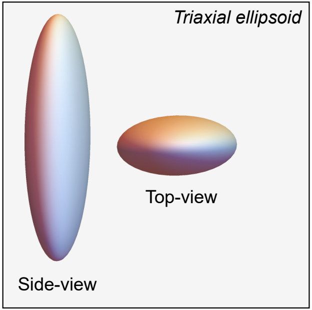
Figure 1: **spherical:** $\beta = 0$ **prolate:** $\beta > 0$ **oblate:** $\beta < 0$

Nuclear Triaxiality

Non-axial shapes

- Deviations from symmetric shapes can occur across the chart of nuclides → **triaxial nuclei**.
- The triaxiality parameter γ (*Bohr, 1969*): departure from axial symmetry





Fingerprints for Triaxiality

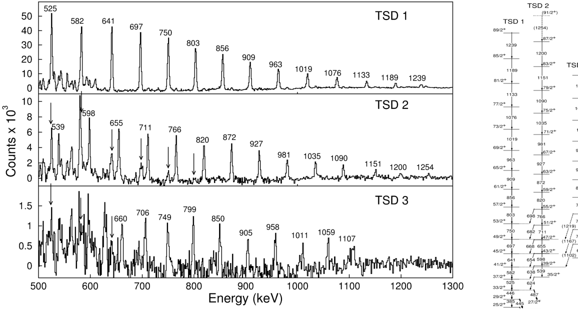
- Stable triaxial nuclei represent a real challenge for experimentalists and theoreticians
- Clear signatures for confirming stable triaxiality in nuclei
  1. Chiral symmetry breaking (*Frauendorf, 1997*)
  2. **Wobbling motion** (*Bohr & Mottelson, 1975*)

Wobbling Motion (WM)

- Unique to non-axial nuclei
- Predicted 50 years ago for even-A nuclei (i.e., the simple wobbler)
- First experimental evidence for ^{163}Lu (*Ødegård*, 2001)
- Currently confirmed wobblers $A \approx [100, 130, 160, 180]$.

Triaxial Rotor Energy

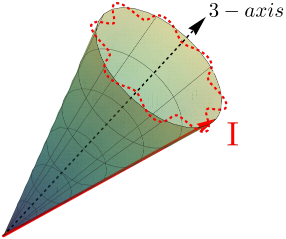
- Rigid body rotational energy: $E_{\text{rot}} \propto \frac{\hbar^2}{2\mathcal{J}_{\text{max}}} I(I+1)$
- A triaxial nucleus can rotate about any of the three axes $\rightarrow$ *rich energy specra spectra*
- MOI anisotropy $\rightarrow$ the *main rotation* around $\mathcal{J}_{\text{max}}$ is disturbed by the other two axes $\rightarrow$ **resulting motion of the rotating nucleus has an oscillating behavior**

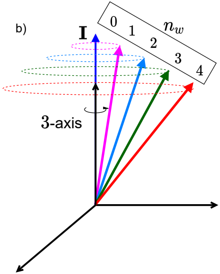


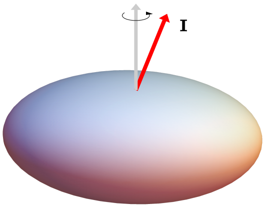
Figures from Schönwaßer et al., 2001

Wobbling Motion

- Oscillatory character of **I** $\rightarrow$ **I** *disaligned* w.r.t. body-fixed axes
- The a.m. **precesses** and **wobbles** around the axis with $\mathcal{J}_{\text{max}}$
- The precession of **I** can increase by **tilting**
- Tilting by an energy quanta $\sim$ *vibrational character* $\rightarrow$ **wobbling phonon** $n_w = 0, 1, 2...$





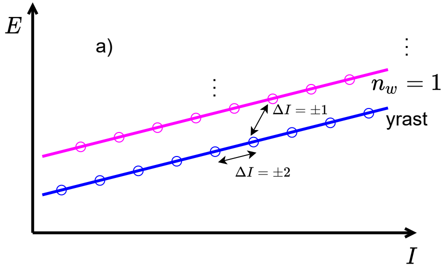


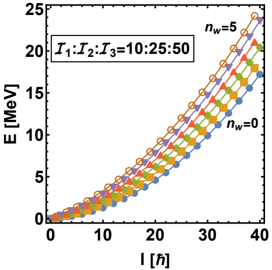
Wobbling Spectrum

Even-A Nuclei

- Employing the Harmonic Approximation *(Bohr, 1969)*
- $\hat{H}$ composed of a *rotational* part and *harmonic oscillation* (i.e., wobbling) part:

$$\hat{H} = \frac{\hbar^2}{2\mathcal{J}_{\text{max}}} I(I+1) + \hbar\omega_{\text{wob}}\left(n_w + \frac{1}{2}\right), n_w = 0, 1, 2, \ldots \quad (1)$$





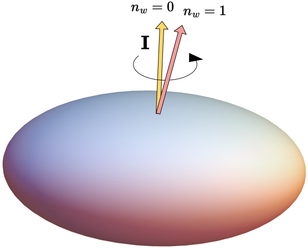
Energy spectrum - simple wobbling

- Employed an energy spectrum of harmonic type according to Eq. 1:

$$E_I = \frac{\hbar^2}{2\mathcal{J}_3} I(I+1) + \hbar\omega_{\text{wob}} \left(n_w + \frac{1}{2} \right)$$

- $\hbar\omega_{\text{wob}}$ - **wobbling frequency** - linear dependence on I (fixed MOI ordering $\mathcal{J}_3 > \mathcal{J}_{1,2}$)

$$\hbar\omega_{\text{wob}}(I) = 2f(\mathcal{J}_1, \mathcal{J}_2, \mathcal{J}_3) \cdot I$$



New Results

- New experimental measurements show *potential* wobbling candidates in the $A \approx 130$ region
- Three even-A are studied with the *simple wobbler* formalism
    1. ^{130}Ba (*Petrache et al. 2019*)
    2. ^{134}Ce (*Petrache and Guo, 2016*)
    3. ^{136}Nd (*Lv et al., 2018*)
- Study the excited spectra: *theoretical model checks the data?*

Model

Harmonic Approximation

- Reproduced the excited spectra for the wobbling bands
- Employ a *free parameter set*: $\mathcal{P} = [\mathcal{J}_1, \mathcal{J}_2, \mathcal{J}_3]$
- Adopt a fitting procedure:

$$\chi^2 = \frac{1}{N_T} \sum_{i=1}^{N_T} \frac{\left(E_{\text{exp}}^{(i)} - E_{\text{th}}^{(i)}\right)^2}{E_{\text{exp}}^{(i)}} \tag{2}$$

- N_T $\rightarrow$ total number of wobbling states within the nucleus

New Results for 130Ba

Recent findings for even-even nuclei

- Two wobbling bands have been identified experimentally in $^{130}\mathbf{Ba}$ (*Petrache et al., 2019*)
- DFT+PRM description of the wobbling motion described the excited spectra (*Chen et al., 2019*)
- Stable triaxiality for $\beta = 0.24$ and $\gamma = 21.5^{\circ}$

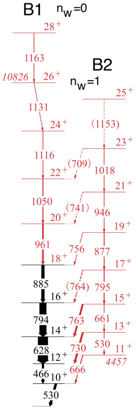


Figure from Petrache et al., 2019