# New Coupling Scheme in Heavy Nuclei


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# NEW COUPLING SCHEME

- SU(3) symmetry of the harmonic oscillator is destroyed in heavy nuclei due to spin-orbit interaction

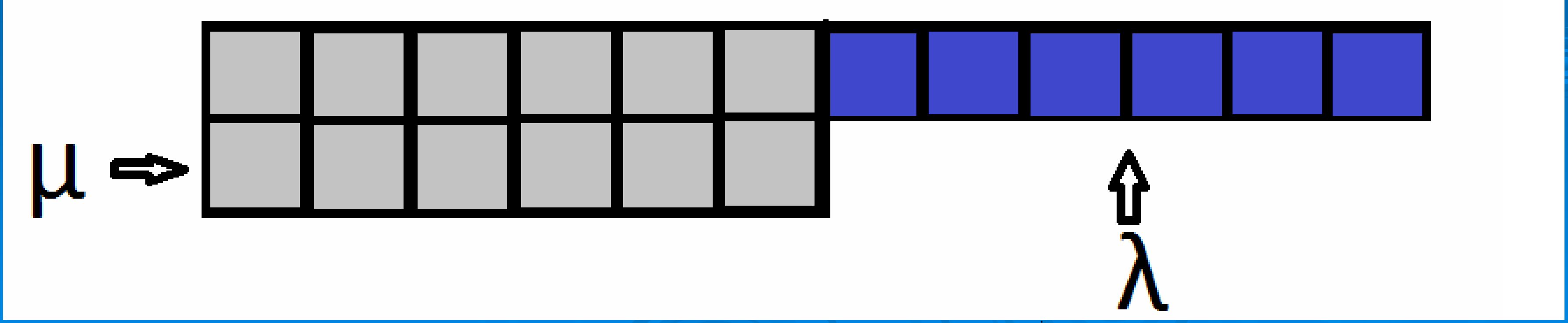
- However the SU(3) symmetry is present at heavy nuclei

- The “partnership” between 0[110] orbitals leads to a scheme conserving the SU(3) symmetry

# THE UNITARY GROUP AND ITS IRREDUCIBLE REPRESENTATIONS

- The unitary group U(n) is the group of n dimensional unitary matrices
- The "pf" shell of a nucleus has U(10) symmetry
- The "sdg" shell of a nucleus has U(15) symmetry
- Every shell of a nucleus can be described using a unitary group of an appropriate dimension

- In order to describe a specific nucleus we use irreducible representations of U(n) groups
- Irreducible representations (=irreps) conserve good quantum numbers
- The irreps of SU(3) (which is a subgroup of U(n)) used are denoted by (λ,μ)
- They can be described graphically by a Young diagram



- λ and μ have to do with the deformation of the nucleus
- λ -> magnitude of deformation
- μ -> axial or triaxial shape
- We need only the irreducible representations (λ,μ) which maximize the quantity

$$\frac{1}{9}\left(\lambda^2+\mu^2+\lambda\mu+3\lambda+3\mu\right)$$

- For example, 168Er has 18 valence protons and 18 valence neutrons
- The most leading SU(3) irrep of U(10) corresponding to the protons is (10,4)
- The  most leading SU(3) irrep of U(15) corresponding to the neutrons is (20,4)
- So the nucleus 168Er can be described by the  (30,8) irrep

# OPERATORS OF THE NEW HAMILTONIAN

- The second order Casimir operator of SO(3) $\hat{L}^2$ with eigenvalues $I_2(L) = L(L+1)$

- The second order Casimir operator of SU(3) with eigenvalues

$$C_2(\lambda, \mu) = \frac{1}{9}(\lambda^2 + \mu^2 + \lambda\mu + 3\lambda + 3\mu)$$

- The third Casimir operator of SU(3) with eigenvalues

$$C_3(\lambda, \mu) = \frac{1}{162}(\lambda - \mu)(2\lambda + \mu + 3)(\lambda + 2\mu + 3)$$

- The third order scalar shift operator of O(3) called Ω in nuclear physics literature.

- The fourth order scalar shift operator of O(3) called Λ in nuclear physics literature.

- Ω and Λ will break the degeneracy between the bands belonging to the same irrep.

- There is no analytical expression for the eigenvalues of Ω  and Λ .Numerical calculations must be performed.

- Including only one body and two body terms leads to a Hamiltonian with eigenvalues

$$E = \alpha L(L+1) + C_2(\lambda,\mu)$$

In this scheme bands belonging to the same irrep are degenarate

- Including terms up to third order leads to a

Hamiltonian with eigenvalues

$$E = \alpha L(L+1) + \beta C_2(\lambda,\mu) + \gamma\Omega + \delta C_3(\lambda,\mu)$$

Ω breaks the degenaracy.  C3(λ,μ) term can be omitted .

This the lowest energy Hamiltonian of the new scheme.

- Including up to fourth order terms leads to a Hamiltonian with eigenvalues

$$E = \alpha L(L+1) + \beta C_2(\lambda,\mu) + \gamma\Omega + \delta C_3(\lambda,\mu) + \xi\Lambda +$$
$$+ \nu L^2(L+1)^2 + \tau L(L+1)C_2(\lambda,\mu) + \rho[C_2(\lambda,\mu)]^2$$

The terms C3(λ,μ) , L(L+1)C2(λ,μ) , [C2(λ,μ)])2 can be omitted

# Ongoing numerical calculations for $\Omega$ and $\Lambda$

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