# Proxy-SU(3) symmetry in heavy nuclei

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# The people behind the work

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# Shell model algebras with SU(3) subalgebras

| shell | algebra | |
|---|---|---|
| sd | U(6) | J.P. Elliott (1958) |
| pf | U(10) | |
| sdg | U(15) | |
| pfh | U(21) | |
| sdgi | U(28) | |
| pfhj | U(36) | |

# U(N) ⊃ SU(3)

J.P. Draayer, Y. Leschber, S.C. Park, R. Lopez,
Comput. Phys. Commun. 56 (1989) 279

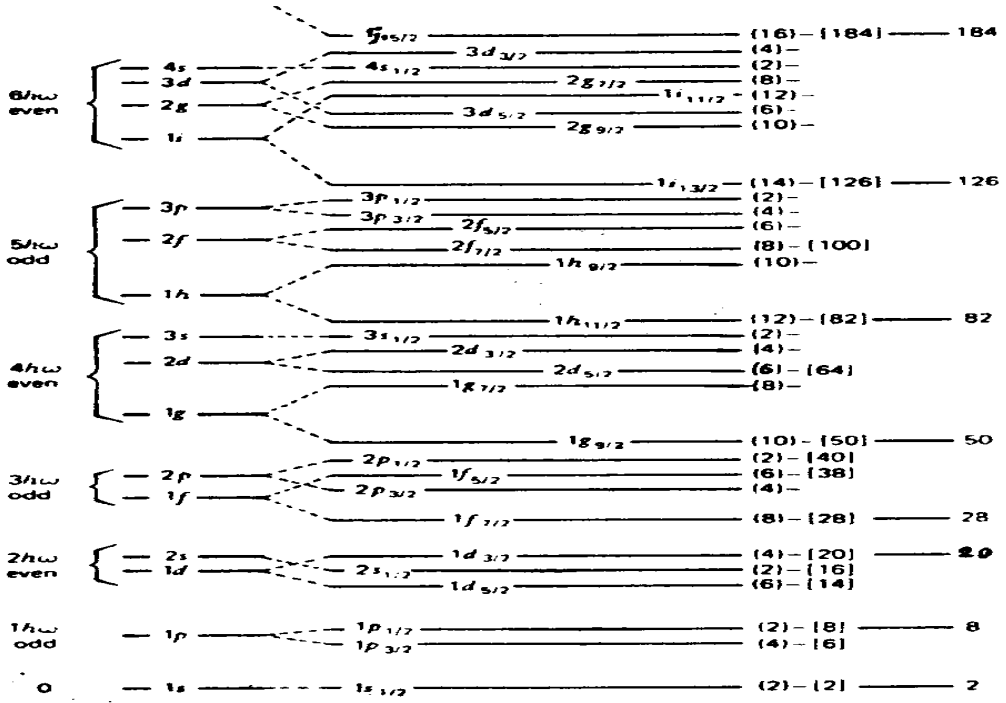
| | sd | pf | sdg | pfh | sdgi | pfhj |
|---|---|---|---|---|---|---|
| | U(6) | U(10) | U(15) | U(21) | U(28) | U(36) |
| N | | | | | | |
| 2 | (4,0) | (6,0) | (8,0) | (10,0) | (12,0) | (14,0) |
| 4 | (4,2) | (8,2) | (12,2) | (16,2) | (20,2) | (24,2) |
| 6 | (6,0) | (12,0) | (18,0) | (24,0) | (30,0) | (36,0) |
| 8 | (2,4) | (10,4) | (18,4) | (26,4) | (34,4) | (42,4) |
| 10 | (0,4) | (10,4) | (20,4) | (30,4) | (40,4) | (50,4) |
| 12 | (0,0) | (12,0) | (24,0) | (36,0) | (48,0) | (60,0) |

# spin-orbit interaction

- Lowers the orbit with highest j
- Mixes the harmonic oscillator shells
- Destroys SU(3) symmetry of h.o. shells

Approximations needed

# shell model


6ħω even
5ħω odd
4ħω even
3ħω odd
2ħω even
1ħω odd
0
4s
3d
2g
1i
3p
2f
1h
3s
2d
1g
2p
1f
2s
1d
1p
1s
1j15/2
3d3/2
4s1/2
2g7/2
1i11/2
3d5/2
2g9/2
1i13/2
3p1/2
3p3/2
2f5/2
2f7/2
1h9/2
1h11/2
3s1/2
2d3/2
2d5/2
1g7/2
1g9/2
2p1/2
1f5/2
2p3/2
1f7/2
1d3/2
2s1/2
1d5/2
1p1/2
1p3/2
1s1/2
(16) – [184] 184
(4) –
(2) –
(8) –
(12) –
(6) –
(10) –
(14) – [126] 126
(2) –
(4) –
(6) –
(8) – [100]
(10) –
(12) – [82] 82
(2) –
(4) –
(6) – [64]
(8) –
(10) – [50] 50
(2) – [40]
(6) – [38]
(4) –
(8) – [28] 28
(4) – [20] 20
(2) – [16]
(6) – [14]
(2) – [8] 8
(4) – [6]
(2) – [2] 2

# Pseudo-SU(3)

- Map the levels of normal parity
- Leave levels of intruder parity unchanged

# Proxy-SU(3)

- Map the levels of intruder parity
- Leave levels of normal parity unchanged

# Nilsson model



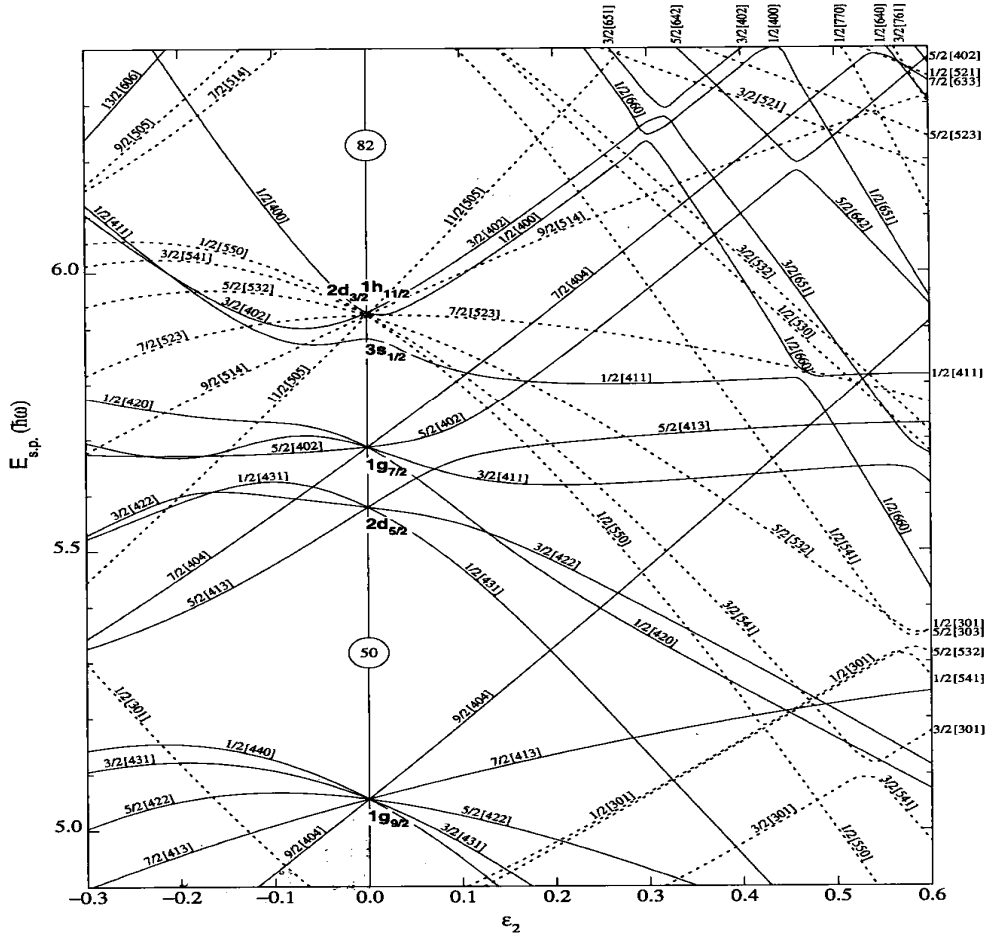



**Figure 5. Nilsson diagram for neutrons, $50 \le N \le 82$ ($\varepsilon_4 = \varepsilon_2^2/6$).**

# Nilsson model

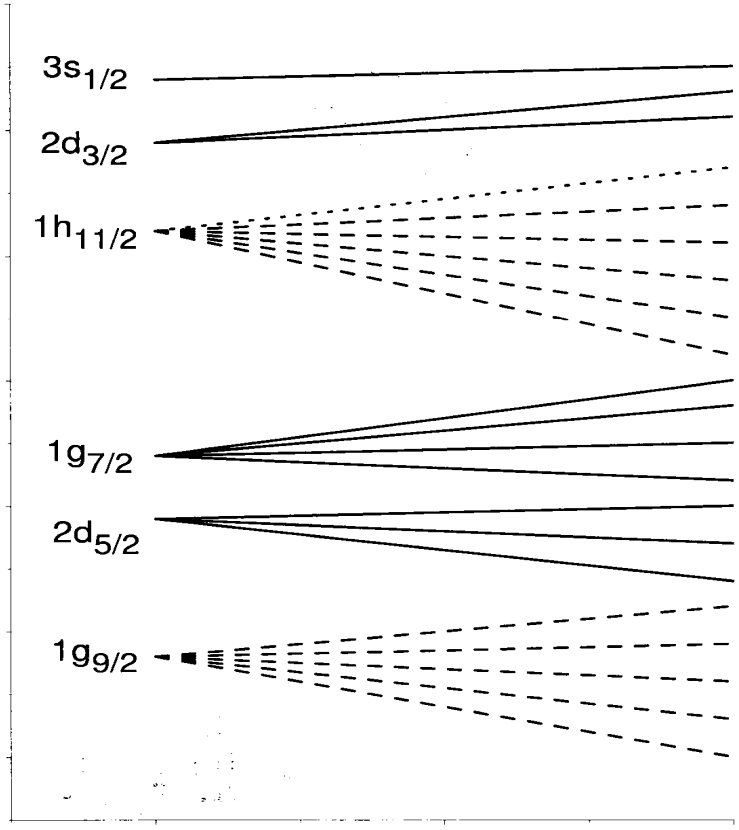
Notation of levels K[N Nz Λ]

K z-projection of total angular momentum
N oscillator quanta
Nz oscillator quanta in z-direction
Λ z-projection of orbital ang. momentum

K=Λ+Σ Σ=projection of spin

S.G. Nilsson and I. Ragnarsson, Shapes and Shells in Nuclear Structure (Cambridge UP, 1995)

# 50-82 shell



# Proxy-SU(3)

Uses 0[110] pairs

First used for proton-neutron interaction

R.B. Cakirli, K. Blaum, and R.F. Casten,
Phys. Rev. C 82 (2010) 061304(R)

Same angular momentum content

Large overlaps

D. B., S. Karampagia, R.B. Cakirli, R.F. Casten, K. Blaum, L. Amon Susam, Phys. Rev. C 88 (2013) 054309

# approximation schemes

| Shell model | pseudo-SU(3) | proxy-SU(3) |
|---|---|---|
| 28-50 | sd U(6) | pf U(10) |
| 50-82 | pf U(10) | sdg U(15) |
| 82-126 | sdg U(15) | pfh U(21) |
| 126-184 | pfh U(21) | sdgi U(28) |
| 184-258 | sdgi U(28) +intruders | pfhj U(36) |

# Example: 168Er in proxy-SU(3)

18 protons in U(15) -> (18,6)

18 neutrons in U(21) -> (36,6)

total (54,12)

next irrep: (50,14)

(54,12) contains:

gsb, γ1, first K=4, first K=6,…

(50,14) contains:

β1, γ2, $2^{nd}$ K=4, $2^{nd}$ K=6, …

# Why does proxy-SU(3) work?

Ioannis E. Assimakis

Compare

- usual Nilsson calculation
- proxy-SU(3) calculation

Few and small extra matrix elements

# What does proxy-SU(3) predict for deformations and spectra?

Andriana Martinou

Parameter-free predictions for β and γ

Need 3-body and/or 4-body SO(3) scalars in the integrity basis of SU(3)

Get parameter-free predictions of ratios of energy levels and B(E2)s

# What does proxy-SU(3) predict for the prolate-oblate transition ?

Smaragda Sarantopoulou

Location of prolate-oblate shape/phase transition

Particle-hole symmetry breaking

# Outlook

- Superheavy elements (SHE)
- Odd-odd, odd nuclei
- A<100
- Scissors mode
- p-n pairs

V.K.B. Kota

# Outlook

- Two shells

  sd+pf = spdf U(16)

  pf+sdg = spdfg U(25)

  sdg+pfh=spdfgh U(36)

  pfh+sdgi=spdfghi U(49)

- Proxy-O(6)

  sd shell U(6) $\supset$ O(6) J.P. Elliott

  pf shell U(10) $\supset$ O(6)

  D. Kusnezov, J. Phys. A 22 (1989) 4271, 5673

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