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A symmetry in-between the shapes, shells and clusters of nuclei

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The fundamental models of nuclear structure are based on different phys- ical pictures, e.g. liquid drop, shell, or molecule. Their intersection was found in 1958 for a single shell problem. In the present-day language we can say that their common overlap is provided by the U(3) ⊃ SU(3) ⊃ SO(3) dynamical symmetry.
For the multi-shell problem the intersection of these models turns out to be the multiconfigurational dynamical symmetry (MUSY) of
Us ⊗Ux ⊃U(3)⊃SU(3)⊃SO(3) (1)
algebraic structure [1]. This chain defines the set of basis states of the multi- shell excitations in the symplectic shell model in the contracted symplectic collective model as well as in the fully microscopic and semimicroscopic al- gebraic cluster models. MUSY is a composite symmetry in the sense that each configuration has the symmetry of chain (1) and in addition a further symmetry connects the different configurations to each other. The latter one is defined by the particle number classification scheme.
MUSY shows a dual breaking of symmetries [2], similarly to many other dynamical symmetries of algebraic structure models. In particular, the larger symmetries (U(3) and SU(3)) are dynamically broken by the interactions (expressed in terms of the invariant operators of their subalgebras), while the rotational symmetry is spontaneously broken in the eigenvalue problem of the intrinsic Hamiltonian [3].
Since MUSY connects different models, it is able to give a unified descrip- tion of spectra of different configurations in different energy and deformation regions. Typically low-lying shell-like or quartet spectra [4] are described together with high-lying alpha-cluster spectra, and exotic cluster configura- tions [1,5] including both super, and hyperdeformation. In some cases the high-lying cluster spectra could be predicted from the low-lying quartet states [6].

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