Spinning Triaxial Nuclei Wobble: Sometimes Transverse, At Others Longitudinal

U. Garg
University of Notre Dame

Supported in part by the National Science Foundation

SPIN-2016, 09/27/2016
(b) Longitudinal Wobbling

(c) Transverse Wobbling
Wobbling bands (TSD) are generally considered as one of the best signatures of nuclear triaxiality. Another is, of course, chirality.

Triaxiality in nuclei had been a longstanding prediction of theory, but had proved very difficult to establish experimentally.

The best example of wobbling has been seen in the Lu nuclei.
“Wobbler Bands”

- Rotational bands corresponding to $n_\omega = 0, 1, 2, \ldots$

- Transitions from $n_{\omega+1} \rightarrow n_\omega$ [“one way” and $\Delta n_\omega = +1$]

- Interband transitions are $\Delta J = 1, E2$
Wobbling frequency, defined by:

\[ E_{\text{wobb}} = E(I, n_\omega = 1) - \left[ E(I+1, n_\omega = 0) + E(I-1, n_\omega = 0) \right]/2 \]

\[ \hbar \omega_w = \frac{j}{J_3} \left[ \left(1 + \frac{J}{j} \left( \frac{J_3}{J_1} - 1 \right) \right) \left(1 + \frac{J}{j} \left( \frac{J_3}{J_2} - 1 \right) \right) \right]^{1/2} \]

“Longitudinal “ wobbler:
Odd-particle aligned with the axis with maximum moment of inertia (the “medium axis”)

\[ \mathcal{I}_3 > \mathcal{I}_2 ; \mathcal{I}_3 > \mathcal{I}_1 \]
\[ \Rightarrow E_\omega \text{ increases with } J \]

Wobbling frequency, defined by:

\[ E_{\text{wobb}} = E(l, n_\omega=1) - [E(l+1, n_\omega=0) + E(l-1, n_\omega=0)]/2 \]

\[
\hbar \omega_w = \frac{j}{j_3} \left[ \left(1 + \frac{J}{j} \left(\frac{j_3}{j_1} - 1\right)\right) \left(1 + \frac{J}{j} \left(\frac{j_3}{j_2} - 1\right)\right) \right]^{1/2}
\]

“Transverse“ wobbler:
Odd-particle aligned with the “small” axis

\[ j_3 < j_2 ; j_3 > j_1 \]
\[ \Rightarrow E_\omega \text{ decreases with } J \]
reaching 0 at \( J_c = j_j_3/(j_2 - j_3) \)
“Standard” wobbler would have increasing $E_{wobb}$. 
\[ \hbar \omega_{\pi}(I) = \frac{E(I) - [E_0(I+1) + E_0(I-1)]}{2} \text{(MeV)} \]

Graph showing the relationship between spin (\( \hbar \)) and \( \hbar \omega_{\pi}(I) \) for different isotopes of Lu and Ta.
$^{123}\text{Sb} \left(^{16}\text{O}, 4n\right)^{135}\text{Pr} @ 80 \text{ MeV}$
Gammasphere at ATLAS
(100 CSGe detectors)
$\gamma-\gamma-\gamma$ coincidences
angular correlations
\[ \delta = -0.16 \pm 0.04 \]
\[ E2\% = 2.4 \pm 1.2 \]
\[ \delta = -1.24 \pm 0.13 \]
\[ E2\% = 60.6 \pm 5.1 \]
\[ \delta = -2.38 \pm 0.37 \]
\[ \text{E2}\% = 85.0 \pm 4.0 \]
INA @ TIFR
20 CS “clover” detectors
polarization measurements
Measurements of level energies, angular distributions, and polarizations of the associated $\gamma$ rays, have established a “wobbler” sequence in $^{135}\text{Pr}$. 

First observation of wobbling in any nuclei away from $A\sim160$ region.

Comparison with calculations in QTR model establishes the observed structure as corresponding to a “transverse wobbler”

The transmutation of the transverse wobbler into a longitudinal wobbler and then to a magnetic rotation structure is observed in line with theoretical predictions. 

Clear indications of gradual change of the rotational axis from “short” into a planar geometry akin to magnetic rotation.

$n_w = 1$
$^{133}\text{La } n_\omega = 1 \text{ band}$

Courtesy of R. Palit, TIFR, Mumbai
FIG. 7. Comparision of experimental levels with TPSM calculations.

Calculations from J. Sheikh et al. Courtesy of R. Palit, TIFR, Mumbai
धन्यवाद

Thanks!
How to speak to a Different Physics Community

- Use no jargon
- Don’t overwhelm with detail
- Use animal pictures, to keep audience attention.
The Question Kitten
FIG. 5. Experimental and calculated electromagnetic properties of the connecting transitions.
FIG. 3. (Color online) Excitation energy minus a rigid-rotor reference for denoted bands in (a) $^{167}$Ta and its isotope (b) $^{165}$Lu [5]. The inertia parameter $A$ was set to 0.007 MeV/$\hbar^2$. The $\pi h_{11/2}$ bands are shown for both nuclei as they are the energetically lowest structures.