From Quark Correlations to Lattice–Like Nuclei. Nuclear Geometry

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Starting with a quark model of the nucleon structure, elaborated by one of the authors, in which the valence quarks are strongly correlated with one another within the nucleon, the smallest nuclei, ^2H, ^3H, ^3He and ^4He can be constructed by assuming similar correlations with the quarks in neighboring nucleons [1, 2]. Applying the model to larger collections of nucleons reveals the emergence of symmetries at the nuclear level that are implied by the quark–quark interaction specifically, geometrical shells and subshells that are isomorphic with those known from the independent-particle (shell) model (Fig. 1). This discrete nuclear symmetry discovered by Cook with coauthors corresponds to face–centered–cubic lattice [3].

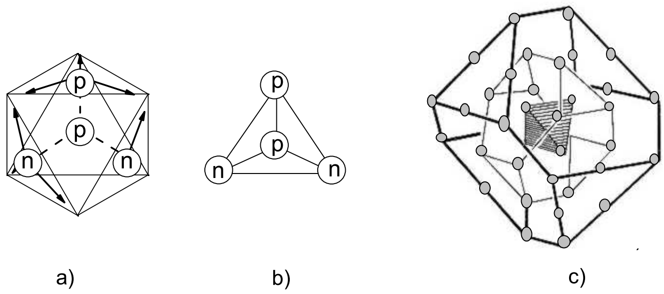

Figure 1: a) The octahedral symmetry of the first nuclear s–shell ($^4He-$) in quark representation. b) On the nucleon level the symmetry of four point nucleons in s–shell corresponds to the tetrahedron. c) First three shells on the nucleon level corresponding to s–, p– and d– shells

Significantly, the nuclear texture implied by the strong correlations in the quark model is not a nucleon gas or independently orbiting nucleons, but rather a nucleon lattice in which local (quark) interactions are responsible for all aspects of nuclear binding. By constructing large nuclei in this way, the quark–based lattice model reproduces the features of the shell, liquid–drop and cluster models in a fully self–consistent manner. In general, lattice arrangements of nucleons lead in natural way to nuclear deformations, even though nuclei with closure shells are not spherically symmetric.

It is shown that quark–quark interactions of adjacent nucleons are responsible for formation of the nuclear configurations that correspond to the exotic (borromean) nuclei [4] . According to the model a pare of loosely bound halo neutrons, say in ^6He, are arranged in triangular configuration with one proton of the core nucleus (Fig. 2). In ^8He another pair of halo neutrons are bound to the second proton of $^4He-$core. Halo nuclei possess maximal deformation.

We therefore claim that the many liquid–drop, shell and cluster characteristics of nuclear structure are manifestations of interquark correlations. The model has been

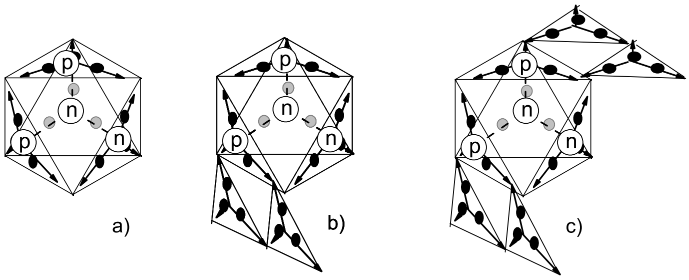

Figure 2: Helium isotopes: a) ^4He, b) ^6He - two neutrons are loosely bound to the core ^4He and c) ^8He - four neutrons are loosely bound to the core ^4He

developed on a qualitative rather than quantitative level, but indicates ways in which the long–standing internal contradictions of nuclear structure theory (orbiting nucleons, solid/liquid/gaseous nuclear phases, etc.) can be resolved on the basis of quark effects.

References

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