Octupole deformation in light actinides

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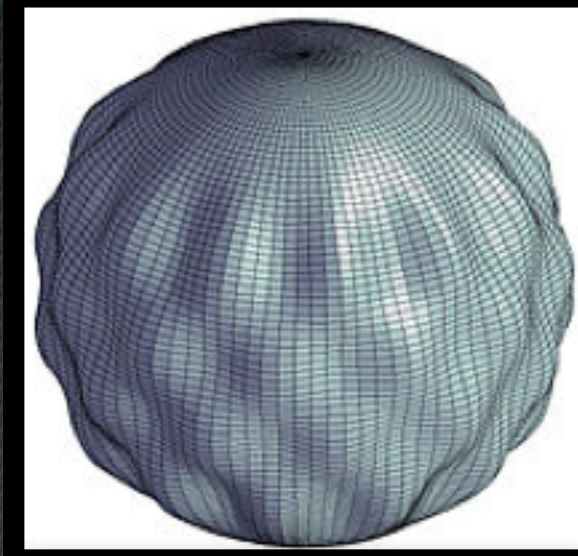
Collective model



The nuclear surface oscillates.

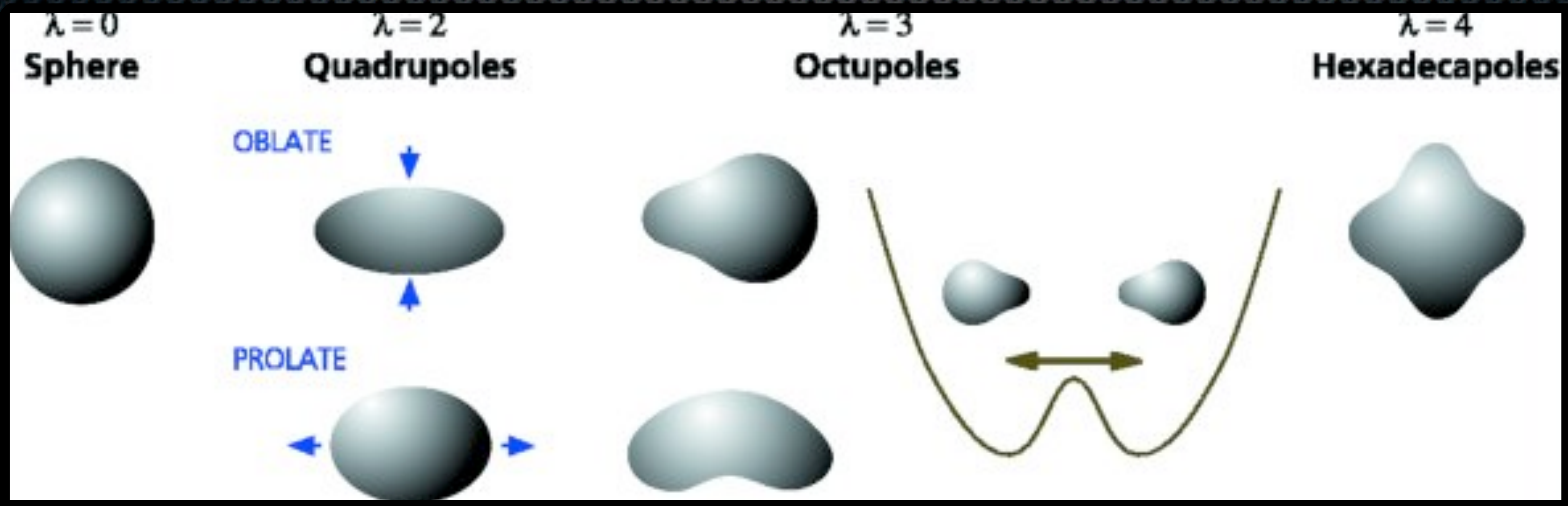
- The multipole expansion of the nuclear radius is:

$$R = R_0(1 + \sum_{\lambda,\mu} \alpha^*_{\lambda,\mu} Y_{\lambda,\mu}(\theta, \phi))$$

- λ=2 → **Quadrupole deformation**
- λ=3 → **Octupole deformation**

Deformation types

- **Equal potential multipole shapes:**



AQOA symmetric model

- **Both quadrupole and octupole deformations are taken into account, with the deformation axes to coincide.**
- **The Hamiltonian of the AQOA is:**

$$\hat{H} = \sum_{\lambda=2,3} \hat{T}_{\lambda} + \hat{V}_{eff,\lambda}(\beta_2, \beta_3)$$

β_2, β_3 — **quadrupole and octupole deformation variables**

B_2, B_3 — **Mass parameters**

D. Bonatsos, D. Lenis, N. Minkov, D. Petrellis, and P. Yotov, Phys. Rev. C 71, 064309 (2005)

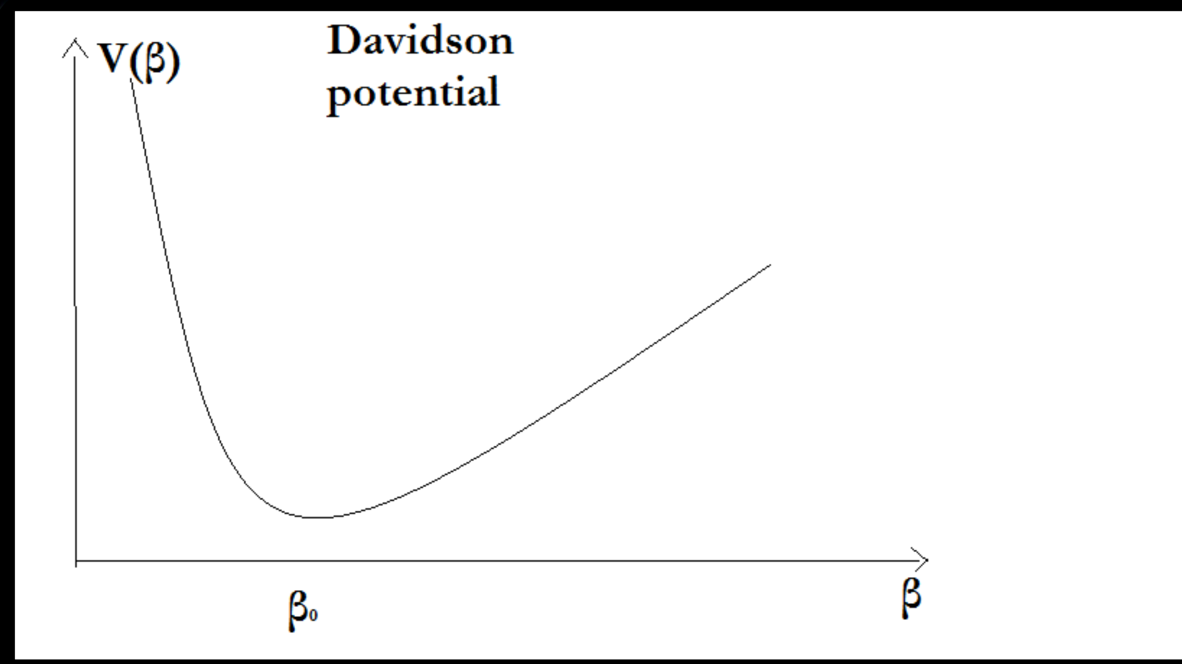
Polar Transformation

$$\beta_2 = \sqrt{\frac{B_2 + B_3}{2B_2}}\beta cos\phi, \beta_3 = \sqrt{\frac{B_2 + B_3}{2B_3}}\beta cos\phi, \beta \in [0, +\infty), \phi \in [-\frac{\pi}{2}, \frac{\pi}{2}]$$

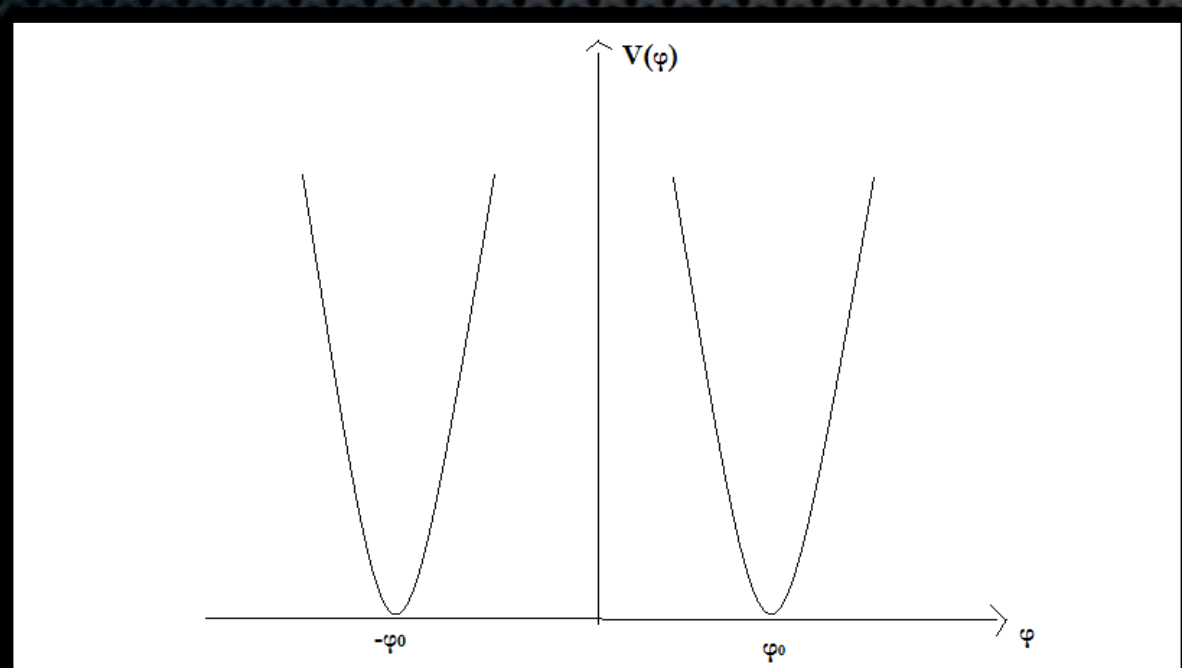
- **φ=0** → **pure quadrupole deformation**
- **φ=±π/2** → **pure octupole deformation**

Potentials

$V(\beta,\varphi)=V(\beta)+V(\varphi)$



exactly solvable Davidson potential



two harmonic oscillators centered at $\pm\varphi_0$

D. Bonatsos, A. Martinou, N. Minkov, S. Karampagia and D. Petrellis, to be published.

Quadrupole + Octupole = ?

+

When the two oscillations occur with the same frequency and phase, a <u>permanent octupole deformation</u> appears, that it seems to rotate.

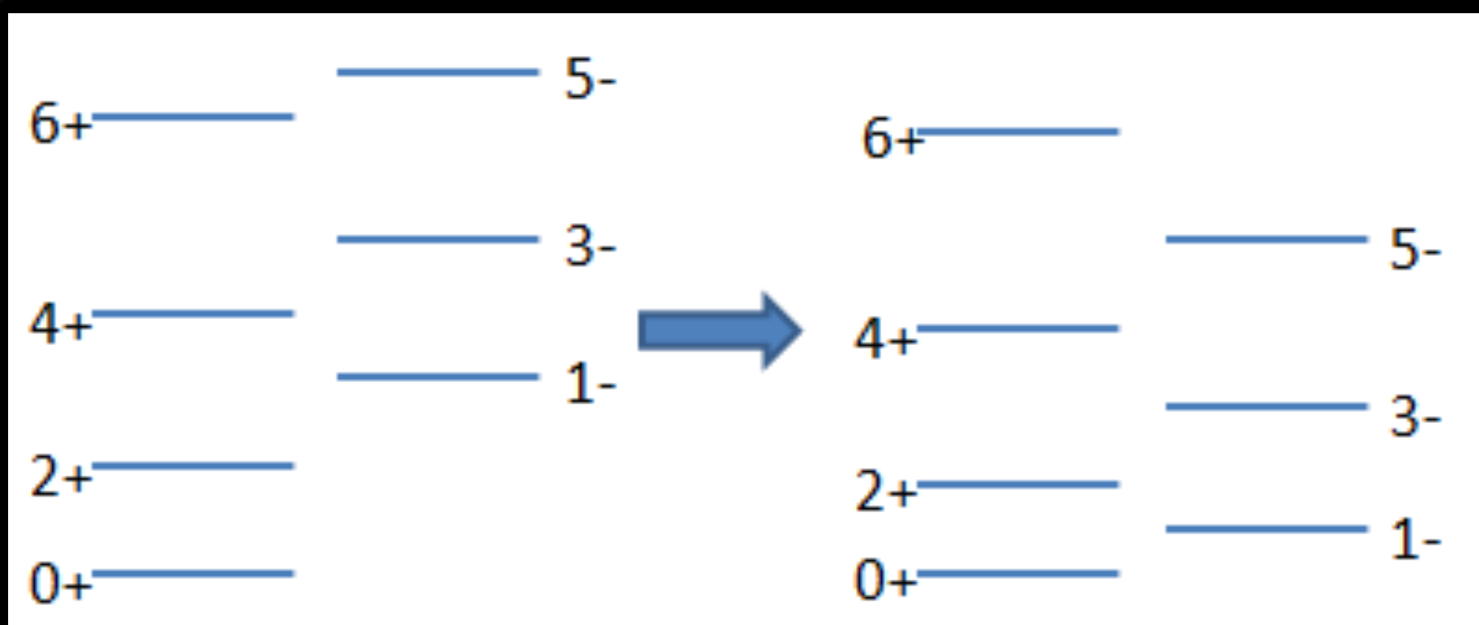
Octupole rotation

When the two oscillations occur with different frequency and phase, the shape is not constant.

Octupole vibration

Energy levels

Octupole vibration | **Octupole rotation**



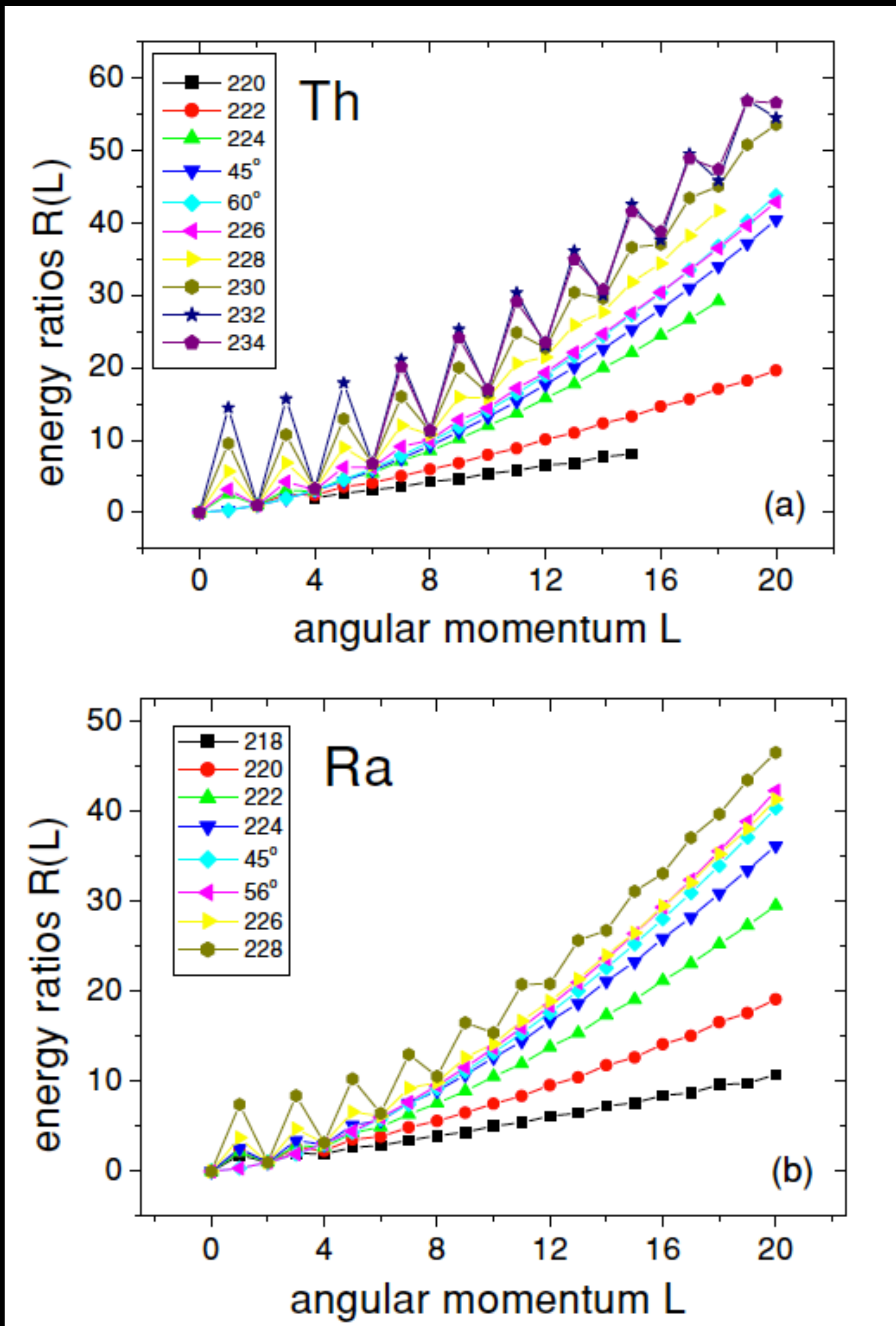
The displacement of the odd L levels is called **staggering** effect.

$\Delta E(L)>0$

$\Delta E(L)=0$

$$\Delta E(L) = E(L) - \frac{E(L-1) + E(L+1)}{2}$$

Critical point in Th and Ra



^{226}Th

^{226}Ra

Critical nucleus between octupole vibration and octupole rotation

Experimental realization

^{224}Ra

Inter-band transitions are supposed to be very small, but instead they proved to be high!

m.e.	exp.	th.
$\langle 0^+ \| E2 \| 2^+ \rangle$	199±3	196
$\langle 2^+ \| E2 \| 4^+ \rangle$	315±6	323
$\langle 4^+ \| E2 \| 6^+ \rangle$	405±15	426
$\langle 6^+ \| E2 \| 8^+ \rangle$	500±60	525
$\langle 1^- \| E2 \| 3^- \rangle$	230±11	236
$\langle 3^- \| E2 \| 5^- \rangle$	410±60	334
$\langle 0^+ \| E2 \| 2^+_\gamma \rangle$	23±4	36
$\langle 0^+ \| E3 \| 3^- \rangle$	940±30	1006
$\langle 2^+ \| E3 \| 1^- \rangle$	1370±140	1137
$\langle 2^+ \| E3 \| 3^- \rangle$	<4000	1176
$\langle 2^+ \| E3 \| 5^- \rangle$	1410±190	1594
$\langle 0^+ \| E1 \| 1^- \rangle$	<0.018	0.013
$\langle 2^+ \| E1 \| 1^- \rangle$	<0.03	0.018
$\langle 2^+ \| E1 \| 3^- \rangle$	0.026±0.005	0.023
$\langle 4^+ \| E1 \| 5^- \rangle$	0.030±0.010	0.032
$\langle 6^+ \| E1 \| 7^- \rangle$	<0.10	0.042

L.P. Gaffney, et al., Nature (London) (497), 199 (2013)

Conclusions

The AQOA symmetric model provides:

- a) critical point predictions,
- b) energy levels,
- c) B(E1), B(E2) and B(E3) calculations.

Εὐχαριστῶ!