Seven years of the proxy-SU(3) shell model symmetry

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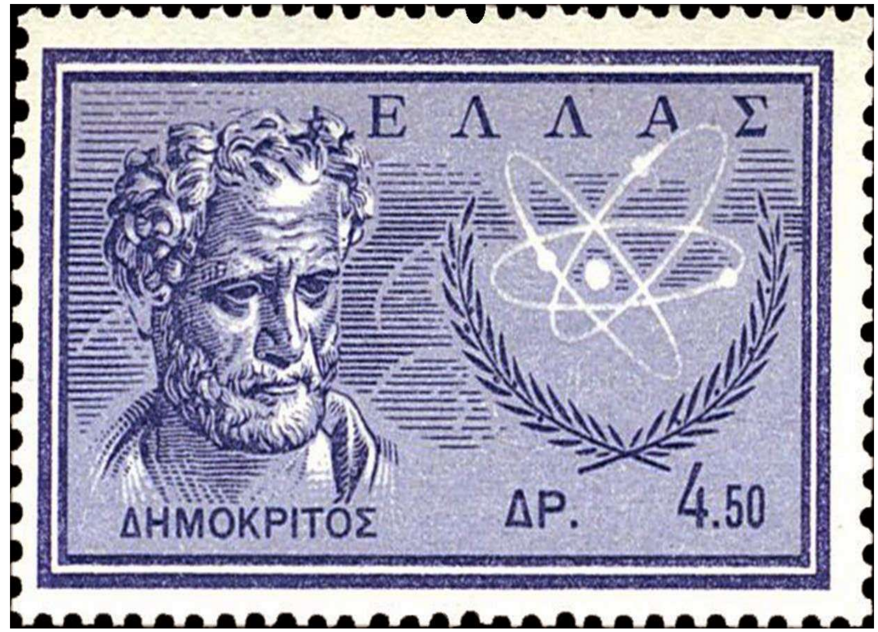

The people behind the work

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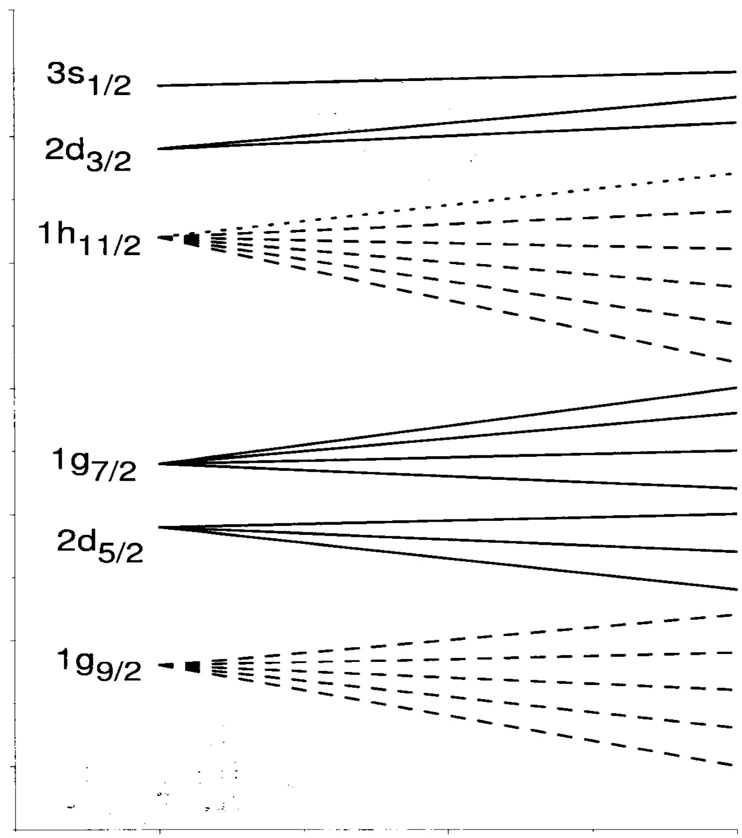
Review: Symmetry 15 (2023) 29 (feature article)

Proxy-SU(3) scheme

- Restoration of SU(3) symmetry of 3D-HO
- Approximation to the Nilsson model
- Connection to spherical shell model
- Highest weight irreps
- Prolate over oblate dominance
- Prolate to oblate shape transition
- Islands of shape coexistence
- Preponderance of triaxial shapes

Restoration of 3D-HO SU(3) symmetry
proxy-SU(3)   1h11/2->1g9/2

PRC95 (2017) 064325



Justification: Matrix of the Nilsson Hamiltonian for the 50-82 proton shell

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	$\frac{1}{2}$[400]	$\frac{1}{2}$[411]	$\frac{3}{2}$[402]	$\frac{1}{2}$[420]	$\frac{3}{2}$[411]	$\frac{5}{2}$[402]	$\frac{1}{2}$[431]	$\frac{3}{2}$[422]	$\frac{5}{2}$[413]	$\frac{7}{2}$[404]	$\frac{1}{2}$[550]	$\frac{3}{2}$[541]	$\frac{5}{2}$[532]	$\frac{7}{2}$[523]	$\frac{9}{2}$[514]	$\frac{11}{2}$[505]
1/2[400]	6.28	−0.13	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0
1/2[411]		5.74	0	0.18	0	0	0.27	0	0	0	0	0	0	0	0	0
3/2[402]			6.26	0	0.16	0	0	0.19	0	0	0	0	0	0	0	0
1/2[420]				5.30	0	0	−0.16	0	0	0	0	0	0	0	0	0
3/2[411]					5.61	0	0	−0.13	0	0	0	0	0	0	0	0
5/2[402]						6.00	0	0	−0.09	0	0	0	0	0	0	0
1/2[431]							5.06	0	0	0	0	0	0	0	0	0
3/2[422]								5.27	0	0	0	0	0	0	0	0
5/2[413]									5.56	0	0	0	0	0	0	0
7/2[404]										5.93	0	0	0	0	0	0
1/2[550]											5.88	0	0	0	0	0
3/2[541]												5.81	0	0	0	0
5/2[532]													5.82	0	0	0
7/2[523]														5.90	0	0
9/2[514]															6.06	0
11/2[505]																6.30

Matrix of the proxy-SU(3) Hamiltonian for the sdg proton shell

PRC95 (2017) 064325

	$\frac{1}{2}[400]$	$\frac{1}{2}[411]$	$\frac{3}{2}[402]$	$\frac{1}{2}[420]$	$\frac{3}{2}[411]$	$\frac{5}{2}[402]$	$\frac{1}{2}[431]$	$\frac{3}{2}[422]$	$\frac{5}{2}[413]$	$\frac{7}{2}[404]$	$\frac{1}{2}[440]$	$\frac{3}{2}[431]$	$\frac{5}{2}[422]$	$\frac{7}{2}[413]$	$\frac{9}{2}[404]$
1/2[400]	6.28	−0.13	0	0.22	0	0	0	0	0	0	0	0	0	0	0
1/2[411]		5.74	0	0.18	0	0	0.27	0	0	0	0	0	0	0	0
3/2[402]			6.26	0	0.16	0	0	0.19	0	0	0	0	0	0	0
1/2[420]				5.30	0	0	−0.16	0	0	0	**0.27**	0	0	0	0
3/2[411]					5.61	0	0	−0.13	0	0	0	**0.27**	0	0	0
5/2[402]						6.00	0	0	−0.09	0	0	0	**0.19**	0	0
1/2[431]							5.06	0	0	0	**0.18**	0	0	0	0
3/2[422]								5.27	0	0	0	**0.22**	0	0	0
5/2[413]									5.56	0	0	0	**0.22**	0	0
7/2[404]										5.93	0	0	0	**0.18**	0
1/2[440]											**5.73**	0	0	0	0
3/2[431]												**5.74**	0	0	0
5/2[422]													**5.82**	0	0
7/2[413]														**5.98**	0
9/2[404]															**6.22**

Connection of proxy-SU(3) to the spherical shell model

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Elliott to shell model basis

[Nz Nx Ny Ms] = R [n L M Ms]

R: unitary transformation

Davies and Krieger, Can. J. Phys. 69 (1991) 62

[n L M Ms] = C | n L J Mj>

C: Clebsch Gordan coefficients

[Nz Nx Ny Ms] =   R C | n L J Mj>

Elliott   shell model

unitary transformation
|0 1 1 0> pairs |Δn ΛL ΔJ ΔMj>

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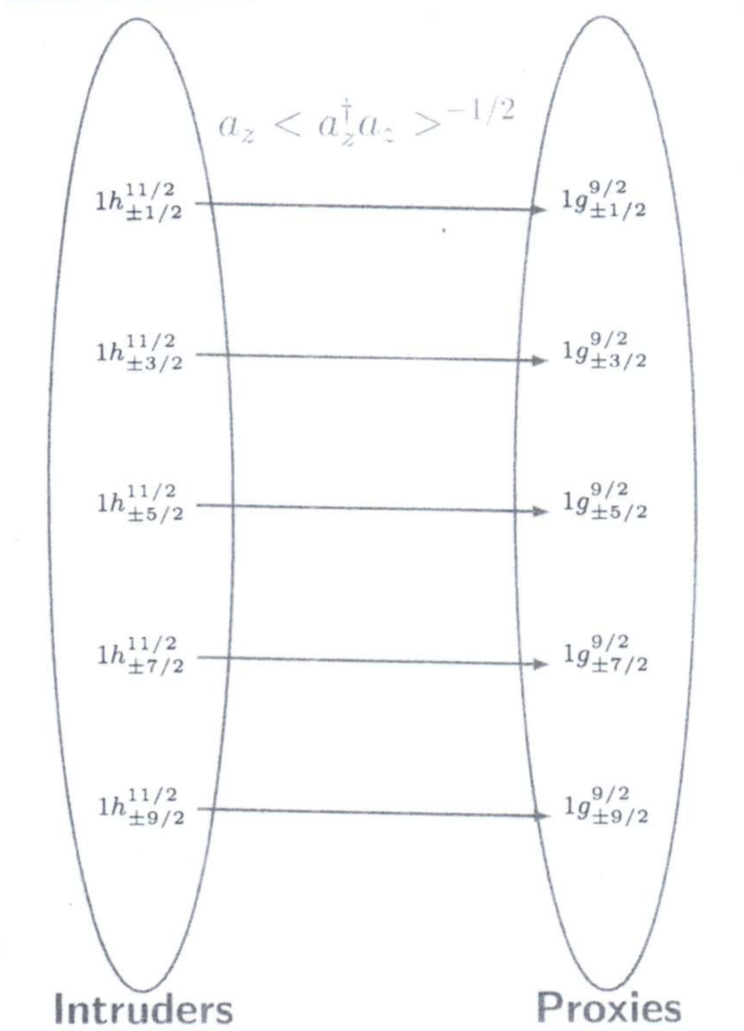

Dominance of highest weight (most symmetric) irreps

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- Pauli principle
- Total wave function = antisymmetric
- Total wave function= space x spin x isospin
- Experimentally known (S=0, T=1) or (S=1, T=0)
- Spin x isospin = antisymmetric
- Spatial part = symmetric
- Short range of the nucleon-nucleon interaction

prolate over oblate dominance

PRC 95 (2017) 064326

TABLE II. Most leading SU(3) irreps [34,35] for nuclei with protons in the 50-82 shell and neutrons in the 82-126 shell. Boldface numbers indicate nuclei with $R_{4/2} = E(4_1^+)/E(2_1^+) \geqslant 2.8$, while * denotes nuclei with $2.8 > R_{4/2} \geqslant 2.5$, and ** labels a few nuclei with $R_{4/2}$ ratios slightly below 2.5, shown for comparison, while no irreps are shown for any other nuclei with $R_{4/2} < 2.5$. For the rest of the nuclei shown (using normal fonts and without any special signs attached) the $R_{4/2}$ ratios are still unknown [46]. Irreps corresponding to oblate shapes are underlined.

N	N_{val}	Z	Ba	Ce	Nd	Sm	Gd	Dy	Er	Yb	Hf	W	Os	Pt
		Z_{val}	56	58	60	62	64	66	68	70	72	74	76	78
		irrep	6	8	10	12	14	16	18	20	22	24	26	28
			(18,0)	(18,4)	(20,4)	(24,0)	(20,6)	(18,8)	(18,6)	(20,0)	(12,8)	(6,12)	(2,12)	(0,8)
88	6	(24,0)	(42,0)*	(42,4)*	(44,4)*									
90	8	(26,4)	**(44,4)**	**(44,8)**	**(46,8)**	**(50,4)**	**(46,10)**	**(44,12)**	(44,10)*	(46,4)*	(38,12)*			
92	10	(30,4)	**(48,4)**	**(48,8)**	**(50,8)**	**(54,4)**	**(50,10)**	**(48,12)**	**(48,10)**	**(50,4)**	(42,12)*			
94	12	(36,0)	(54,0)	**(54,4)**	**(56,4)**	**(60,0)**	**(56,6)**	**(54,8)**	**(54,6)**	**(56,0)**	**(48,8)**	**(42,12)**	(38,12)*	
96	14	(34,6)	(52,6)	(52,10)	**(54,10)**	**(58,6)**	**(54,12)**	**(52,14)**	**(52,12)**	**(54,6)**	**(46,14)**	**(40,18)**	(36,18)*	
98	16	(34,8)	(52,8)	(52,12)	(54,12)	**(58,8)**	**(54,14)**	**(52,16)**	**(52,14)**	**(54,8)**	**(46,16)**	**(40,20)**	(36,20)*	
100	18	(36,6)	(54,6)	(54,10)	(56,10)	(60,6)	**(56,12)**	**(54,14)**	**(54,12)**	**(56,6)**	**(48,14)**	**(42,18)**	**(38,18)**	(36,14)*
102	20	(40,0)	(58,0)	(58,4)	(60,4)	(64,0)	**(60,6)**	**(58,8)**	**(58,6)**	**(60,0)**	**(52,8)**	**(46,12)**	**(42,12)**	(40,8)*
104	22	(34,8)	(52,8)	(52,12)	(54,12)	(58,8)	(54,14)	**(52,16)**	**(52,14)**	**(54,8)**	**(46,16)**	**(40,20)**	**(36,20)**	(34,16)*
106	24	(30,12)	(48,12)	(48,16)	(50,16)	(54,12)	(50,18)	(48,20)	**(48,18)**	**(50,12)**	**(42,20)**	**(36,24)**	**(32,24)**	(30,20)*
108	26	(28,12)	(46,12)	(46,16)	(48,16)	(52,12)	(48,18)	(46,20)	(46,18)	**(48,12)**	**(40,20)**	**(34,24)**	**(30,24)**	(28,20)*
110	28	(28,8)	(46,8)	(46,12)	(48,12)	(52,8)	(48,14)	(46,16)	(46,14)	(48,8)	**(40,16)**	**(34,20)**	**(30,20)**	(28,16)*
112	30	(30,0)	(48,0)	(48,4)	(50,4)	(54,0)	(50,6)	(48,8)	(48,6)	(50,0)	**(42,8)**	**(36,12)**	**(32,12)**	(30,8)**
114	32	(20,10)	(38,10)	(38,14)	(40,14)	(44,10)	(40,16)	(38,18)	(38,16)	(40,10)	(32,18)	**(26,22)**	**(22,22)**	(20,18)**
116	34	(12,16)	(30,6)	(30,10)	(32,10)	(36,6)	(32,12)	(30,14)	(30,12)	(32,6)	(24,14)	(18,28)*	**(14,28)**	(12,24)**
118	36	(6,18)	(24,18)	(24,22)	(26,22)	(30,18)	(26,24)	(24,16)	(24,24)	(26,18)	(18,26)	(12,30)	(8,30)*	(6,26)**
120	38	(2,16)	(20,16)	(20,20)	(22,20)	(26,16)	(22,22)	(20,24)	(20,22)	(22,16)	(14,24)	(8,28)	(4,28)*	(2,24)**

Prolate to oblate transition

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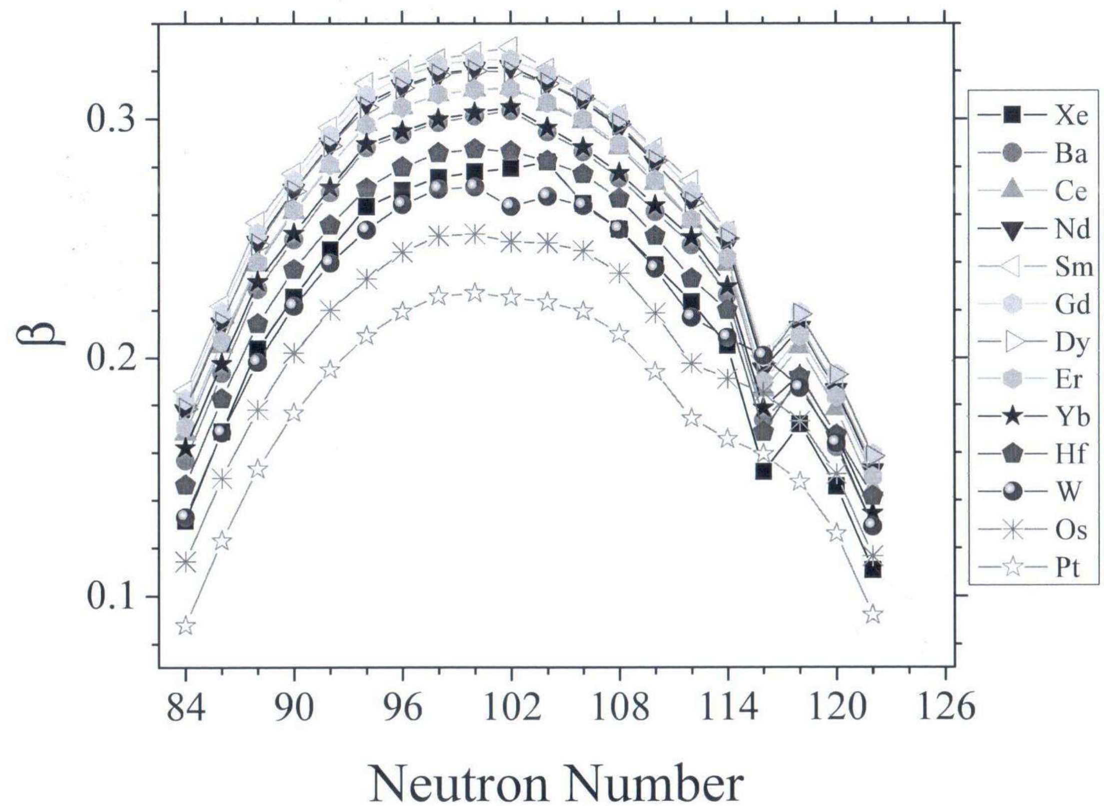

proxy-SU(3) symmetry dual shell mechanism for shape coexistence

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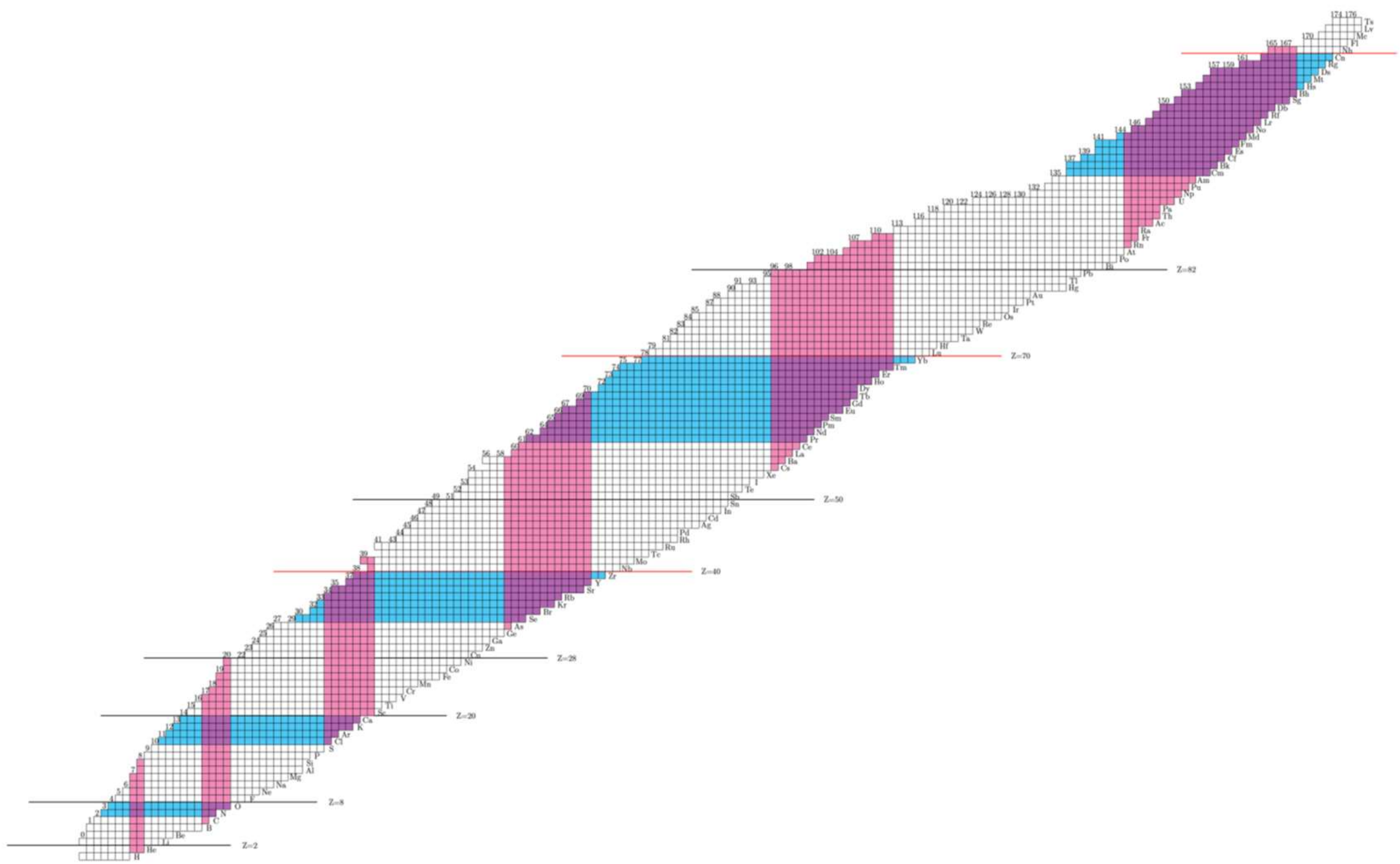
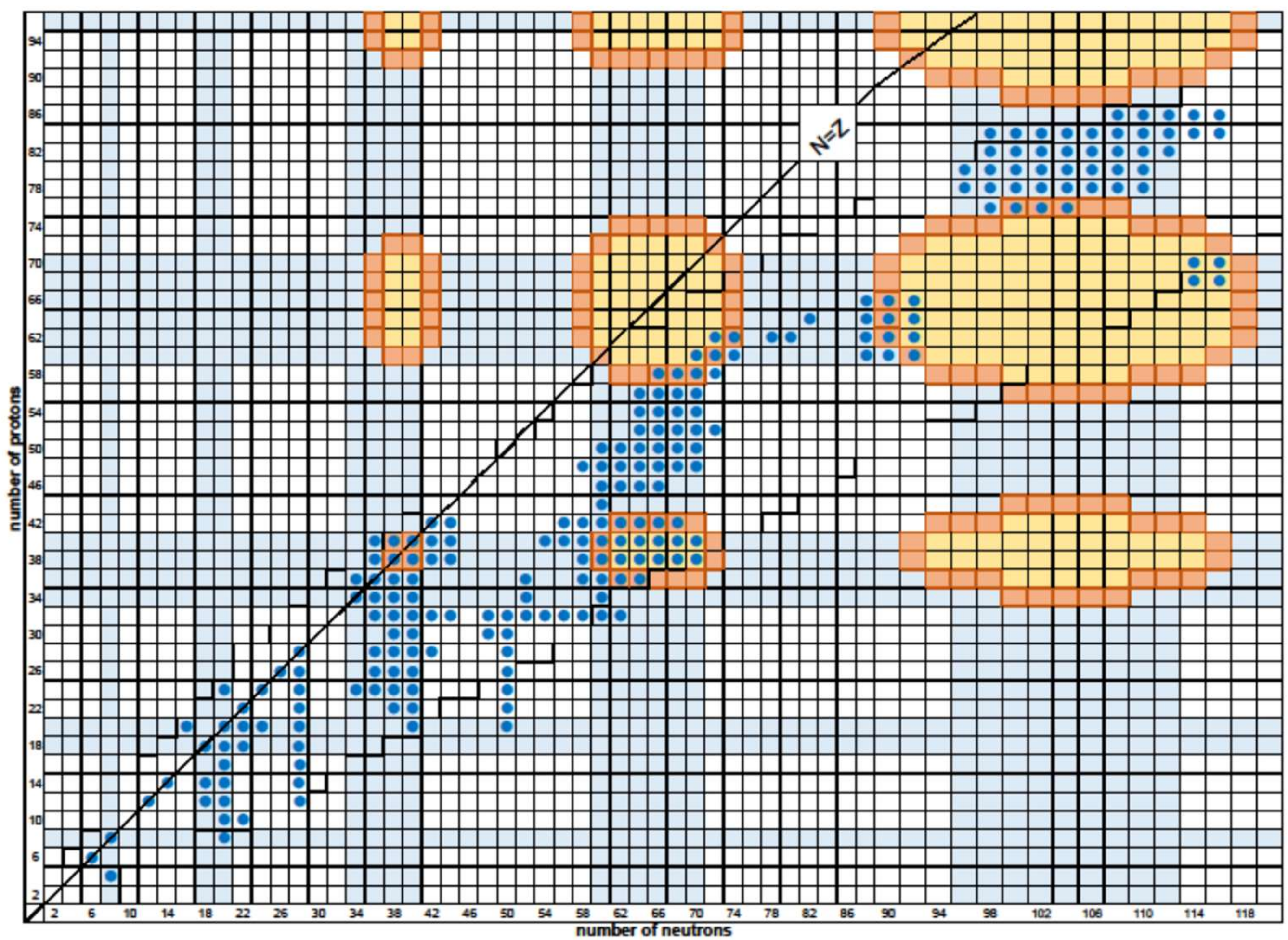


nuclei with shape coexistence

Atoms 11 (2023) 117 (cover story)

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Shape Coexistence in Even–Even Nuclei: A Theoretical Overview
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Preponderance of triaxial shapes

- Monte Carlo shell model – tensor force

  Tsunoda and Otsuka PRC 103 (2021) L021303

  Otsuka et al. arXiv: 2303.11299 [nucl-th]

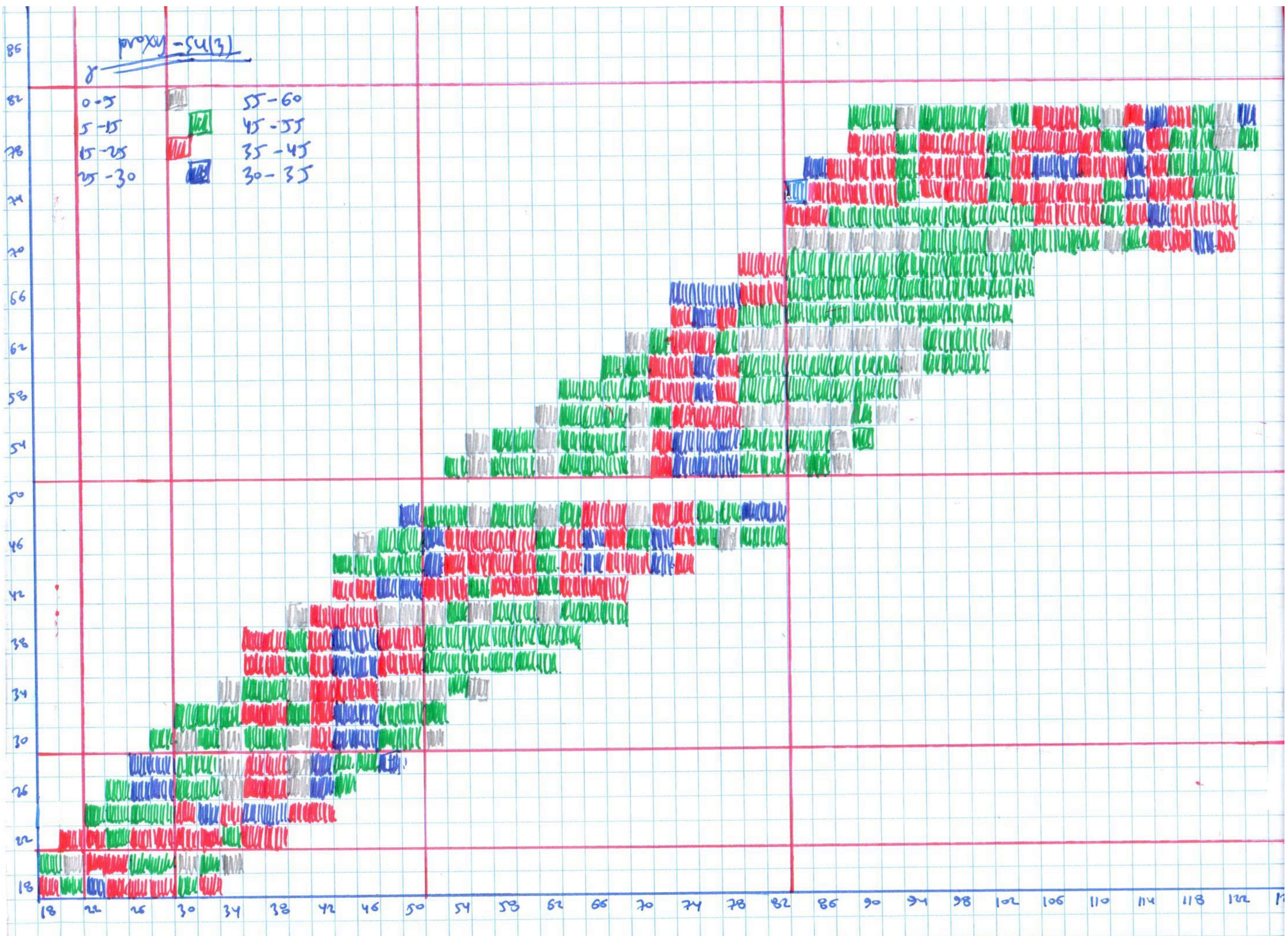
- Triaxial Projected Shell Model

  Rouoof et al. EPJA 60 (2024) 40

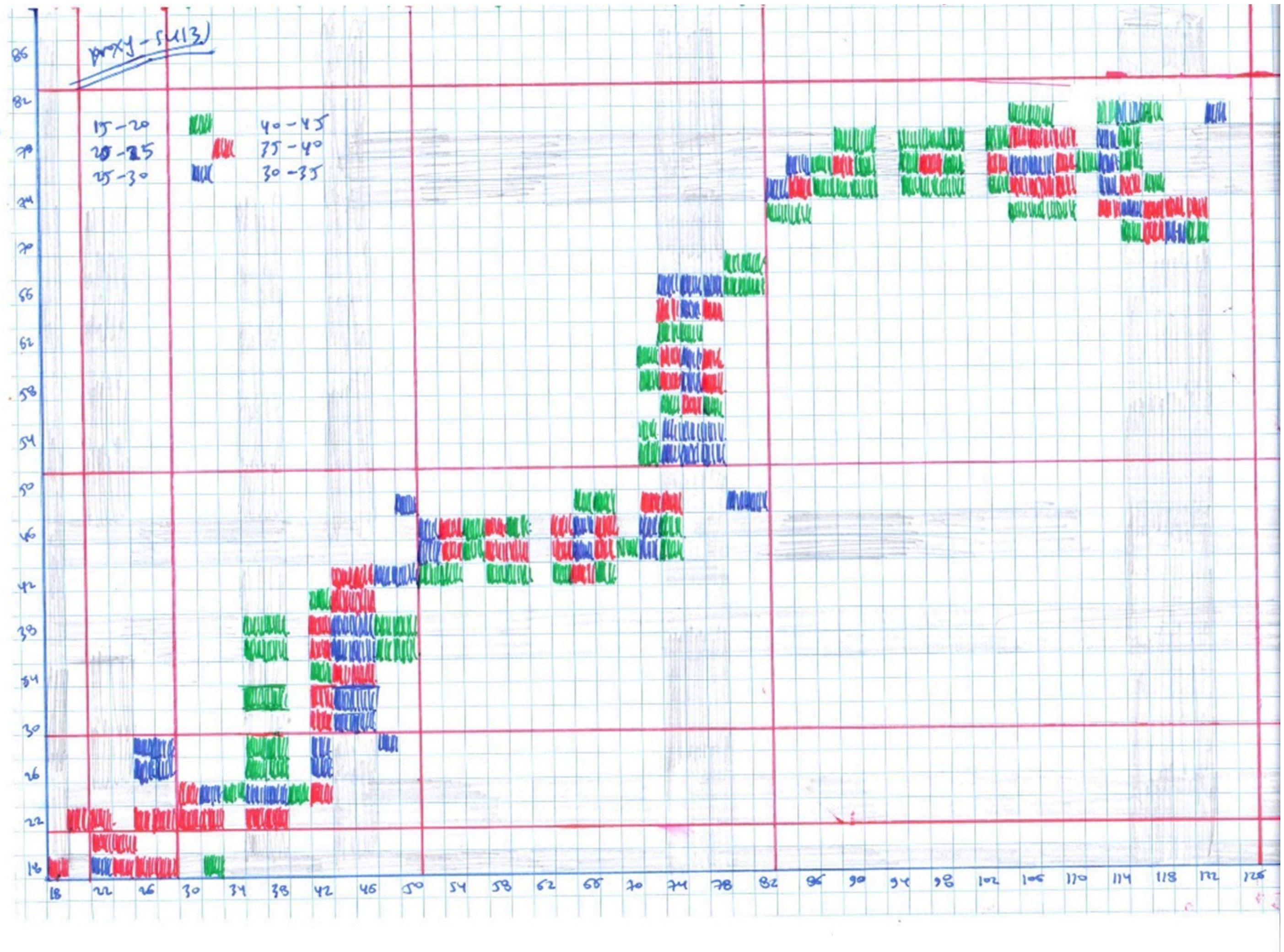
- Empirical (consistent modelling)

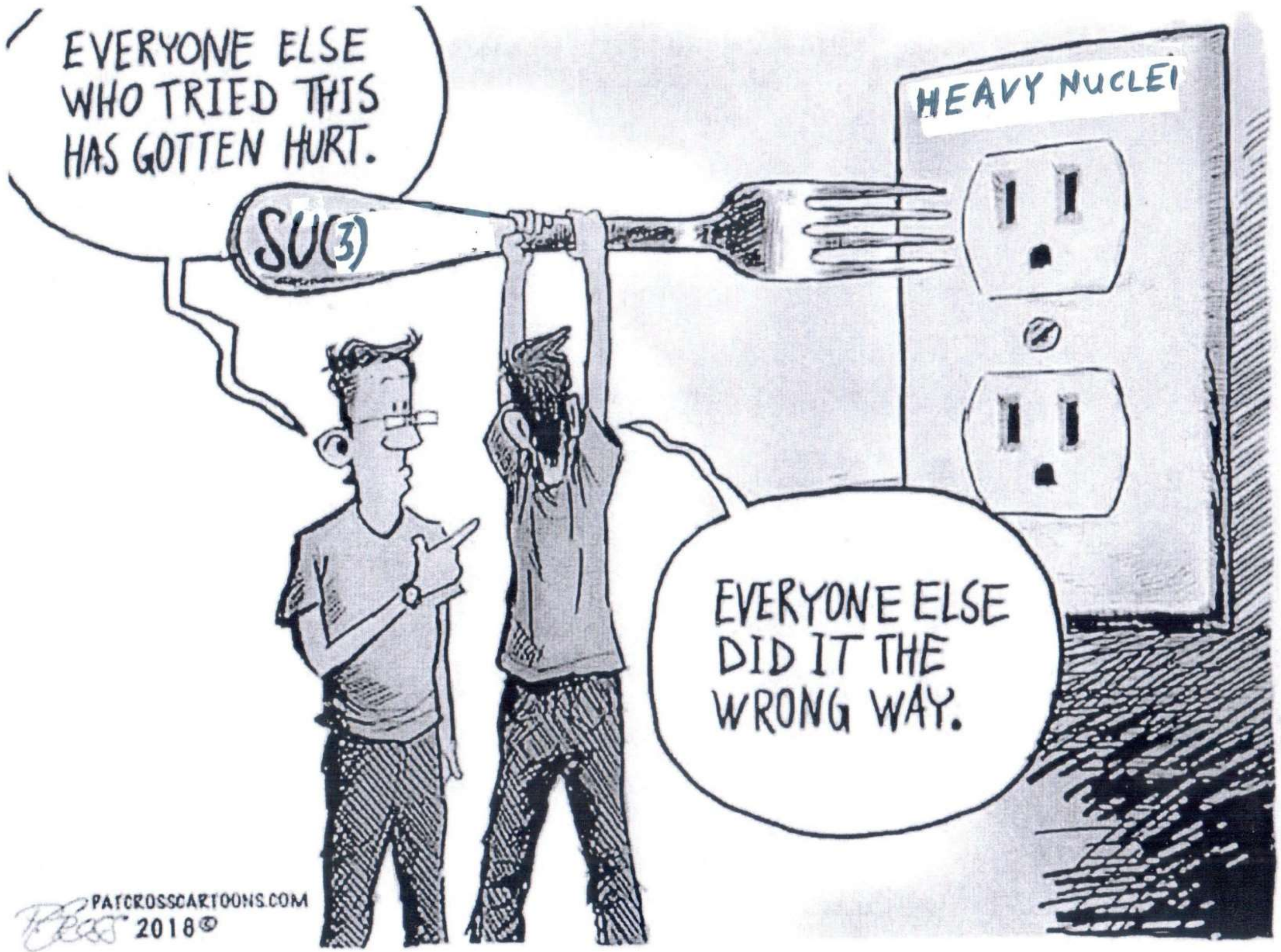
  Grosse and Junghans PLB 833 (2022) 137328

Proxy-SU(3) predictions for triaxiality



Proxy-SU(3) predictions for high triaxiality





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SU(3)
HEAVY NUCLEI
EVERYONE ELSE DID IT THE WRONG WAY.
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