A Systematic Description of the Wobbling Motion in Odd-Mass Nuclei Within a Semi-Classical Formalism

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A presentation for the degree of Doctor of Philosophy

May 11, 2023

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Aim

Research Objectives

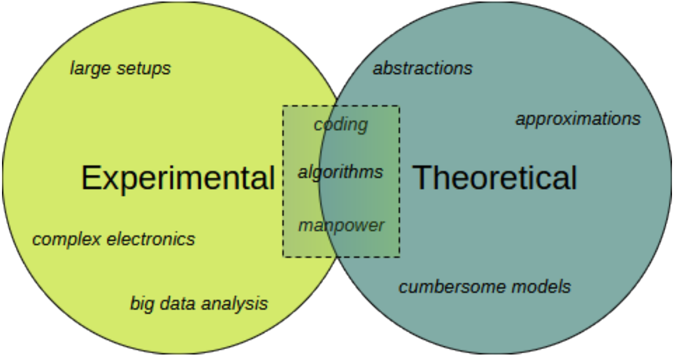
- Extend the current interpretation of the **nuclear triaxiality** in the context of its unique fingerprint: **Wobbling Motion**
- Adopt a framework that is as close as possible to **classical physics**.
- Provide new formalisms for the phenomena related to **nuclear deformation**.

Objectives exclusive to the thesis

- Give the reader enough context towards a better understanding of the underlying concepts, methods, and results.
- create a completely *open-source* project.

Motivation

- **Nuclear Triaxiality** has become a *hot topic* within the scientific community.
- Identifying nuclei with triaxial deformations represents a real **experimental** and **theoretical** challenge.



Fingerprints of Triaxiality

Evidence

- Currently, there are **only two** well-established phenomena uniquely attributed to triaxial deformation.
    1. **Wobbling Motion** WM (*Bohr and Mottelson, 1950s*)
    2. **Chiral Motion** χM (*Frauendorf, 1997*)
- These two can be measured/detected experimentally.

Experimental observations

First experimental evidence for **nuclear wobbling motion** in 2001.

Goal

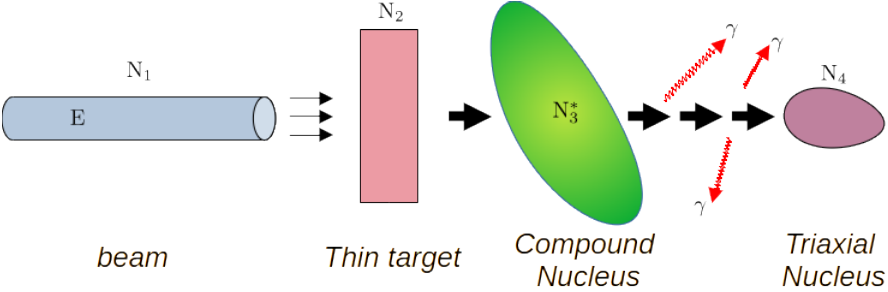
Describe the elusive character of Wobbling Motion in the context of nuclear triaxiality.

Probing triaxiality in nuclei

Triaxial nuclei can be observed/obtained in several experiments:

- Nuclear fission: $A \rightarrow B + C$
- Nuclear fusion: $X + Y \rightarrow Z$
- **Fusion-evaporation reactions**: Long-lived + enhanced deformation

$$Beam(N_1, E) + Target(N_2) \longrightarrow N_3^* \rightarrow \cdots \rightarrow triaxial(N_4)$$



Nuclear facilities

Figure: Gammasphere detector, ANL-ATLAS USA. *Source: aps.org*

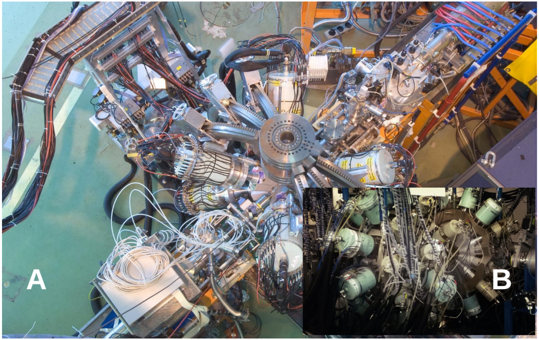


Figure: a) IDS detector, CERN. *Source: isolde.web.cern.ch* b) JUROGAM II, Finland. *Source: twitter.com*

Nuclear Shapes (in the context of WM)

Nuclear Radius

The **shape** of the nucleus is most generally described in terms of the *nuclear radius*:

$$R(\theta,\varphi;t) = R_0\left(1+\sum_{\lambda=0}^{\infty}\sum_{\mu=-\lambda}^{\lambda}\alpha_{\lambda\mu}(t)Y_{\lambda}^{\mu}(\theta,\varphi)\right) \tag{1}$$

Quadrupole deformations

- For us: Most relevant modes are the **quadrupole vibrations** $\lambda = 2$ $\Longrightarrow$ *Play a crucial role in the rotational spectra of nuclei:*

Axial shapes

Collective coordinates

- Most of the nuclei are either **spherical** or **axially symmetric** in their ground-state (Budaca, 2018).
- Coordinates $\alpha_{2\mu}$ can be reduced to only two *deformation parameters*: β_2 (*eccentricity*) and γ (triaxiality).
- Moments of inertia: $\mathcal{I}_{1,2,3}$: two are equal, one is different.

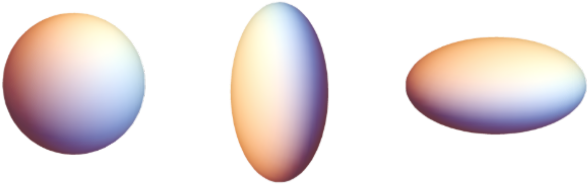
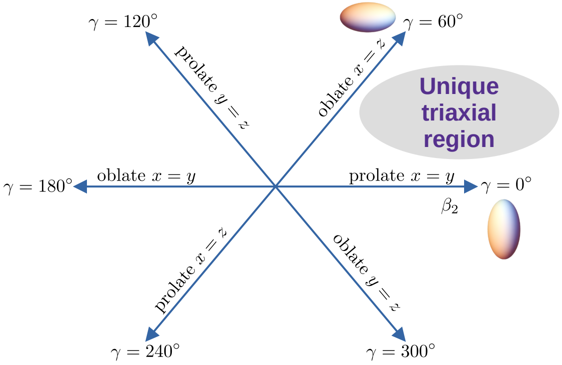
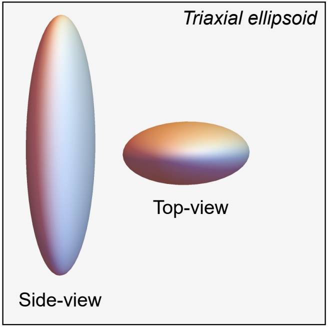


Figure: **spherical:** $\beta_2 = 0$ **prolate:** $\beta_2 > 0$ **oblate:** $\beta_2 < 0$. ($\gamma = 0°$).

Non-axial (triaxial) shapes

- The triaxiality parameter γ (*Bohr, 1969*): departure from axial symmetry.
- Moments of inertia: $\mathcal{I}_1 \neq \mathcal{I}_2 \neq \mathcal{I}_3$.





Wobbling Motion

Characteristics

- $\gamma \neq 0^\circ \rightarrow$ 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**
- The **total angular momentum** (a.m.) **precesses** and **wobbles** around $\mathcal{J}_{\text{max}}$
- Tilting by an energy quanta $\sim$ *vibrational character* $\rightarrow$ **wobbling phonon** $n_w = 0, 1, 2...$

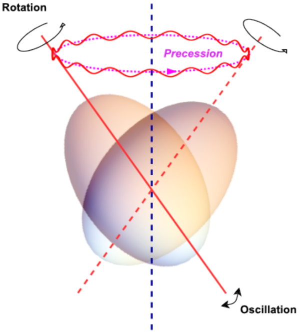


Figure: Geometrical interpretation of a wobbling triaxial nucleus: *rotation* + *precession* + *oscillation*. *R. Poenaru, PhD Thesis (WIP)*

Rotational Energy

Thank you for your attention ❤