A magszerkezet egyesítő szimmetriája

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ATOMKI

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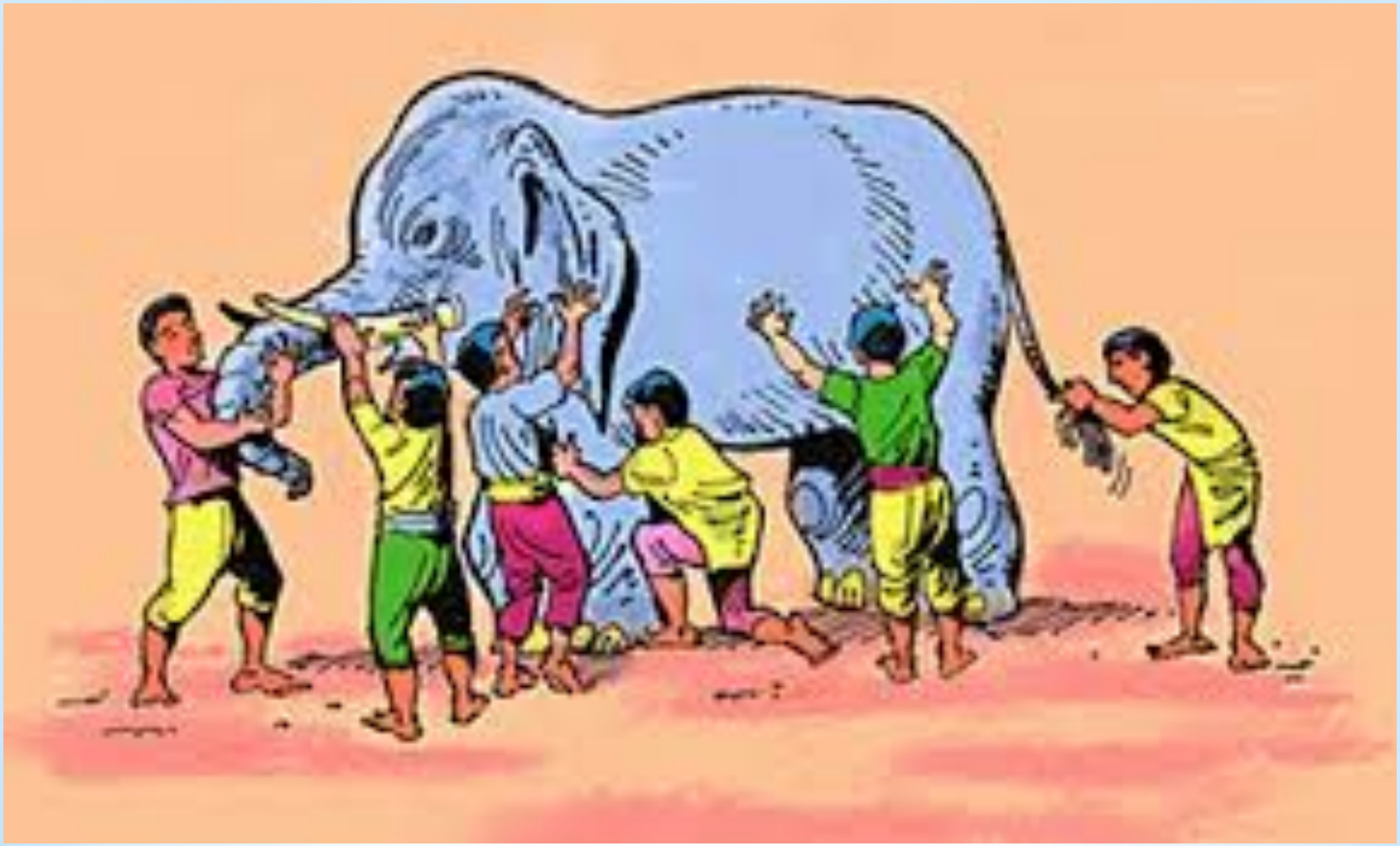
Atommag: túl sok nukleon.

Kvantummechanikai soktetst-probléma:
nincs egzakt megoldás.

Kulcsszerep: magmodellek.
Magmodellek: különböző fizikai képek.



The elephant is like

snout: a thick snake
ear: a fan
leg: a pillar…

The nucleus is like

magic numbers: small atom
rotational bands: liquid drop
decay: molecule, cluster…

Connection 1958

Elliott: *Proc. Roy. Soc. A 245, 28,562 (1958)*

Spectra of light nuclei,
deformation + rotation from spherical shell model:
SU(3).

From shell model to cluster model:
Wildermuth-Kanellopoulos: *Nucl. Phys. 7, 150 (1958)*
Harm. osc. appr.

Cluster-shell connection: SU(3).
Bayman-Bohr: *Nucl. Phys. 9, 596 (1958/59).*

A quadrupole collective or a cluster band is picked up from the spherical shell model basis by their special SU(3) symmetry.

For a single major-shell problem the connection between the shell, collective and cluster models is provided by an SU(3) dynamical symmetry:

$$U(3) \supset SU(3) \supset SO(3) .$$

Mi a helyzet a főhéj-gerjesztésekkel?

Multiconfigurational dynamical symmetry (MUSY)

$$U_s(3) \otimes U_e(3) \supset U(3) \supset SU(3) \supset SO(3)$$

Extension of the U(3) connection from 1958

(J. Cseh, Phys. Rev. C 103 (2021) 064322.)

Intersection of the algebraic

- shell
- collective
- cluster models

of multi-shell problems, with microscopic spaces.

Sokfőhéj-modellek kellenek, melyek

1958 tanúlsága szerint

a) szimmetriákra alapiulnak,

b) tudják az antiszimmetrát

Shell model

1. Symmetry Adapted No Core Shell Model (SA-NCSM)
LSU
T. Dytrych, K. D. Sviratcheva, J. P. Draayer, C. Bahri, and J. P. Vary,
J. Phys. G **35**, 123101 (2008)

$$U_s(3) \otimes U_e(3)$$

2. Semimicriscopic Algebraic Quartet Model (SAQM).
J. Cseh, Phys. Lett. B **743**, 213 (2015).
Wigner scalar, i.e S=T=0.

Collective model

Spectrum:
Contacted symplectic model
D. J. Rowe and G. Rosensteel, Phys. Rev. C **25**, 3236(R) (1982).
O. Castanos and J. P. Draayer, Nucl. Phys. A **491**, 349 (1989).

$$U_s(3) \otimes U_e(6) \supset U_s(3) \otimes U_e(3) \supset U(3)$$

Shapes:
Stabiity and self-Consistency of Symmetry (SCS)
J. Cseh, G. Riczu, and J. Darai, Phys. Lett. B **795**, 160 (2019).

Cluster model

Fully algebraic (both states and operators)
Vibron model: dipole collectivity.
F. Iachello, Phys. Rev. C **23**, 2778 (1981)

$$U_R(4) \supset U_R(3)$$

Coupled degrees of freedom.
ACM: phenomenologic, no Pauli principle

Semimicroscopic Algebraic Cluster Model (SACM)
J. Cseh, Phys. Lett. B **281**, 173 (1992);
J. Cseh and G. Lévai, Ann. Phys. (NY) **230**, 165 (1994).
Fully algebraic and includes Pauli principle.

Features of MUSY

1. Composite symmetry of a composite system

A) Dynamical symmetry in each configuration

$$U_s(3) \otimes U_e(3) \supset U(3) \supset SU(3) \supset SO(3)$$

B) Transformations between the configurations

$$U(3N) \supset U(3) \otimes U(N)$$

J. Cseh, *Symmetry* **2023**, *15*, 371.

Logical analogy with supersymmetry
of nuclear and particle physics

Invariant operators: MUSY and Part-SUSY

Non-invariant operators: MUSY and loc. gauge inv.

J. Cseh, *Symmetry* **2023**, *15*, 371.

2. Dual symmetry breaking

J. Cseh, Eur. Phys. J. Special Topics 229, 2543–2554 (2020)

A) Dynamical breaking of U(3) and SU(3)

$$U_s(3) \otimes U_e(3) \supset U(3) \supset SU(3) \supset SO(3)$$

B) Spontaneous breaking of SO(3)

Deformation of nuclei and spont. symm. breaking

Spontaneous breaking:
symmetric H, asymmetric ground state.

Elliott model 1958
Elliott, Dawber: Symmetry in Physics 1986

A) Dynamical breaking of U(3) and SU(3)

Spontaneous breaking of SO(3)

J. Cseh, Eur. Phys. J. Special Topics 229, 2543–2554 (2020)

Spont. symm. breaking in the Elliott model

J. Cseh, Phys. Lett. B **793**, 59 (2019)

$$H = n\hbar\omega + aQQ + b'LL \;\; = H_{intr} + H_{coll},$$

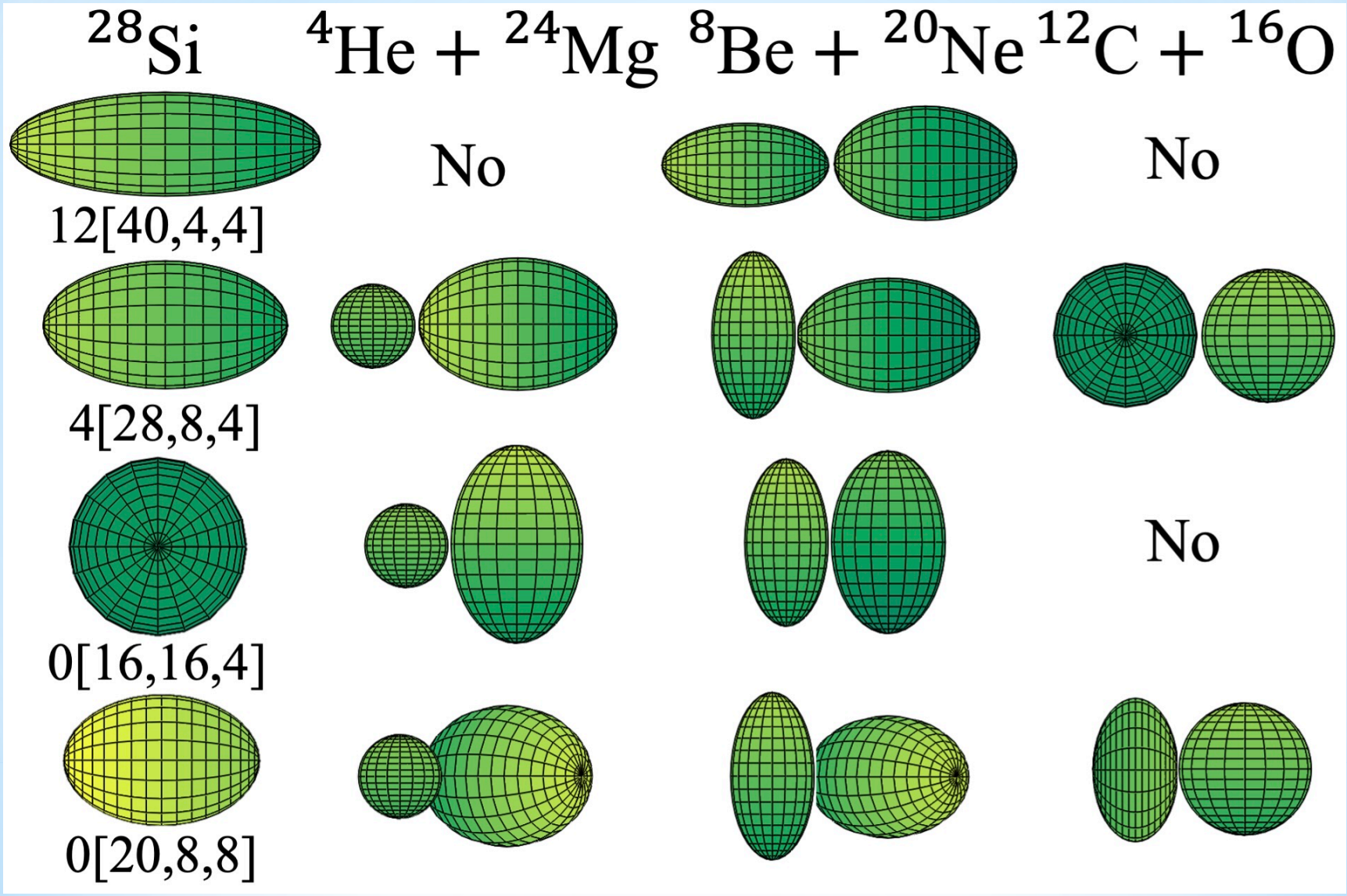
$$H_{intr} = aC_{U3} + bC_{SU3}, \quad H_{coll} = C_{SO3} = LL$$

1. Separate the fast and slow degrees of freedom.
2. The rotational symmetry is spontaneously broken for the intrinsic H (when there is degeneracy).
3. Deformed GS and Goldstone bosons appear.
4. For the complete H the symmetry is restored.

Spont. symm. breaking in MUSY

$$H = H_{intr} + H_{coll}, \quad H_{coll} = C_{SO3} = LL$$

Not only quadrupole but also octupole and molcular deformation.


^{28}Si
^{4}He + ^{24}Mg
^{8}Be + ^{20}Ne
^{12}C + ^{16}O
No
No
No
12[40,4,4]
4[28,8,4]
0[16,16,4]
0[20,8,8]

Cluster-shell coexistence

3. Most importantly: unified description of spectra of different configurations

(different reaction channels)

in different regions of energy and deformation.

Which are usualy described by different models.

Considerable predictive power.

Konklúzó

“Nézni a világot becsukott szemekkel,
látni azt, amit még nem látott meg ember,
gyönyörködni titkos, mély harmóniákban,
emlékezni arra, mit sohasem láttam.”

Teller Ede

Köszönöm a figyelmet!