ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN—POLONIA
VOL. XL/XLI, 40 SECTIO AAA 1985/1986

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The Strictly Restricted Dynamics Nuclear Model and Elliott's Collective Bands

Ściśle ograniczona dynamika jądrowa a schemat pasmowy Elliota

Строго ограниченная динамика модели атомного ядра и коллективные полосы Эллиотта

1. Introduction

In 1958 Elliott has demonstrated [1] that the spectrum of the non-central quadrupole-quadrupole interaction, acting within a single SU_3-shell consists of the rotational-type bands built on the SU_3-irreducible states. This result is usually being commented as a relationship between the shell-model and collective features. Without referring to the shell-model picture, in this paper we present another interpretation of Elliott's model, proposed in § 24 [2], naturally following from the general microscopic theory of the collective motion in nuclei. This interpretation is based on both the restricted dynamics idea and algebraic scheme employing the unitary group U_{A-1}, with A giving the number of particles in the nucleus.

In two following sections we sketch main features of the Elliott's model and the realization of the many-particle Hilbert space, needed for its new interpretation. Sections 4 and 5 are devoted to the generalizations of Elliott's approach and in the next two sections the strictly restricted dynamics model is described, taking into account the collective and the pairing-like features. In the references, given at the very end of this paper, further generalizations of the nuclear models, based on the restricted dynamics idea, can be found.

2. Elliott's collective bands

In the pioneering papers [1] which have started the applications of SU_3-scheme to the nuclear structure problems the SU_3-shell model has been proposed. In this model the states were used, composed from the isotropic harmonic oscillator functions, characterized by SU_3-irreducible representations $(\lambda\mu)$ with the basis KLM, labelled by the irreducible representations of groups in the chain $SU_3 \supset SO_3 \supset SO_2$ as well as by the missing label K, related with the projection of the angular momentum L into the body-fixed z-axis. In [1] the spectrum of the non-central quadrupole-quadrupole interaction

$$V_{qq} = V_0 \sum_{i<j=1}^{n} r_i^2 r_j^2 P_2(\cos\vartheta_{ij}), \tag{1}$$

acting within the SU_3-shell $\mathcal{E}^n$ ($\mathcal{E}$ denotes the SU_3-irreducible representation $(\mathcal{E}0)$) has also been studied. This spectrum has been obtained using the following decomposition of V_{qq}

$$V_{qq} = \hat{V}^0_{qq} + \hat{V}'_{qq}, \tag{2}$$

where $\hat{V}^0_{qq}$ is the term of V_{qq}, depending only on infinitesimal operators of the group SU_3. This term may be easily obtained presenting V_{qq} in the form

$$V_{qq} = \frac{1}{2} V_0 \sum_{s_1,s_2,s_1',s_2'=1}^{3} \sum_{i<j=1}^{n} x_i^{s_1} x_i^{s_2} x_j^{s_1'} x_j^{s_2'} \pi^{s_1 s_2 s_1' s_2'} \tag{3}$$

with

$$\pi^{s_1 s_2 s_1' s_2'} = 3\,\delta(s_1 s_1')\,\delta(s_2 s_2') - \delta(s_1 s_2)\,\delta(s_1' s_2'), \tag{4}$$

where x_i^s is the particle Carthesian variables ($s = 1,2,3$; $i =$

$= 1, 2, \ldots, n$). Using the relations

$$x_i^s = \frac{1}{\sqrt{2}}\left(\overset{+}{\eta}{}_i^s + \eta_i^s\right)$$

$$\frac{\partial}{\partial x_i^s} = \frac{1}{\sqrt{2}}\left(\overset{+}{\eta}{}_i^s - \eta_i^s\right) \tag{5}$$

connecting x_i^s and derivatives with respect to them with the creation η_i^s and annihilation $\overset{+}{\eta}{}_i^s$ operators, V_{qq} can be presented in terms of η_i^s and $\overset{+}{\eta}{}_i^s$. Taking from the expression obtained the term depending on SU_3-infinitesimal operators, $\hat{V}_{qq}^o$ in the explicit form can be derived.

Let us discuss the matrix representations of $\hat{V}_{qq}^o$ in the SU_3-shell model states

$$\phi\left(\varepsilon^n f_0 \mu_{f_0} \alpha_{f_0} (\lambda\mu) KLM\right), \tag{6}$$

introduced in [1] and characterized by $(\lambda\mu)KLM$ as well as by the space partition f_0 with basis μ_{f_0} and the missing label α_{f_0} for the chain $U_{dim\,\varepsilon} \supset SU_3$ ($dim\,\varepsilon$ denotes the dimension of ($\varepsilon 0$)). The matrix elements of $\hat{V}_{qq}^o$ on the SU_3 -shell model states are degenerated with respect to f_0, $\mu_{f_0}, \alpha_{f_0}, K, M$. In [1] it has been proved, that the eigenvalues $\mathcal{E}(\hat{V}_{qq}^o)$ depend both on $(\lambda\mu)$ and L in the form

$$\mathcal{E}(\hat{V}_{qq}^o) = \frac{3}{4} V_0 \left(6\,G(\lambda\mu) - \frac{1}{2} L(L+1)\right), \tag{7}$$

where G - the eigenvalue

$$G(\lambda\mu) = \frac{1}{9}\left(\lambda^2 + \mu^2 + \lambda\mu + 3(\lambda+\mu)\right) \tag{8}$$

of the SU_3 -Casimir operator

$$\hat{G} = \frac{1}{6}\sum_{s,s'=1}^{3} \hat{I}^{ss'}\hat{I}^{s's} - \frac{1}{18}\left(\sum_{s=1}^{3}\hat{I}^{ss}\right)^2. \tag{9}$$

In (9) $\hat{I}^{ss'}$ denotes the SU_3 -infinitesimal operators

$$\hat{I}^{ss'} = \sum_{i=1}^{n} \eta_i^s \overset{+}{\eta}{}_i^{s'} \tag{10}$$

presented in terms of the creation and annihilation operators.

The Elliott's collective bands (7), already mentioned in the introduction, have been obtained in the SU_3-shell basis. In the next section we will describe the more general basis, useful for the far reaching generalization of the Elliott's model.

3. The unitary scheme basis

The operator $\hat{V}^{o}_{qq}(\hat{I}^{ss'})$, depending only on SU_3-infinitesimal operators (10), possesses the additional symmetry, giving the guiding idea about further generalizations. Acting on indices i of $\hat{\eta}^{s}_{i}$ and $\hat{\xi}^{s}_{i}$ with operators of the unitary group U_n it is easy to check, that $\hat{I}^{ss'}$ are U_n-scalars. Thus $\hat{V}^{o}_{qq}$ is also U_n -scalar operator, consequently $\hat{V}^{o}_{qq}$ conserves U_n-irreducible representations. This feature of $\hat{V}^{o}_{qq}$, useless in SU_3-shell states, having no U_n characteristics, has advantage in U_n-irreducible spaces. This is the reason, why we must discuss another realization of the basis in the many-particle Hilbert space labelled by irreducible representations of unitary and orthogonal groups with the rank, depending on the number of particles A.

We are also going to improve the Elliott's model taking instead of (1) the central quadrupole-quadrupole interaction

$$H_{qq} = V_{oc} \sum_{i<j=2}^{A} (\vec{r}_i - \vec{r}_j)^4 , \tag{11}$$

which can be considered as a term in Taylor's expansion of the potential energy for the nucleon-nucleon interaction. Due to the translational-invariance of the expression, we also need translational-invariant basis functions. It is easy to assure this property using instead of one-particle variables x^{s}_{i} the translational-invariant Jacobi variables ρ^{s}_{i}, with $s = 1, 2, 3$ and $i = 1, 2, \ldots, A$.

Translational-invariant functions with the properties described, introduced in [3], are labelled by irreducible representations of the groups in the chain

$$\begin{array}{ccc} U_{3(A-1)} \supset & U_3 & \times \; U_{A-1} \\ & \cup & \cup \\ & SO_3 & O_{A-1} \\ & \cup & \cup \\ & SO_2 & S_A \end{array} , \tag{12}$$

where U, O, SO and S correspondingly denote the unitary, orthogonal, special orthogonal and symmetric groups. Let us label the $U_{3(A-1)}$-, U_3-, U_{A-1}-, O_{A-1}- and S_A-irreducible representations correspondingly as $E_0 \equiv [E_0 0 \ldots 0]$, $E \equiv [E_1 E_2 E_3]$, $E \equiv [E_1 E_2 E_3 0 \ldots 0]$, $\omega \equiv (\omega_1 \omega_2 \omega_3 0 \ldots 0)$ and $f \equiv [f_1 f_2 \ldots f_A]$. Note, that both U_3 and U_{A-1}-irreducible representations have the same notation, thus there is no need to repeat them. Taking into account the relations $\lambda = E_1 - E_2$, $\mu = E_2 - E_3$ between the notations $[E_1 E_2 E_3]$ and $(\lambda\mu)$, as well as the condition $E_1 + E_2 + E_3 = E_0$ we can use $(\lambda\mu)$ instead of $E \equiv [E_1 E_2 E_3]$. We will refer to the functions

$$\phi\begin{pmatrix} E_0 E K L M \\ \delta \omega \alpha f \mu_f \end{pmatrix} \vec{\rho}_1, \ldots, \vec{\rho}_{A-1} \Big) \tag{13}$$

depending on the space partition f with the basis μ_f and other characteristics described as well as on the missing labels δ and α for the chains $U_{A-1} \supset O_{A-1}$ and $O_{A-1} \supset S_A$ as to the unitary scheme basis.

The unitary scheme basis gives natural generalization of the SU_3-shell model states. The relation of the ground SU_3-shell states with unitary scheme functions gives the expression

$$\phi\left((0)^4(1)^{12}\ldots(\mathcal{E}-1)^{2\mathcal{E}(\mathcal{E}+1)}\mathcal{E}^n [4\ldots4f_0]\mu_f \alpha_f (\lambda\mu) KLM \,\middle|\, \vec{x}_1, \ldots, \vec{x}_A\right) = 2\,\frac{(\nu A)^{3/4}}{\pi^{1/4}}\, e^{-\frac{1}{2}\nu A R^2}\, \phi\left(\begin{matrix} E_{0min}\, E K L M \\ \delta \omega \alpha [4\ldots4f_0]\mu_f \end{matrix} \,\middle|\, \vec{\rho}_1, \ldots, \vec{\rho}_{A-1}\right), \tag{14}$$

where ν is the oscillator frequency, $n = A - (4 + 12 + \ldots + 2\mathcal{E}(\mathcal{E}+1))$. E_{0min} denotes the minimum number of oscillator quanta allowed by the Pauli principle and $[4\ldots4f_0]$ – the space partition containing as the fragment the f_0 of the open shell $\mathcal{E}^n$. The first factor in the r.h.s. of (14) gives the oscillator vacuum state of the centrum-of-mass motion. For the states with $E_{0min}+1, E_{0min}+2, \ldots$, the unitary scheme basis multiplied by the vacuum state of the centrum-of-mass motion can be presented as some definite superposition of SU_3-configurations with more than one open shell (for details – see [4] and references there). Let us also note, that the basis, used in so called microscopic symplectic nuclear models is equivalent to the unitary scheme basis (see for details [5]).

Now we are going to discuss the following problem: instead of considering the interaction $\hat{V}^{0}_{qq}$ acting within the space, spanned on a single SU_3 -shell functions(6), let us separate from (11) its U_{A-1} -scalar term H^{0}_{qq}, acting within the space, spanned on the unitary scheme basis (13) and examine its matrix representation.

4. U_{A-1} -scalar term of the central quadrupole-quadrupole interaction

Let us analyse the algebraic structure of the interaction (11). Using (5) for the Jacobi variables we can present H_{qq} in the form

$$H_{qq} = \bar{H}_{qq} + H'_{qq}, \tag{15}$$

where $\bar{H}_{qq}$ gives all the terms of H_{qq} depending on the $U_{3(A-1)}$ -infinitesimal operators, i.e. the terms of H_{qq} acting within the $U_{3(A-1)}$-irreducible space. The U_{A-1} -scalar term H^{0}_{qq} of H_{qq} is contained in $\bar{H}_{qq}$, thus, continuing our analysis, let us examine the decomposition

$$\bar{H}_{qq} = H^{0}_{qq} + \bar{H}'_{qq}. \tag{16}$$

This decomposition is described in detail in [4] . Here we present only the final expression for H^{0}_{qq} , explicitly obtained in [6] ,

$$H^{0}_{qq} = V_{0C}\left(\frac{15}{8}A(A-1) + \frac{5}{2}(A-1)\hat{K}^{(1)} + \frac{5}{6}(\hat{K}^{(1)})^{2} + 6\hat{G} - \frac{1}{2}\hat{L}^{2}\right), \tag{17}$$

where $\hat{L}^{2}$ and $\hat{K}^{(1)}$ -operators with the eigenvalues $L(L+1)$ and E_0 . Taking the matrix representation of the operator (17) in the unitary scheme basis we see, that the spectrum $\mathcal{E}(H^{0}_{qq})$ of H^{0}_{qq} has the expression

$$\mathcal{E}(H^{0}_{qq}) = V_{0C}\left(\frac{15}{8}A(A-1) + \frac{5}{2}(A-1)E_0 + \frac{5}{6}E_0^{2} + 6G(\lambda\mu) - \frac{1}{2}L(L+1)\right), \tag{18}$$

i.e. it possesses Elliott's collective bands structure. This formula gives the new interpretation of Elliott's model. In the next section we will see, that this interpretation is convenient for generalizations.

5. The U_{A-1} -scalar term of the arbitrary interaction

Instead of (11) let us consider the potential energy operator

$$H_w = \sum_{i<j=1}^{A} V(r_{ij}) \tag{19}$$

with the arbitrary nucleon-nucleon interaction $V(r_{ij})$. In order to separate the U_{A-1} -scalar term from (19) we employ the density matrix technique, developed in a series of papers, described in [4]. Using this technique in [7] it has been shown, that the matrix of H_w on the unitary scheme basis (13) is diagonal with respect to all of its characteristics but K, independent on $M\delta\omega\alpha f\mu_s$, and has the following expression:

$$\mathcal{E}^{E_0(\lambda\mu)L}_{KK'} = \left\langle \begin{matrix} E_0 E K L M \\ \delta\omega\alpha f \mu_s \end{matrix} \middle| H^0_w \middle| \begin{matrix} E_0 E K' L M \\ \delta\omega\alpha f \mu_s \end{matrix} \right\rangle =$$

$$= \sum_{\varepsilon\ell} I^{\nu}_{\varepsilon\ell}\, Q_{\varepsilon\ell}(EKL, EK'L), \tag{20}$$

where $Q_{\varepsilon\ell}$ -components of the U_{A-1} -scalar density matrix

$$Q_{\varepsilon\ell} = \frac{A(A-1)}{2} \sum_{\bar{E}} \frac{\dim \bar{E}}{\dim E} \sum_{\bar{K}\bar{L}} B^{(\bar{E}\bar{L})}_{\bar{K}\bar{K}'}\, C^{\bar{E}\ \ \varepsilon\ \ E}_{\bar{K}\bar{L}\ \ell\ KL}\, C^{\bar{E}\ \ \varepsilon\ \ E}_{\bar{K}'\bar{L}\ \ell\ KL} \tag{21}$$

and $I^{\nu}_{\varepsilon\ell}$ -the integrals

$$I^{\nu}_{\varepsilon\ell} = \int_0^{\infty} r^2 dr\, R^{\nu}_{\varepsilon\ell}(r)\, V(\sqrt{2}r)\, R^{\nu}_{\varepsilon\ell}(r), \tag{22}$$

calculated on isotropic three-dimensional oscillator radial functions, depending on the frequency ν and the radial variable $\sqrt{2}r \equiv \sqrt{2}\,|\vec{r}_{A-1} - \vec{r}_A|$. In (21) $\dim E$ and $\dim \bar{E}$ denote the dimensions of the U_{A-1} - and U_{A-2} -irreducible representations E and $\bar{E}$, $B^{(\bar{E}\bar{L})}$ -the overlap of unitary scheme functions, and C -isoscalar factors of SU_3-coupling coefficients in the Elliott's basis. Explicit polynomial expressions of C have been obtained in [8], $B^{(\mathcal{E}L)}$ is also known, thus we can find $Q_{\mathcal{E}\ell}$ and calculate the matrix elements (20) for a given potential $V(r_{ij})$. In particular, in the case of the interaction r_{ij}^4, (18) follows from (20).

Let us discuss the spectrum of H_w^0. Typical dependence of the diagonal matrix elements (20) on L has a form of the polynomial in $L(L+1)$

$$\mathcal{E}_{KK}^{E_0(\lambda\mu)L} = \sum_t \left(a_t \left(L(L+1)\right)^{m_t} + (-1)^L b_t \left(L(L+1)\right)^{n_t} \right), \tag{23}$$

with a_t, b_t, m_t, n_t and limits for t given by $E_0(\lambda\mu)K$, as well as by the potential $V(r_{ij})$ used. In the case of not too trivial potentials, non-diagonal with respect to K matrix elements (20) are not zero, consequently the effect of K-bands mixing exists, depending on $V(r_{ij})$. Thus we conclude, that the Elliott's model, generalized for the arbitrary interaction, possesses more rich and sophisticated spectrum, in comparison with Elliott's collective bands.

6. The strictly restricted dynamics collective model

We have discussed only the U_{A-1} -scalar term H_w^0 of the Wigner interaction H_w. The total Hamiltonian H of the nucleus consists of the kinetic H_k, Coulomb H_e, central $H_c = H_w + H_M + H_B + H_H$ (the terms in this expression correspondingly denote Wigner, Majorana, Bartlett and Heizenberg interactions), vectorial H_v and tensorial H_t terms, thus

$$H = H_k + H_e + H_w + H_M + H_B + H_H + H_v + H_t . \tag{24}$$

Acting on H with operators of the group U_{A-1} we can present this Hamiltonian in the U_{A-1} -irreducible form

$$H = H^0 + \sum_{\varkappa q} H^{\varkappa q}, \tag{25}$$

where the first term H^0 is the U_{A-1} -scalar part of H and terms with $\varkappa \neq [0]$ possess some U_{A-1} -irreducible properties. According to the definition proposed in [9] and described in details in [2], H^0 is the strictly restricted dynamics collective Hamiltonian

$$H^{o} \equiv H^{o}_{coll} = H^{o}_{k} + H^{o}_{e} + H^{o}_{w} + H^{o}_{M} + H^{o}_{B} + H^{o}_{H} + H^{o}_{v} + H^{o}_{t} \,. \tag{26}$$

The states of the Schrodinger equation for H^{o}_{coll} give the strictly restricted dynamics collective model. Every term in (24) contributes to (26), thus besides the features, related with Wigner interaction and already discussed in the previous section, in the strictly restricted dynamics collective model we obtain additional effects, conditioned by the exchange operators, the coupling of the spin-isospin and orbital degrees of freedom, etc. Due to the dependence of H^{o}_{coll} on the space and spin-isospin degrees of freedom, the space H^{o}_{coll} acts in, is spanned on the antisymmetric functions, built using (13) and spin-isospin supermultiplet basis

$$\phi(\tilde{f}\tilde{m}_{f}\tilde{\alpha}\, S M_S T M_T \,|\, \zeta_{\sigma_1}\zeta_{\tau_1}, \cdots, \zeta_{\sigma_A}\zeta_{\tau_A}), \tag{27}$$

depending on spin-isospin variables $\zeta_{\sigma}\zeta_{\tau}$ and characterized by the total spin S, isospin T, their z-projections M_S and M_T, S_A -irreducible representation $\tilde{f}$ with the basis $\tilde{m}_{\tilde{f}}$, both uniquely related with f, m_f and the missing label $\tilde{\alpha}$ for the chain $U_4 \supset SU_2 \times SU_2$. Coupling L with S to J and f with $\tilde{f}$ to the antisymmetric representation a of the group S_n we construct the antisymmetric unitary scheme functions

$$\phi\begin{pmatrix} E_0 E\, K(LS) J\, M_J \\ \delta\, \omega\, \alpha\, f\, \tilde{\alpha}\, T M_T \end{pmatrix} \!\!\Big|\, \hat{\varrho}_1, \cdots, \hat{\varrho}_{A-1}; \zeta_{\sigma_1}\zeta_{\tau_1}, \cdots, \zeta_{\sigma_A}\zeta_{\tau_A} \Big), \tag{28}$$

introduced in [3]. The Hamiltonian H^{o}_{coll} in the basis (28) is diagonal with respect to all the quantum numbers, but KLS. The matrix of H^{o}_{coll} in this basis is independent on $M_J \delta\omega\alpha$ and has a form of

$$\mathcal{E}^{coll}_{KL\tilde{\alpha}S,K'L'\tilde{\alpha}'S'}(J\pi; E_0(\lambda\mu) f T M_T) =$$

$$= \left\langle \begin{matrix} E_0 E\, K(LS) J\, M_J \\ \delta\, \omega\, \alpha\, f\, \tilde{\alpha}\, T M_T \end{matrix} \right| H^{o}_{coll} \left| \begin{matrix} E_0 E\, K'(L'S') J\, M_J \\ \delta\, \omega\, \alpha\, f\, \tilde{\alpha}'\, T M_T \end{matrix} \right\rangle, \tag{29}$$

where π gives the parity of the states; $\pi = +1$, if E_0-even and $\pi = -1$, if E_0 -odd. Using the developed algebraic technique and computers it is possible to calculate matrix elements (29) in the wide range of U_{A-1} -irreducible states and mass numbers A. From (29) it follows, that the integrals of motion of H^0_{coll} consist of $\{ J\pi ; E_0(\lambda\mu) \} TM_T$. The matrix of H^0_{coll} with given integrals of motion has a finite dimension, thus its diagonalization can be performed without essential approximations used. In other words, we can find exact solutions and the spectrum of H^0_{coll}. A qualitative analysis of this spectrum has been described in [2].

7. Pairing-like effects and further generalizations

The collective forms of motion represent only one aspect of many-sided features of the nuclei. Other important effects are related with the pairing interaction, studied from the algebraic point of view in the shell-model basis in [10-12]. This type of interaction is not taken into account in the Elliott's model, and this is one of the reasons, why it is difficult to compare the predictions of this model with experimental data.

The question is whether it is possible to take into account the pairing-like features in the strictly restricted dynamics models. Before discussing this question we shall explain in a few words the restricted dynamics idea (for details see [2, 13]). Let us consider the Hamiltonian H, acting in the space $\mathcal{R}$, presented as the direct sum of the subspaces $\mathcal{R}^{(\Gamma)}$

$$\mathcal{R} = \mathcal{R}^{(\Gamma')} \dotplus \mathcal{R}^{(\Gamma'')} \dotplus \ldots \quad . \tag{30}$$

To the decomposition (30) we adopt the following decomposition of H

$$H = H^0 + H' + H'' + \ldots \tag{31}$$

with terms arranged in such a way, that all the nondiagonal with respect to Γ elements of H^0 vanish. It means, that H^0 acts within the space $\mathcal{R}^{(\Gamma)}$, i.e. H^0 is the Hamiltonian, restricted to the subspace $\mathcal{R}^{(\Gamma)}$ of the space $\mathcal{R}$. We refer to such a Hamiltonian as to the restricted dynamics Hamiltonian (with respect to the space $\mathcal{R}^{(\Gamma)}$). The expression (25) provides an example of the operatorial decomposition (31). The Hamiltonian H^0_{coll}, discussed in the previous section, representing collective features of H, is the term of H, obtained restricting H to the U_{A-1} -irreducible space $\mathcal{R}^{(E)}$.

In order to take into account other features, hidden in H, we restrict H to the U_3 -irreducible space $\mathcal{R}^{(E)}$ (we remember, that E denotes both U_{A-1}- and U_3 -irreducible representations). By those means we introduce the U_3 -scalar term $H^0_{anticoll}$ of H, which describes the features, opposite to the collective ones. For this reason we refer to $H^0_{anticoll}$ as to the strictly restricted anticollective Hamiltonian. This Hamiltonian takes into account strong space correlations and in this sense $H^0_{anticoll}$ is an analogue of the pairing interaction. Considering the Schrodinger equation for the Hamiltonian $H^0_{coll} + H^0_{anticoll}$ the strictly restricted dynamics model has been introduced [9] which gives a far reaching generalization of the Elliott's model. More detailed description of this Hamiltonian, including the qualitative analysis of its spectrum and some applications can be found in [2, 6].

We conclude with the following remark. Starting from the Elliott's collective bands operator $\tilde{V}^{0}_{0\varphi,\nu\nu}$, we described step by step its generalizations, ending with the strictly restricted dynamics Hamiltonian. Originally this Hamiltonian and even much more sophisticated restricted dynamics Hamiltonians have been introduced axiomatically, and were used to build up the nuclear models of various degrees of complexity. Their general description and references to original papers are given in [14].

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STRESZCZENIE

Nowa interpretacja modelu Elliotta oparta na U_{A-1}-nieprzywiedlnym rozkładzie centralnych oddziaływań kwadrupolowych między A-cząstkami została zaproponowana oraz wyjaśnione zostało jej powiązanie z operacyjnymi seriami używanymi w modelu ograniczonej dynamiki. Krok po kroku przedyskutowano uogólnienie dowolnego potencjału nukleonowego jak i innych członów Hamiltonianu, kończąc na ograniczonym modelu dynamicznym przy uwzględnieniu zarówno kolektywnych jak i antykolektywnych efektów.

РЕЗЮМЕ

Предложена новая интерпретация модели Эллиотта основана на неприводимом U_{A-1} распределении центральных квадрупольных взаимодействий между А-частицами и выяснена ее связь с операционными сериями применяемыми в модели ограниченной динамики. Подробно рассматривается обобщение любого нуклонного потенциала, а также других членов гамильтониана, останавливаясь на ограниченной динамической модели с учетом так коллективных, как и антиколлективных эффектов.