APPARENT CONSISTENCY OF RUTHERFORD'S HYPOTHESIS OF THE NEUTRON AS A COMPRESSED HYDROGEN ATOM

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Abstract

In this note we summarize certain recent results, presented in detail elsewhere, according to which Rutherford's historical conception of the neutron as a "compressed hydrogen atom" is apparently consistent, provided that the problem is studied via the hadronic generalization of quantum mechanics. In particular, the spin is recovered via a simple constraint on the orbital angular momentum of the electron when moving in condition of total immersion of its wavepacket within the hyperdense medium in the interior of the proton. An isotopic lifting of Schrödinger's equation for the hydrogen atom then allows the quantitative interpretation of all characteristics of the neutron, such as: rest energy, meanlife, spin, charge, space and charge parity, magnetic and electric dipole moments and decay.

1 INTRODUCTION

Rutherford [1] conceived the neutron as a "compressed hydrogen atom", i.e., as a bound state $n = (p^+, e^-)$ of a proton p^+ and an electron e^- totally compressed inside the proton, as conceivable, say, in the core of a star.

Rutherford's hypothesis on the existence of the neutron was confirmed some twelve years later by Chadwick [2]. Nevertheless, Rutherford's conception of the neutron structure was claimed to be afflicted by several "inconsistencies", i.e., the inability to reach a quantitative representation of:

1. the neutron rest energy, because $E_n = 939.6$ MeV$> E_p + E_e + 938.8$ MeV, thus requiring a *positive* binding energy which would be against basic quantum mechanical laws on bound states;

2. the neutron very large meanlife (for particle standards) of $15' = 917''$, owing to the inability to bound the very light electron inside the proton for such a long period of time;

3. the neutron spin $\frac{1}{2}$, because the quantum mechanical bound state of two particles of spin $\frac{1}{2}$ can only produce an integer total spin;

and additional problematic aspects.

In a contribution of 1978, this author [3] questioned the exact applicability of quantum mechanics for the physical conditions of Rutherford's compression, and suggested the construction of a covering of quantum mechanics specifically conceived for the hadronic structure under the name of *hadronic mechanics*.

The main contention is that quantum mechanics can at best provide a treatment of Rutherford's hypothesis $n = (p^+, e^-)$ as a sort of "small atom", i.e., as *an electron freely orbiting inside the proton*. A host of "inconsistencies" then follow, besides those recalled above, such as the existence of a spectrum of levels of atomic type with energies near that of the proton, which are evidently without verification in Nature.

Clear experimental evidence indicates that the proton is not an empty sphere with points in it. Even though its constituents are expected to have a point-like charge structure, there exist no "point-like wave packets" in the physical reality. As a matter of fact, all massive particles, including the electron, have a wavepacket which is of the order of the size of all hadrons ($\sim 1F = 10^{-13}$cm). Thus, the interior of the proton is a hyperdense medium composed of the wavepackets of all constituents in condition of total mutual immersion (called *hadronic medium* [3]).

It is evident that Rutherford's electron cannot freely orbit inside one of the densest objects measured in laboratory, in a quantitative way similar to the free orbiting of the same electron in empty space when a member of the hydrogen atom. The profound physical differences between motion in vacuum and motion inside the proton are therefore expected to render the study of Rutherford's hypothesis via ordinary quantum mechanics inconsistent and, at best, inconclusive.

Hadronic mechanics was conceived [3] and subsequently developed (see papers [4–16] and quoted references), in general, to attempt the identification of the hadronic constituents with physical, ordinary, massive, particles generally produced in the spontaneous decays and, in particular, for a quantitative study of Rutherford's hypothesis.

The central assumption is the admission in the hadronic structure, not only of all conventional Hamiltonian interactions, but also of additional contact, nonlocal and non-Hamiltonian interactions which are expected from the motion of extended wavepackets within the hadronic medium constituted by the wavepackets of the remaining constituents. The non-Hamiltonian character of the latter forces then renders *necessary* a certain generalization of the structure of quantum mechanics called of *isotopic type* (see next section).

Hadronic mechanics was applied in its original, rudimentary form to the construction of a structure model of the π^0 as a "compressed positronium", $\pi^0 = (e^+, e^-)$, i.e., as a generalized bound state of one electron and one positron with wavepackets in condition of total mutual immersion. It was first shown that the use of quantum mechanics would render the model inconsistent on numerous counts. In this way, paper [3] showed the *necessity* of generalizing quantum mechanics for the possible identification of the hadronic constituents with physical particles already at the level of the lightest known hadron.

The use of the covering hadronic mechanics allowed the quantitative interpretation via model $\pi^0 = (e^+, e^-)$ of *all* characteristics of the π^0, such as: rest energy, meanlife, spin, charge radius, electric and magnetic moments, space and charge parity, as well as primary decays. The model was extended in ref. [3] to the remaining light mesons which resulted to be hadronic bound states of electrons and positrons in number increasing with mass, according to a physical law previously established at the atomic and nuclear levels. Ref. [3] ended with the suggestion to develop hadronic mechanics up to a point suitable for the quantitative treatment of Rutherford's historical hypothesis on the neutron.

Thanks to recent developments in hadronic mechanics [4–16], we are now in a position to present a quantitative treatment of the historical hypothesis $n = (p^+, e^-)$ and show that the model can indeed represent *all* the intrinsic characteristics of the neutron, as well as its decay. In this way, problematic aspects 1), 2), and 3) above are not "inconsistencies" of Rutherford's hypothesis, but rather problematic aspects in the use of quantum mechanics for physical conditions under which it appears to be inapplicable.

In this note we summarize the main results of our studies on Rutherford's neutron. A comprehensive representation is provided elsewhere [14].

2 QUANTITATIVE REPRESENTATION OF RUTHERFORD'S HYPOTHESIS

Hereon we shall assume a knowledge of hadronic mechanics as presented in paper [4]. We are referring to a universal enveloping isoassociative algebra $\hat{\mathcal{A}}$ [5] of operators $A, B, \cdots$ with isoproduct and isounit

$$\begin{aligned} \hat{\mathcal{A}}: \quad & A * B \stackrel{\text{def}}{=} ATB\,, \quad T = T^\dagger = \text{fixed and nonsingular}\,, \\ & \hat{I} * A = A * \hat{I} = A\,, \quad \text{for all } A \in \hat{\mathcal{A}}\,, \quad \hat{I} = T^{-1} \end{aligned} \tag{2.1}$$

acting isomodularly on an iso-Hilbert space with composition law

$$\hat{\mathcal{H}}: \langle \phi \hat{|} \psi \rangle \stackrel{\text{def}}{=} \langle \phi | G | \psi \rangle \hat{I} \tag{2.2}$$

over the isofield

$$\hat{\mathbf{C}} = \{\hat{c} | \hat{c} = c\hat{I}\,, \quad c \in \mathbf{C}\,, \quad \hat{I} \in \hat{\mathcal{A}}\} \tag{2.3}$$

with composition $\hat{c}_1 * \hat{c}_2 = \widehat{c_1 c_2} = c_1 c_2 \hat{I}$.

Throughout our analysis we shall assume that the isotopic elements T and G coincide and are positive-definite, $T = G > 0$. Under these assumptions, isohermiticity on $\hat{\mathcal{H}}$ coincides with Hermiticity in a conventional Hilbert space $\mathcal{H}$. As a result, *observables of quantum mechanics (such as the Hamiltonian H of the positronium or the hydrogen atom) remain observable in hadronic mechanics* [4]. Moreover, their eigenvalues remain real, although different than the original ones. Thus, if E_0 represents a (spectrum of) eigenvalues of the quantum mechanical Hamiltonian H, the eigenvalues of the same operator under isotopic liftings are different and we shall write

$$H\psi = E_0 \psi \rightarrow H * \psi \stackrel{\text{def}}{=} HT\psi = \hat{E} * \psi \equiv E\psi\,. \tag{2.4}$$

We are now in a position to formulate our objective: *identify isotopies (2.4) of the Hamiltonian of the positronium and of the hydrogen atom which are such to provide a quantitative representation of all intrinsic characteristics of the π^0 and of neutron, respectively.* Besides resolving the "inconsistencies" recalled in the Introduction, we shall be seeking isotopies (2.4) which are capable of *suppressing the atomic spectrum of energy levels* down to only one level: the π^0 or the neutron, depending on the isotopy considered.

The primitive classical quantity is Janussis' [6], noncanonical, Birkhoffian [7] action functional of the two-body, closed non-Hamiltonian system

$$\hat{\mathcal{A}} = \int_{t_1}^{t_2} \left\{ \vec{p} * \dot{\vec{r}} - \left[\frac{1}{2} \frac{\vec{p} * \vec{p}}{m} + V(\vec{r}) \right] \right\} dt \tag{2.5.a}$$

$$\vec{p} * \vec{p} = \frac{1}{\rho} \vec{p} \cdot \dot{\vec{r}}\,, \quad H = \frac{1}{2} \frac{\vec{p} * \vec{p}}{m} + V\,, \quad \rho = \frac{m}{m - g} \tag{2.5.b}$$

where ρ represents a non-Newtonian acceleration-dependent force. In general $\rho = \rho(\vec{r})$. But since only the circle is admitted [3,6], we shall assume hereon for simplicity $\rho =$ const. The understanding is that substantially less trivial noncanonical models exist [6,7].

As well known, Schrödinger's equations can be derived from the conventional, classical, canonical action functional $\mathcal{A}$ via the naive quantization $\mathcal{A} \rightarrow I(-i\log\psi)$, $I = \text{diag.}(1, 1, \cdots, 1)$, $\hbar = 1$, applied to the canonical Hamilton-Jacobi equations.

In ref. [8] we argued that such a naive quantization cannot be applied to *noncanonical* action functionals (2.5), but must be replaced by the more general mapping called *naive hadronization*

$$\hat{\mathcal{A}} \rightarrow \hat{I}(-i \log \psi)\,, \quad \hat{I} = T^{-1} \tag{2.6}$$

under which the Birkhoffian Hamilton-Jacobi equations [7] are mapped into the Schrödinger-isotopic equations of hadronic mechanics

$$-\frac{\partial \hat{\mathcal{A}}}{\partial t} = H \rightarrow i \frac{\partial}{\partial t} \psi = \left[H - i \left(\frac{\partial \hat{I}}{\partial t} \right) \log \psi \right] * \psi\,, \tag{2.7.a}$$

$$\frac{\partial \hat{\mathcal{A}}}{\partial \vec{r}} = \frac{1}{\rho} \vec{p} \rightarrow -i \vec{\nabla} \psi = \frac{1}{\rho} \left[\vec{p} + i\rho \left(\vec{\nabla} \hat{I} \right) \log \psi \right] * \psi\,. \tag{2.7.b}$$

Under the assumption that $\hat{I}$ does not depend on the local coordinates, Eq.s (2.7) reduce to the form

$$\vec{p} * \psi = -i\rho \vec{\nabla} \psi \tag{2.8.a}$$

$$
\begin{aligned}
i\frac{\partial}{\partial t}\psi &= \left[-\frac{1}{2\overline{m}}\hat{\Delta} + \hat{V}(\bar{r}) - i\left(\frac{\partial \hat{I}}{\partial t}\right)\log\psi\right] * \psi = H_{\text{eff}} * \psi = E\psi && \text{(2.8.b)} \\
\overline{m} &= m/\rho\,, \quad \hat{\Delta} = \Delta\hat{I}\,, \quad \hat{V} = V\hat{I}\,. && \text{(2.8.c)}
\end{aligned}
$$

In our isotopic liftings, one should therefore expect: a) the alteration of the eigenvalue equation for the linear momentum; b) the alteration of the corresponding expression in the kinetic energy; c) the general appearance of a logarithmic term in the effective iso-Hamiltonian; d) the isotopic action of the effective iso-Hamiltonian in the states; and e) the alteration (*mutation* [3]) of the original energy eigenvalues. Notice also the ultimate *nonlinearity* of the theory [3].

The classical origin of the non-Hamiltonian forces is clearly expressed by the noncanonical character of generalized action (2.5). The operator counterpart is expressed by the emergence of the modular-isotopic action of the isoenveloping operator algebra $\hat{\mathcal{A}}$ on the elements ψ of the iso-Hilbert space.

According to the original proposal [3], the conventional unit of quantum mechanics, Planck's constant $\hbar = 1$, is generalized into the *isotopic unit* (or *isounit*) $\hat{I}$ which was conceived to admit, in general, integrodifferential realizations as one way to represent the nonlocal nature of the conditions of mutual wave-overlapping of the hadronic constituents.

In this work we shall assume the expression of the isounit worked out in paper [9]

$$
\hat{I} = \hat{I}(0)e^{-i|E_{\overline{u}}|\langle\overline{u}|\psi\rangle t}\,, \quad \hat{I}(0)^2 = \hat{I}(0) \tag{2.9}
$$

which clearly expresses the mutual penetration of the wavepackets of the constituents. In particular, when this overlapping is null, the isotopic unit recovers the trivial unit I, hadronic mechanics recovers quantum mechanics in its entirety, and generalized action (2.5) becomes canonical.

The original, radial, hadronic, two-body equation submitted empirically in proposal [3] is given by

$$
\left(-\frac{1}{2\overline{m}}\Delta_r + \frac{e^r}{r} + V_0\frac{e^{-br}}{1-e^{-br}}\right)\psi = E\psi\,, \quad \overline{m} = m/\rho\,. \tag{2.10}
$$

Paper [9] has shown that the above equation emerges precisely as the isotopic lifting of the conventional radial equation for the Coulomb interactions under

assumption (2.8) for the isounit, according to the expressions

$$
\begin{aligned}
&\left(-\frac{1}{2m}\Delta_r - \frac{e^2}{r}\right)U(r) = E_u U(r) \to \left(-\frac{1}{2\overline{m}}\Delta_r - \frac{e^2}{r}\right) * \psi(r) = \\
&= \left(-\frac{1}{2\overline{m}}\Delta_r \frac{e^2}{r} - E_{\overline{u}}\langle\overline{u}|\psi\rangle\right)\psi(r) \\
&\cong \left(-\frac{1}{2\overline{m}}\Delta_r - \frac{e^2}{r} + |E_{\overline{u}}|\langle\overline{u}|\psi\rangle\frac{e^{-br}}{1-e^{-br}}\right)\psi(r) = E\psi(r)\,. \qquad \text{(2.11)}
\end{aligned}
$$

Owing to the known property

$$
V_{\text{Hulton}} = V_0\frac{e^{-br}}{1-e^{-br}}\bigg|_{r\approx 0} \approx \frac{V_0}{b}\frac{1}{r} \tag{2.12}
$$

the hadronic radial equation (2.10) was written in ref. [3]

$$
\left[\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d}{dr}\right) + \overline{m}\left(E - V\frac{e^{-br}}{1-e^{-br}}\right)\right]\psi(r) = 0 \tag{2.13}
$$

and its solutions were reduced to the two equations in the two unknown parameters k_1 and k_2, Eq. (5.1.32), ref. [3],

$$
\begin{aligned}
k_1\left[1-(k_2-1)^2\right] &\stackrel{\text{def}}{=} k_1(1-\varepsilon^2) = \frac{1}{2c}(E^{\text{Tot}}b^{-1}) && \text{(2.14.a)} \\
\frac{(k_2-1)^3}{k_1} = \frac{\varepsilon^3}{k_1} &= \frac{9\times 10^6}{4\pi c}(\tau^{-1}b^{-1}) && \text{(2.14.b)}
\end{aligned}
$$

where E^{Tot}, τ and b^{-1} are the total energy, mean life and charge radius of the particle considered.

The model was applied to the π^0 particle as a "compressed positronium" $\pi^0 = (e^+, e^-)$, according to Eq.s (5.1.14), p. 836, ref. [3], which we can now write in the *identical* isotopic form

$$
\begin{aligned}
i\frac{\partial}{\partial t}\psi_{\pi^0} &= \left[-\frac{1}{2\overline{m}}\hat{\Delta} - \frac{\hat{e}^2}{r} + i\left(\frac{\partial\hat{I}}{\partial t}\right)\log\psi\right] * \psi_{\pi^0} = E\psi_{\pi^0} && \text{(2.15.a)} \\
E^{\text{Tot}}_{\pi^0} &= 2E^{\text{Rest}}_e + 2E^{\text{Kin}}_e - E = 135\ \text{MeV} && \text{(2.15.b)} \\
\tau^{-1}_{\pi^0} &= 4\pi\lambda\!\!\!^{-}|\psi(0)|^2 E^{\text{Tot}}_e = 10^{16}\ \text{sec}^{-1}\,, && \text{(2.15.c)} \\
b^{-1}_{\pi^0} &= 10^{-13}\ \text{cm}\,, && \text{(2.15.d)} \\
\overline{m} &= m/\rho\,, \quad \hat{\Delta} = \Delta\hat{I}\,, \quad \hat{e}^2 = e^2\hat{I}\,, \quad \hbar = 1\,. && \text{(2.15.e)}
\end{aligned}
$$

The above model resulted to be consistent, i.e., Eq.s (2.14), under values (2.15.b)-(2.15.d) admit the values

$$k_1 = 0.34\,, \quad k_2 = 1 + 4.27 \times 10^{-2}\,. \tag{2.16}$$

In particular, since $k_2 \simeq 1$, the model achieved the suppression of the positronium spectrum down to only one level of energy, that of the π^0. The original proposal [3] therefore permitted a quantitative representation of *all* physical characteristics of the π^0 as a bound state of one ordinary electron e^- and one ordinary positron e^+ at distances of the order of 10^{-13}cm, including: the rest energy, the mean life, the total zero spin, the total null charge, the total null magnetic and electric dipole moments, the space and charge parity, as well as the primary decay $\pi^0 \to \gamma\gamma$. The additional decay $\pi^0 \to e^+ + e^-(< 2 \times 10^{-6}\%)$ could be interpreted evidently as a tunnel effect in which the constituents penetrate the hadronic barriers of Hamiltonian and non-Hamiltonian forces.

The electrons (and positrons) $e^\pm$ were called *eletons* (and *antieletons*) and denoted with the symbols $\epsilon^\pm$ in ref. [3] in order to indicate the expectation that the penetration of their wavepackets in the hyperdense hadronic medium inside the proton may well cause deformations (called *mutations*) of their characteristics. Structure model (2.15) was then denoted $\pi^0 = (\epsilon^+, \epsilon^-)$, and the positonium compression denoted with

$$\text{pos.} = (e^+, e^-)_{\text{Quantum Mech.}} \to \pi^0 = (\epsilon^+, \epsilon^-)_{\text{Hadr. Mech.}}\,. \tag{2.17}$$

The hypothesis of mutation of elementary particles in the transition from motion in vacuum to motion within hadronic matter was subsequently studied in details in ref.s [10,11,12], and appears to be confirmed in a preliminary way by neutron interferometric measures by Rauch and his collaborators (see ref. [13] and quoted references) on the apparent alteration of the charge distribution and magnetic moment of neutrons under sufficiently intense external nuclear (as well as electromagnetic) fields.

It was stressed in ref. [3] that the model $\pi^0 = (\epsilon^+, \epsilon^-)$ is inconsistent if treated via conventional quantum mechanics. In fact, this would provide a representation of the π^0 as a sort of "small positronium", with a host of inconsistencies. The first one is the inability of quantum mechanics to achieve a representation of the total energy 135 MeV of the π^0 as a bound state of two particles each with 0.5 MeV rest energy. In fact, this would call for a *positive* binding energy which is not admissible in terms of real energy solutions. Hadronic mechanics resolves this difficulty in full because

the non-Hamiltonian forces result in a sort of renormalization $\overline{m}_e = m_e/\rho$ of the rest energy of the electron m_e up to such a value to allow indeed a real negative binding energy in Eq. (2.15.a) and a total value of 135 MeV.

In different terms, the consistency of the model is due precisely to the *noncanonical* nature of Jannussis' Birkhoffian action (2.5) which, via hadronization (2.6), implies the consistency of Eq.s (2.15).

Rutherford's historical hypothesis can now be written $n = (p^+, \epsilon^-)$, where the use of the symbol p^+ stands to denote the assumption that the proton is not mutated in the structure owing to its rest energy much higher than that of the electron, while the electron e^- is mutated into the eleton ϵ^- because of its penetration within the hyperdense medium in the interior of the proton.

We shall therefore write Rutherford's compression

$$\text{Hydr. Atom} = (p^+, e^-)_{\text{Quantum Mech.}} \to n = (p^+, \epsilon^-)_{\text{Hadr. Mech.}}\,. \tag{2.18}$$

The hadronic structure model of the neutron can then be written

$$\begin{aligned}
i\frac{\partial}{\partial t}\psi_n &= \left[-\frac{1}{2\overline{m}}\hat{\Delta} - \frac{\hat{e}^2}{r} + \left(\frac{\partial \hat{I}}{\partial t}\right)\log\psi_n\right] * \psi_n = E\psi_n && \text{(2.19.a)}\\
E_n^{\text{Tot}} &= E_p^{\text{Rest}} + E_\epsilon^{\text{Rest}} + E_\epsilon^{\text{Kin}} - E = 939.6\ MeV && \text{(2.19.b)}\\
\tau_n^{-1} &= 4\pi\lambda\!\!\!^{-}\,|\psi(0)|^2\,\alpha E_\epsilon^{\text{Tot}} = 1.09 \times 10^{-3}\text{sec}^{-1} && \text{(2.19.c)}\\
b_n^{-1} &= 0.8 \times 10^{-13}\text{cm}\,, && \text{(2.19.d)}\\
\overline{m} &= m/\rho\,, \quad \hat{\Delta} = \hat{\Delta}\hat{I}\,, \quad \hat{e}^2 = e^2\hat{I}\,, \quad \hbar = 1\,, && \text{(2.19.e)}
\end{aligned}$$

and they result to be consistent, with solutions of Eq.s (2.14)

$$k_1 = 2.6, \qquad k_2 = 1 + 0.81 \times 10^{-8}\,, \tag{2.20}$$

that are close to value (2.16) for the π^0. This implies, again, the suppression of the Hulten spectrum of energy

$$E = \frac{b^2}{4\overline{m}}\left(\frac{\overline{m}V_0}{b^2}\frac{1}{n} - n\right) = \frac{b^2}{4\overline{m}}\left[k_2\frac{1}{n} - n\right] \tag{2.21}$$

down to only one level: the neutron.

This implies the apparent possibility of representing the rest energy, meanlife and charge radius of the neutron, as well as the elimination of the atomic-type spectrum of excited levels of energy near the neutron rest energy which do not exist in the physical reality.

The representation of the spin $\frac{1}{2}$ is permitted by the recent studies on the hadronic angular momentum and spin [15,16] which can be summarized as follows.

The *hadronic angular momentum* is characterized by the operators

$$\hat{L}_k = \varepsilon_{ijk} r_i * p_j \quad \varepsilon \hat{\mathcal{A}} \tag{2.22}$$

and isocommutation rules [16]

$$[r_i, r_j]_{\hat{\mathcal{A}}} = 0\,, \quad [p_i, p_j]_{\hat{\mathcal{A}}} = 0\,, \quad [r_i, p_j]_{\hat{\mathcal{A}}} = i\rho\delta_{ij} \tag{2.22.a}$$

$$\left[\hat{L}_i, \hat{L}_j\right]_{\hat{\mathcal{A}}} = i\rho\varepsilon_{ijk}\hat{L}_k \tag{2.22.b}$$

where the brackets

$$[A, B]_{\hat{\mathcal{A}}} = A * B - B * A = ATB - BTA \tag{2.23}$$

characterize the (operator version of) the *Lie-isotopic algebra* $\widehat{SO}(3)$ of ref.s [15].

As in the conventional case, the isosquare and third component constitute a maximal set of isocommuting operators which can be simultaneously diagonalized, with isoeigenvalue equations [16]

$$\hat{\vec{L}}^2 * \hat{Y}_{lm}(\theta,\varphi) = \rho l(\rho l + 1)\hat{Y}_{lm}(\theta,\varphi) \tag{2.24.a}$$

$$\hat{L}_3 * \hat{Y}_{lm}(\theta,\varphi) = \rho m \hat{Y}_{lm}(\theta,\varphi) \tag{2.24.b}$$

$$l = 1,2,3,\ldots\,, \qquad m = l, l-1, \ldots, -l$$

where

$$\hat{\vec{L}}^2 = \sum_{k=1}^{3} \hat{L}_k * \hat{L}_k\,, \quad \hat{Y}_{lm}(\theta,\varphi) = T^{-1/2} Y_{lm}(\theta,\varphi) \tag{2.25}$$

the Y's are the conventional spherical harmonics, and the quantity ρ is precisely that emerging from Jannussis' Birkhoffian action (2.5). Intriguingly, isocommutation rules (2.22) are equivalent to the corresponding classical ones using Birkhoffian brackets [16].

The *hadronic spin* is characterized by the isorepresentations of the $\widehat{SU}(2)$ covering [16] of the $\widehat{SO}(3)$ symmetry [15], here defined as the isotopic Lie group of isounitary operators $\hat{U}$ leaving invariant the generalized separation in complex two-dimensional space

$$\widehat{SU}(2): \quad z_i^\dagger g_{ij} j_j = z_1^* g_{11} z_1 + z_2^* g_{22} z_2\,, \quad g_{kk} > 0\,. \tag{2.26}$$

The universal enveloping isoassociative algebra $\hat{\mathcal{A}}(\widehat{SU}(2))$ is now characterized by the isotopic element $T = g$, and the isounit $\hat{I} = g^{-1}$. The operators $\hat{U}$ verify the condition of isounitarity [16]

$$\hat{U} * \hat{U}^{-\hat{1}} = \hat{U}^{-\hat{1}} * \hat{U} = \hat{I} \tag{2.27}$$

with explicit form

$$\hat{U} = e_{\hat{\mathcal{A}}}^{i\hat{J}_k\theta_k} = \hat{I} e^{i\theta_k T \hat{J}_k} = e^{i\hat{J}_k T\theta_k}\hat{I} \tag{2.28}$$

where the $\hat{J}$'s are isohermitean. If one assumes the iso-Hilbert space with isoinner product

$$\hat{\mathcal{H}}_{\hat{S}} : \langle a \hat{|} b\rangle = \langle a|T|b\rangle \hat{I} \tag{2.29}$$

then isohermiticity coincides with conventional hermiticity, as recalled earlier, and we shall write $\hat{J} = \hat{J}^\dagger$.

Finally, the isounimodularity condition $\hat{\det}\hat{U} = \hat{I}$, holds iff det $U = 1$, i.e., iff [16]

$$\mathrm{Tr}(\hat{J}_k p) = 0\,, \quad k = 1,2,3\,. \tag{2.30}$$

Under the condition that $g > 0$, $\widehat{SU}(2) \approx SU(2)$ [16]. We can then write the isocommutation rules with the conventional structure constants

$$\left[\hat{J}_i, \hat{J}_j\right]_{\hat{\mathcal{A}}} = \hat{J}_i * \hat{J}_j - \hat{J}_j * \hat{J}_i = \hat{J}_i g \hat{J}_j - \hat{J}_j g \hat{J}_i = i\varepsilon_{ijk}\hat{J}_k\,. \tag{2.31}$$

The construction of the isorepresentations of $\widehat{SU}(2)$ then yields the *fundamental isorepresentation* of $\widehat{SU}(2)$ [16]

$$\hat{J}_1 = \frac{1}{2}\begin{pmatrix} 0 & g_{22}^{1/2} \\ g_{11}^{-1/2} & 0 \end{pmatrix}, \quad \hat{J}_2 = \frac{1}{2}\begin{pmatrix} 0 & -ig_{22}^{-1/2} \\ ig_{11}^{-1/2} & 0 \end{pmatrix},$$

$$\hat{J}_3 = \frac{\Delta^{1/2}}{2}\begin{pmatrix} g_{11}^{-1/2} & 0 \\ 0 & -g_{22}^{-1/2} \end{pmatrix} \tag{2.32}$$

where $\Delta = \mathrm{Det}g = g_{11}g_{22} > 0$, with isoeigenvalues equations

$$\hat{\vec{J}}^2 * |\hat{b}_i^2\rangle = \frac{\Delta^{1/2}}{2}\left(\frac{\Delta^{1/2}}{2} + 1\right)|\hat{b}\rangle \tag{2.33.a}$$

$$\hat{J}_3 * |\hat{b}\rangle = \pm\frac{\Delta^{1/2}}{2}|\hat{b}\rangle \tag{2.33.b}$$

and with similar results for representations of higher dimensions.

The *total hadronic angular momentum* is given by the tensorial product of the angular and intrinsic momentum, with total values given by [16] $\hat{J}^{T_0}_{\mathrm{Tot}} = \hat{L}_l \otimes \hat{J}_s$ and total isoeigenvalues

$$\begin{aligned}
\hat{J}^2_{\mathrm{Tot}} * |Y \otimes b\rangle &= (\rho l + \Delta^{1/2}s)\left[\rho l + \Delta^{1/2}s + 1\right]|Y \otimes b\rangle \\
\hat{J} * |Y \otimes b\rangle &= (\rho m_l + \Delta^{1/2}m_s)|Y \otimes b\rangle \qquad (2.34) \\
l = 0,1,2,3,\cdots\,, \quad & s = 0,\frac{1}{2},1,\frac{3}{2},\cdots \\
m_l = l, l-1,\ldots,-l\,, \quad & m_s = s, s-1,\ldots,-s
\end{aligned}$$

Thus, the *total hadronic spin of the neutron* in model $n = (p^+, \epsilon^-)$ is given by

$$j^{\mathrm{Neutron}}_{\mathrm{Tot}} = s_p + \rho l_\epsilon - \Delta^{1/2}s_\epsilon = \frac{1}{2} \qquad (2.35)$$

and evidently holds under the values

$$\rho = \frac{1}{2}\Delta^{1/2} \qquad (2.36)$$

i.e.,

$$\begin{aligned}
j^{\mathrm{Neutron}}_{\mathrm{Tot}} &= \frac{1}{2} + \frac{1}{2} - \frac{1}{2} = s_p = \frac{1}{2} \qquad (2.37.a) \\
j^{\mathrm{Eleton}}_{\mathrm{Tot}} &= \rho l + \Delta^{1/2}s = 0\,. \qquad (2.37.b)
\end{aligned}$$

The conceptual interpretation of the latter expression is so simple, to appear trivial (see Fig. 1).

The quantitative interpretation of the (anomalous) magnetic moment of the neutron is fully in line with the notion of mutation of the electron e^- into the eleton ϵ^- [3]. In fact, the isotopy originating from hadronization (2.6), results first into an isotopic lifting of the three-dimensional Euclidean metric $\delta = \mathrm{diag}(1,1,1)$ of the type $g = T\delta$, $T = (b_1^2, b_2^2, b_3^2)$ which, in turn, results into a generalization of the Minkowski metric of the type [10,11]

$$\begin{aligned}
\eta &= \mathrm{diag}(1,1,1,-1) \qquad (2.38.a) \\
g &= T\eta\,, \quad T = \mathrm{diag}(b_1^2, b_2^2, b_3^2, b_4^2)\,, \quad b_\mu > 0\,. \qquad (2.38.b)
\end{aligned}$$

The above expressions are motivated by several phenomenological calculations on the apparent deviations of the behavior of the meanlife of unstable hadrons at different speeds from Einstenian predictions (see ref.s [10,11] and

quoted papers). Lifting (2.39) essentially expresses a form of *geometrization* of the medium inside the proton, where the deviation $T > I$ from the Minkowski metric η represents the deviation of the hadronic medium from empty space.

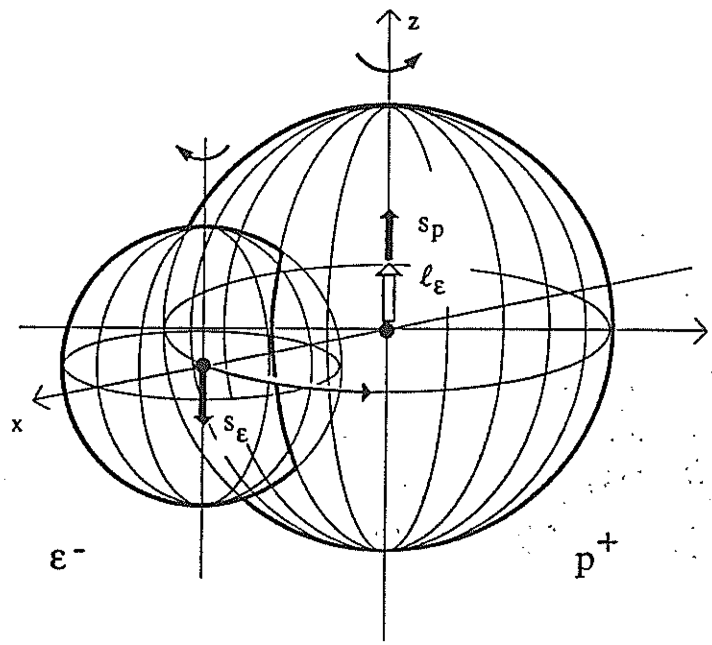

FIGURE 1. A schematic view of the structure model of the neutron $n = (p^+, \epsilon^-)$ proposed in this paper along Rutherford's historical hypothesis. The proton is represented, not as an empty sphere with points in it, but as one of the densest objects measured in laboratory until now. As such, the proton is depicted as a sphere of radius equal to that of the charge distribution ($\sim$ 1F) filled up with the wavepackets of the constituents in conditions of total mutual overlapping (because their size is also of the order of 1F). Rutherford conceived his hypothesis on the neutron as a "compressed hydrogen atom". The figure therefore depicts the initiation of Rutherford's compression of the electron inside the proton where the electron is represented by a sphere schematizing its wavepacket, and sizes are not necessarily in scale. Once this physical setting is clearly identified, it is then easy to see that the electron can only penetrate inside the proton with the relative spinning "in phase" [3]

(to avoid high dissipative effects expected from the spinning of wavepackets one against the other), and with its angular momentum parallel to the spin of the proton. Only singlet states are therefore stable in hadronic mechanics [3], with triplet states being prohibited by high drag forces. These initial conditions appear to be rather plausible and well founded experimentally. The final phase of the compression is conjectural as of this writing. We argue that, when the electron is totally compressed inside the proton, the angular momentum is expected to coincide with the spin of the proton owing to their physical identity and, thus, to prevent inconsistencies in the mathematical treatment of the structure. This automatically allows to represent the spin of the neutron in model $n = (p^+, \epsilon^-)$ as coinciding with that of the proton, Eq. (2.39.a). The representation of all other intrinsic characteristics of the neutron is then readily allowed by the techniques of hadronic mechanics.

As expected from isorepresentations (2.35), lifting (2.39) requires the construction of a compatible generalization of Dirac's equations [12] where the elements b_μ enter directly into the structure of the generalized gamma matrices. In turn, these generalized matrices imply the following necessary mutation of the magnetic and electric dipole moments

$$\tilde{\mu} = \frac{b_3}{b_4}\mu = \frac{b_3}{b_4}\frac{e}{2m\ c}, \quad \tilde{\underline{m}} = \frac{b_3}{b_4}\underline{m} = \frac{b_3}{b_4}\frac{ie}{2mc}. \tag{2.39}$$

The (anomalous) magnetic moment of the neutron $n = (p^+, \epsilon^-)$ is then interpreted via the mutation (see Fig. 1 for signs)

$$\begin{aligned} \mu_n = -1.9\frac{e}{2m_pc} &= \mu_p - \mu_\epsilon^{\text{orb}} + \mu_\epsilon^{\text{intr.}} \\ &= 2.7\frac{e}{2m_pc} - 4.6\frac{e}{2m_pc} \end{aligned} \tag{2.40}$$

i.e.,

$$\mu_\epsilon^{\text{Tot}} = -4.6\frac{e}{2m_pc} = 2.5 \times 10^{-3}\mu_e\,, \quad \frac{b_3}{b_4} = 2.5 \times 10^{-3} \tag{2.41}$$

which is plausible when compared to the total angular momentum of the eleton (2.39b).

The electric dipole moment of the model $n = (p^+, \epsilon^-)$ can be proved to be null (at the level of nonrelativistic approximations) as in conventional quantum mechanics.

In conclusion, we can state that recent advances on hadronic mechanics permit the apparent quantitative representation of all the intrinsic characteristics of the neutron according to Rutherford's historical hypothesis as a

"compressed hydrogen atom", such as:

1. the rest energy of 939.6 MeV;
2. the meanlife of 917"=15';
3. the charge radius of $0.8 \times 10^{-13} cm$;
4. the total angular momentum $\frac{1}{2}$;
5. the zero total charge;
6. the anomalous magnetic moment $-1.9\mu_p$;
7. the null dipole electric moment; and
8. the space and charge parities.

The spontaneous decay of the neutron

$$n \to p^+ + e^- + \bar{\nu}_e \tag{2.42}$$

therefore appears to be a form of tunnel effect of the constituents through the Hamiltonian and non-Hamiltonian hadronic barriers. The emergence of the antineutrino is then expected to be due to the decay

$$\epsilon^- \to e^- + \bar{\nu}_e \tag{2.43}$$

where the decays of the eleton $\epsilon^\pm$ is inferred from the model when the eleton exits the hadronic medium in the interior of the proton, thus reacquiring the conventional characteristics for motion in vacuum under electromagnetic interactions, the latter occurring only via the emission of an antineutrino. We can therefore state that *Rutherford's compression of the electron in the interior of the proton may well result to be the mechanism at the origin of neutrinos in Nature. In particular, the neutrinos originate when the constraints in the orbital motion of the electron inside the proton are terminated when the electron exits the proton structure.*

Simple calculations show that the *eleton is, in our first approximation, at rest in the center of the proton*, because

$$E_\epsilon^{\text{Kin}} = k_1 bc \approx 0\,, \quad E = \frac{b^2}{2\overline{m}}\left(\frac{\overline{m}V_0}{b^2}\frac{1}{n} - n\right) \cong \epsilon V_0 \approx 0\,. \tag{2.44}$$

This implies that the rest energy of the eleton is 1.3 MeV. The use of the generalized energy equivalence for hyperspace (2.39) [10,11], $E = mb_4^2c^2$ where $m = m_e = 0.5$ MeV, then allow a first computation of all the parameters of the models as follows

$$\Delta_s \cong 1\,, \quad \rho \cong \frac{1}{2}\,, \quad b_4 \cong 16.5\,, \quad b = b_1 = b_2 = b_3 \cong 4 \times 10^{-2}\,, \tag{2.45}$$

with the understanding that other alternatives are possible [14].

According to this model, the ordinary electron e^- (positron e^+), when compressed down to the center of the proton p^+ (antiproton p^-) to yield a structure model of the neutron (antineutron $\bar{n}$) experiences a mutation of its characteristics according to the following ones of the eleton ϵ^- (antieleton ϵ^+):

1. rest energy 1.3 MeV;
2. meanlife of $15' \cong 917''$;
3. charge radius null;
4. total angular momentum null;
5. magnetic moment $2.5 \times 10^{-3} \mu_e$;
6. electric moment null; 7. space and charge parity null;

with primary decays.

$$\epsilon^- \rightarrow e^- + \bar{\nu}_e\,, \quad \epsilon^+ \rightarrow e^+ + \nu_e \tag{2.46}$$

where we have assumed the exact validity of the CTP symmetry with $m_n = m_{\bar{n}}$ and $m_p = m_{\bar{p}}$.

A relativistic study of the model presented in this paper is under way [17]. We should mention here that this relativistic extension is made possible by a certain generalization of Dirac's equation identified by Dirac himself in two of his last papers [18]. This "Dirac's generalization of Dirac's equation" results to possess an essential isotopic structure [12] and, most importantly, it implies the mutation of the spin, from the original value $\frac{1}{2}$, down to the value 0 for at rest condition, exactly as needed for Rutherford's hypothesis (2.18).

In conclusion, this author was aware since 1978 that rest energy, meanlife and charge radius of the neutron could be represented with essentially the same hadronic structure model of the pions introduced in paper [3]. However, at the time of that paper, this author was unaware that *the spin of the neutron in Rutherford's historical hypothesis had already been solved by Dirac in 1971 and 1972, although in a way unknown to Dirac.* In this paper we have merely worked out the nonrelativistic treatment of the case.

3 Concluding Remarks

The claimed "inconsistencies" of Rutherford's hypothesis on the neutron structure via conventional quantum mechanics caused an historical change

in the direction of research in particle physics, from the traditional patterns established at the atomic and nuclear levels (identification of the constituents with physical particles detectable in laboratory), to more abstract approaches (hadronic constituents such as the quarks which cannot be isolated in laboratory).

The apparent consistency of Rutherford's hypothesis via the hadronic generalization of quantum mechanics appears to offer the possibility of a "return ad originem", i.e., the identification of the hadronic constituents with physical ordinary, massive, particles produced in the spontaneous decays. In fact, by keeping in mind the identification of the constituents of light mesons with electrons and positrons of the original proposal [3], the achievement of a consistent representation of Rutherford's neutron evidently offers the possibility of reducing all remaining hadrons to a few stable particles.

Rather than being in conflict with quark theories, this "return ad originem" offers some genuine possibilities of resolving at least some of the now vexing problems afflicting quark theories, such as: the existence of a finite, nonnull probability of tunnel effects for free quarks by protons and neutrons [19], which is evidently contrary to experimental evidence; the inability to reach an interpretation of the fractional charge of the quarks; etc. These aspects are under investigation in papers [20].

Above all, the usefulness of a theory should not be judged solely via the mere interpretation of available data, but also from its possibility to foresee new applications.

Along these lines, it is well known that quark theories, in their currently available form, have been unable to provide any practical application of any nature.

The situation for the "return ad originem" advocated here is rather different. In fact, if the neutron is indeed a bound state of one proton and one electron, not only a host of new scientific applications appear on the horizon (as we hope to investigate in some future paper), but we open the door to potentially *new military applications.*

In the final analysis, the currently available scientific and military applications of the process for fission and fusion processes are the result of the achievement of the quantum mechanical generalization of classical mechanics, and its application to the *nuclear structure.* It is therefore easy to predict that, the hadronic generalization of quantum mechanics and its application to the *hadronic structure,* if consistent, will likely result in a variety of new, scientific and military applications. After all, fission and fusion have only touched the energy reservoir inside hadrons.

All these possibilities are centrally dependent on whether Einstein's Special Relativity is exactly or only approximately valid in the interior of hadrons. In fact, one can readily see that, if Einstein's Special Relativity is *exactly* valid for the interior dynamical problem of hadrons, then one can readily see that the mutation of ordinary particles needed to achieve a consistent interpretation of the hadronic structure models of Section 2 are impossible.

On the contrary, if Einstein's Special Relativity is only *approximately* valid in the interior dynamical problem (with the clear understandings, stressed in the literature of this research [10,11], that it must remain exactly valid for the center-of-mass motion of hadrons in vacuum, e.g., in particle accelerators), then the emerging generalization of the Casimir invariants of the Poincaré symmetry induced by geometric, generalized, metrics of type (2.39) [11] do allow indeed full theoretical grounds for the mutation of the characteristics of particles when immersed within the interior of hadronic matter, thus permitting precisely the "return ad originem" advocated here.

It is therefore hoped that experimentalists will finally conduct truly fundamental tests suggested in the literature since several decades ago, such as the measure of the meanlife of unstable hadrons at a sufficient number of different energies to allow the resolution whether it follows Einstenian laws or generalized laws [11].

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