Wobbling excitations and tilted rotation in $^{163}$Lu

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Wobbling motion:

- Orientation fluctuations of the angular momentum vector.
- Should appear in triaxial nuclei on top of rotational bands. $\Delta I = 1$
- Identified in TSD band in $^{163}$Lu.

We use:

- Self-consistent cranked HFB
- Pairing+QQ Hamiltonian
- RPA

Results:

- Right energy of the lowest solution.
- Pairing influence phonon energy.
- Transition to a tilted solution.
- Our *wobbling* solution is of isovector type. (High spin scissors mode)

Cranking Hamiltonian

**Quadrupole+pairing Hamiltonian:**

\[
\hat{H} = \hat{h}_{\text{Nilsson}} - \frac{\kappa}{2} \vec{Q} \cdot \vec{Q} - \sum\limits_{\tau} \hat{P}_\tau^{\dagger} \hat{P}_\tau
\]

Mean field Hamiltonian in the rotating frame:

\[
\hat{h}'(\omega, \epsilon_2, \gamma, \theta) = \hat{h}_0 - \frac{2}{3} h\bar{\omega}_0 \epsilon_2 \left\{ \hat{Q}_0 \cos \theta - \left( \hat{Q}_2 + \hat{Q}_{-2} \right) \sin \theta \right\} - \vec{\omega} \cdot \vec{J} - \sum\limits_{\tau} \Delta_{\tau} \left( \hat{P}_\tau^{\dagger} + \hat{P}_\tau \right) - \lambda_{\tau} \hat{N}_\tau
\]

Self-consistency conditions (energy minimum):

\[
\kappa \langle \hat{Q}_0 \rangle = \frac{2}{3} \epsilon \cos \gamma \quad \kappa \langle \hat{Q}_2 + \hat{Q}_{-2} \rangle = \frac{2}{3} \epsilon \sin \gamma \quad \vec{\omega} \parallel \vec{J} \quad \Delta_{\tau} = G_{\tau} \langle \hat{P}_\tau \rangle
\]
Deformation in $^{163}$Lu

![Graph showing deformation in $^{163}$Lu with and without pairing. The graph plots $\varepsilon_2$ and $\gamma$ against $\hbar\omega$ (in MeV). The graph includes two curves: one for 'Without pairing' and another for 'With pairing'.]
RPA energy in $^{163}$Lu

$$[\hat{H}_{\text{RPA}}, \hat{O}_\lambda] = \Omega_\lambda \hat{O}_\lambda$$

![Graph showing RPA energy comparison between experiment and RPA wobbling.](image)

**Legend:**
- RPA Wobbling $\Delta=0$
- Experiment
- RPA Wobbling
Wobbling angle in $^{163}$Lu

$$\Delta J_i^2 = \langle \lambda | \hat{J}_i^2 | \lambda \rangle - \langle 0 | \hat{J}_i^2 | 0 \rangle = 2 \left[ \hat{J}_i, \hat{W} \dagger \right] \left[ \hat{W}, \hat{J}_i \right] = 2 \left[ \hat{W}, \hat{J}_i \right]^2$$

Diagram showing the wobbling angle with Neutron, Proton, i13/2 proton, and Total contributions.
Isovector wobbling angle in $^{163}$Lu

$$\Delta J_i^2 = 2 \left\{ \left| [\hat{J}_i, \hat{W}^\dagger]_{\text{proton}} \right| + \left| [\hat{J}_i, \hat{W}^\dagger]_{\text{neutron}} \right| \right\}^2$$

$$\theta_{RPA} = 90 - \arctan \left( \frac{\sqrt{\Delta J_y^2 + \Delta J_z^2}}{J_x} \right)$$

$$\phi_{RPA} = \arctan \left( \sqrt{\frac{\Delta J_y^2}{\Delta J_z^2}} \right)$$
Transition probabilities in $^{163}$Lu

<table>
<thead>
<tr>
<th>$\hbar\omega$ [MeV]</th>
<th>B(E2) out/B(E2) in</th>
<th>B(M1) out/B(E2) in</th>
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<td>0.5</td>
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Experiment
With pairing
Without pairing
Summary

- Low lying vibrations on top of TSD-bans in $^{163}$Lu.
- Transition to tilted solution at high spin.
- Pairing influence phonon energy indirectly by reducing the $\gamma$-deformation.
- Our *wobbling* solution is isovector type (high spin scissors mode.)
- Experimental B(E2) well described but B(M1) to large

Outlook...

- Other nuclei? (even-even)
- Spin-spin force, isovector force, ...
Pairfield in $^{163}$Lu

D. Almehed
Moment of inertia in $^{163}$Lu

$J_{\text{Inglis-Belayev}} \left[ \frac{(h/2\pi)^2}{\text{MeV}} \right]$
Wobbling angle in $^{163}$Lu

![Graph showing wobbling angle in $^{163}$Lu](image)

- Neutron
- Proton
- i13/2 proton
- Total

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