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Nuclear Forces and General Relativity

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Abstract

Based on the binding energies of atomic nuclei, the article explains that the nuclear force field is equivalent to the non-inertial system, can be described by General Relativity. Solving the field equations obtains a series of numerical solutions, which show the characters of nuclear forces. On this basis, the nuclear force saturation is explained, the radius formula and radius constant of atomic nuclei are educeed. And the formula of nuclear binding energies is educeed in combination with the quantum theory. All of these are more systematic and perfect than traditional theories. In addition, based on these solutions, the constructions of meson-baryon resonances and hyperons are explained, and their masses are calculated, which are consistent with the experiments.

Keywords

Nuclear Force, Meson Field, General Relativity

1. Introduction

The nuclear forces are the interaction caused by the mass character of nucleons, which have a similar expression and formational essence to gravity. Gravity can be geometry, which is described systematically by General Relativity. The basis describing nuclear forces is the theory of meson field. However, the meson field equation is still approximate, especially for the nuclear forces in the medium and short ranges, it is not suitable, and many nuclear phenomena can only be explained using phenomenological theories. However, the meson field equation can be an approximate equation of Einstein's field equations with cosmological constants in the weak stationary states, which relates to General Relativity. Based on these similarities and theoretical connection, can we also consider the nuclear forces as geometry and use General Relativity to describe it and related nuclear properties more completely and systematically. Of course, nuclear forces involve the micro-world, which also has its own laws. It is difficult, even impossible, to explain all nuclear problems with General Relativity, we only want to seek basal and essential things.

2. Meson Field Equation and Nuclear Force Constant

Let us briefly describe the meson field equation of nuclear forces. The nuclear force is the mass attribute of nuclear matter, now we use the mass density as the source to express meson field equation as follows

$$\left.\begin{aligned}&\left(\nabla^2-k^2\right)\varphi\left(r\right)=4\pi G_{\mathrm{N}}\rho\left(r\right)\\&k=\frac{mc}{\hbar}\end{aligned}\right\}, \tag{1}$$

where $\varphi\left(r\right)$ is the nuclear force potential, G_{N} is the proportionality coefficient, m is the meson mass, and $\rho(r)$ is the mass density of the source, if there is only one point nucleon source, its mass is μ, the mass density can be expressed using the δ function as $\rho(r) = \mu\delta(\mathrm{r})$, the solution of Equation (1) is

$$\varphi=-G_{\mathrm{N}}\mu\frac{\mathrm{e}^{-kr}}{r}, \tag{2}$$

where G_{N} is similar to the gravitational constant, we call it the nuclear force constant. Equation (2) is equivalent to Yukawa potential, according to it the potential energy of another nucleon in the nuclear force field is

$$U=\mu\varphi=-G_N\mu^2\frac{\mathrm{e}^{-kr}}{r}. \tag{3}$$

From Equation (3), we can derive the relationship between nuclear force F and field strength E as

$$F=\mu E. \tag{4}$$

3. The Principle of Equivalence of the Nuclear Force Field

In the preface, we only, based on the comparability of nuclear forces and the gravitation as well as the relation of describing theories, put forward whether can use General Relativity to describe nuclear force fields. Now we look for the theoretic basis that regards nuclear forces as geometry.

The mass μ introduced in Equations (2), (3) and (4) reflects the ability of nucleons to generate and accept nuclear forces, we call it nuclear force mass. By definition, it differs from inertial mass introduced in Newton's second law. Usually the masses of nucleons and atomic nuclei are the inertial mass. In this way, there is a question of whether the nuclear force mass is equal to the inertial mass.

According to nuclear physics, nucleons release the binding energy when they combine to form an atomic nucleus. Saying from the point of view of field, they release the nuclear potential energy, some of which translate into the kinetic energy motioning in nuclear interior (center-of-mass system), others release in the laboratory system. Let the nuclear force mass of the i-th nucleon be μ_i, the inertia mass be M_i, its kinetic energy of motion within nucleus be T_i, the kinetic energy carried by the unit inertia mass be τ_i, and the nuclear potential at the junction be φ_i. According to the conservation of energy and Equation (3), the energy released by the entire atomic nucleus in the laboratory system express as

$$Q = -\sum_i \left(\mu_i \varphi_i + M_i \tau_i \right), \tag{5}$$

where the sum covers all the combined nucleons. For stable nuclei, the τ_i and φ_i should be constants, the subscripts can be threw off, and move them out of the sum. So, by simple operation from Equation (5), for an atomic nucleus with the mass number A, the average binding energy of nucleon can express as

$$\beta = -\frac{Q}{A} = \bar{M} \left(\frac{\sum_i \mu_i}{\sum_i M_i} \varphi + \tau \right), \tag{6}$$

where $\bar{M}$ is the average inertial mass of the nucleon in a nucleus. For nuclei with mass number from 40 to 120, their inertia mass changes three times, but the changes of average inertia mass of nucleon are very small, and the average binding energies are almost the same, independent of the mass of the nucleus. Based on this, the two summation parts in Equation (6), namely the nuclear force mass and inertia mass of the atomic nucleus, must be equal and eliminated regardless of whether the summation terms are many or few. Therefore, the nuclear force mass and inertia mass of each nucleon are also equal. In this way, we can assume that these two quantities are the same (experimental data explanation can be found in **Appendix**).

The nuclear force constant can be determined. Theoretical and experimental knowledge show that the coupling constant $g^2/\hbar c \approx 1$ for the interaction between π-mesons and baryons, *i.e.* for π^0-proton interaction, $G_\mathrm{p}\mu_\mathrm{p}^2/\hbar c \approx 1$. The nuclear force constant is

$$G_\mathrm{p} \approx \frac{\hbar c}{\mu_\mathrm{p}^2} = \frac{\hbar c}{M_\mathrm{p}^2} = 1.1300417 \times 10^{28}\ \mathrm{N \cdot m^2 \cdot kg^{-2}}. \tag{7}$$

where μ_p and M_p are two labels for the proton mass, but they are the same. However, G_N may vary for different baryonic fields, and how to take their values can see in the following text.

Furthermore, more importantly, the nuclear forces expressed by both Newton's second law and the field should have the same effect (see [1]), *i.e.*

Inertial mass × Acceleration = Nuclear force mass × Field strength.

By eliminating the two equal masses in the equation, we know that the acceleration of nucleons in the nuclear force field is independent of their masses. Therefore, similar to gravity [2], we can consider the motion in a specific nuclear force field to be equivalent to the motion in a non-inertial system without any external field. In short, a specific nuclear force field is equivalent to a non-inertial system. We refer to this equivalence as the equivalence principle of nuclear force field. It is the theoretical bases for us want to describe nuclear force using geometry [3].

4. The Equation of Nuclear Force Fields and Its Solutions

The mesons in the nuclear force field are zero-spin and non-zero-mass particles, so the nuclear force field is short-range and zero-spin field. Below, we will discuss the spin properties of the field described by Einstein's field equations and explore the equation form for describing nuclear force fields.

Einstein's field equations are

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G}{c^4} T_{\mu\nu}, \quad (\mu, \nu = 0,1,2,3). \tag{8}$$

where the $R_{\mu\nu}$ is Ricci tensor, the $g_{\mu\nu}$ is metric tensor, the R is a curvature scalar, and the $T_{\mu\nu}$ is the energy momentum tensor of matter. References [4] (pp. 292-294) and [5] have proved that Einstein's field equation can describe various fields composed of particles with different spins. They include the radiant transverse field made up of particles with spin 2, the mixed field made up of virtual particles with spin 1, longitudinal field and time-like field made up of virtual particles with spin 0. However, in the case of static spherical symmetry, there is neither radiation field [4] (p. 391) nor mixed field, there is only the time-like field made up of virtual particles with spin 0. In this case, the Equation (8) actually only describes the field of zero-spin virtual particles, However, Equation (8) only describes long-range fields, cannot describe nuclear force fields for short-range.

Einstein's field equations with cosmological constants are

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R - \lambda g_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu}, \tag{9}$$

$$T_{\mu\nu} = P g_{\mu\nu} + \left(\rho c^2 + P\right) u_\mu u_\nu. \tag{10}$$

where u_μ, u_ν are the fourth degree velocities, which define as $g^{\mu\nu} u_\mu u_\nu = -1$. The fields described by Equation (9) have the same spin properties with Equation (8), but which are the short-range and non-zero-mass particles fields. In addition, in weakly stationary states, the time component of Equation (9) can be approximately simplified as (refer to [4], pp. 171-172)

$$\left(\nabla^2 - \lambda\right) g_{00} = 0. \tag{11}$$

According to Schwarzschild metric, the Newtonian potential is

$$\varphi = -\frac{1}{2}\left(1 + g_{00}\right) c^2, \tag{12}$$

Appendix proves that for a static spherically symmetric field, Equation (12) is accurate and unique. Solving g_{00} from Equation (12) and replacing g_{00} in Equation (11) by it, we obtain

$$\left(\nabla^2 - \lambda\right)\varphi = 4\pi G_{\mathrm{N}} \left(\frac{\lambda c^2}{8\pi G_{\mathrm{N}}}\right). \tag{13}$$

Equation (13) resembles Equation (1), that is, under weak stationary states, the time component of Einstein's field equations containing the cosmological constant is exactly the meson field equation. Based on the properties of Equation (9) and its relationship with the meson field equation, in order to seek a more accurate and comprehensive description, after replacing G with G_N, we use Equation (9) to describe the nuclear force field, such as π-meson field and K-meson field. However, now we refer to λ as the spatial constant of the nuclear force field.

Now, Let us determine size of the λ.

Comparing Equation (13) with meson field Equation (1), we know that the space constant of the nuclear force field is

$$\lambda \equiv k^2 = \left(\frac{mc}{\hbar}\right)^2 . \tag{14}$$

it relates to the mass of meson, for the π^0-meson field, $\lambda = 4.677856 \times 10^{29}\ \mathrm{m}^{-2}$.

In addition, by comparison, we also know that the constant $\lambda c^2/8\pi G_N$ is a uniformly distributed mass density in space, which relate to the meson mass and is a kind of nuclear force source too. According to the idea that nuclear forces are transmitted through virtual mesons, it should be the mass density of virtual meson "cloud" or virtual meson "sea", denoted as

$$\rho_0 \equiv \frac{\lambda c^2}{8\pi G_N} . \tag{15}$$

Now let us explore the kinetic energy density of virtual meson "sea".

In General Relativity, the equation of motion for a particle to fall freely is

$$\frac{\mathrm{d}^2 x^\lambda}{\mathrm{d}\tau^2} + \Gamma^\lambda_{\mu\nu} \frac{\mathrm{d}x^\mu}{\mathrm{d}\tau} \frac{\mathrm{d}x^\nu}{\mathrm{d}\tau} = 0 . \tag{16}$$

where $\Gamma^\lambda_{\mu\nu}$ is the affine connection. But for constrained non-free falling particles, vector

$$N^\lambda \equiv \frac{f^\lambda}{m} = \frac{\mathrm{d}^2 x^\lambda}{\mathrm{d}\tau^2} + \Gamma^\lambda_{\mu\nu} \frac{\mathrm{d}x^\mu}{\mathrm{d}\tau} \frac{\mathrm{d}x^\nu}{\mathrm{d}\tau} , \tag{17}$$

is not zero, we call it the contra-variance vector of the controlled strength (see reference [2], 139 page), the m is particle's mass. We can define the covariant vector of the controlled strength as

$$N_\lambda = g_{\lambda\nu} N^\nu . \tag{18}$$

We also may lead in the controlled strength scalar N, its definition is

$$N = \pm\sqrt{N_\lambda N^\lambda} . \tag{19}$$

We also define a kind of scalar of the proper energy density

$$\tau = \frac{1}{8\pi G} N_\lambda N^\lambda . \tag{20}$$

For a particle which is restricted to hold still, $E^\lambda = -N^\lambda$, $E_\lambda = -N_\lambda$, $E = -N$ are respectively the contra-variance vector of the field strength, the covariant vector of the field strength, and the scalar field strength, and (20) is a kind of energy density of the field. For a vacuum and static spherically symmetric field, if the "spherical coordinate" variables r, θ, φ are selected, then the vector field strength only has the radial components, which can be obtained from (17) to (20)

$$E^1 = -\frac{c^2 g_{00,1}}{2 g_{00} g_{11}}, \tag{21}$$

$$E_1 = -\frac{c^2 g_{00,1}}{2 g_{00}}, \tag{22}$$

$$E = -\frac{c^2 g_{00,1}}{2 g_{00} \sqrt{g_{11}}}, \tag{23}$$

$$\tau = \frac{1}{8\pi G}\left(-\frac{c^2 g_{00\ ,1}}{2 g_{00} \sqrt{g_{11}}}\right)^2. \tag{24}$$

where $g_{00,1}$ is the first derivative of g_{00} with respect to *r*. We can write (20) and (24) as $\tau = E^2/8\pi G$, which is the same as the energy density of electrostatic field. Electrostatic fields neither field matter that has mass, nor self-interaction, only the kinetic energy density of the field quanta. Therefore, Equations (20) and (24) are actually the kinetic energy density of meson "sea". Besides, the macroscopic behavior of the nuclear force field is static, and due to its self-interactions, internal pressure P must exist to maintain static equilibrium. According to the Bernoulli equation, pressure P is also a kind of energy density. Therefore, under vacuum and static spherical symmetry, the energy density of meson "sea" is

$$\rho c^2 = \frac{1}{8\pi G_{\mathrm{N}}}\left(-\frac{c^2 g_{00\ ,1}}{2 g_{00} \sqrt{g_{11}}}\right)^2 + P. \tag{25}$$

Solving the field equation requires constructing an energy momentum tensor. Nuclear forces have a repulsive core, indicating that nuclear forces include attraction and repulsion. According to the static equilibrium equations derived from Equations (23) and (10) (see [4], p. 145 and 345), the change in pressure as $P'(r) \sim E$. For the attractive field $P'(r) \sim E < 0$, it is reasonable that the pressure P decreases with the increase of *r*. But for a repulsive field, $P'(r) \sim E > 0$, the pressure P increases with the increase of *r*, or rather increases with the decrease of field strength, which is obviously unreasonable. In order to derive a static equilibrium equation that adapts to both, the energy momentum tensor of the meson "sea" should expand as

$$T_{\mu\nu} = \pm P g_{\mu\nu} + \left(\rho c^2 \pm P\right) u_\mu u_\nu, \tag{26}$$

So there is

$$\frac{g_{00\ ,1}}{g_{00}} = -\frac{\pm 2P'}{\rho c^2 \pm P}. \tag{27}$$

Refer to [4] (p. 14). According to Equation (23), when the left side of equation (27) is represented by field strength, then $P'(r) \sim \pm E$. For the attractive field $P'(r) \sim E < 0$, and for the repulsive field $P'(r) \sim -E < 0$, they are reasonable.

For the convenience of solving, we write Equations (9) and (10) as

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G_{\mathrm{N}}}{c^4} \tilde{T}_{\mu\nu}, \tag{28}$$

$$\tilde{T}_{\mu\nu} = \tilde{P} g_{\mu\nu} + \left(\tilde{\rho} c^2 + \tilde{P}\right) u_\mu u_\nu \,, \tag{29}$$

$$\tilde{\rho} c^2 = \rho c^2 + \frac{\lambda c^4}{8\pi G_{\mathrm{N}}}, \quad \tilde{P} = \pm P - \frac{\lambda c^4}{8\pi G_{\mathrm{N}}}. \tag{30}$$

Assuming the nuclear force fields are static spherically symmetric, and selecting the spatial "spherical coordinates" r, θ, φ, and time *t*, then the standard metric is

$$\mathrm{d}s^2 = -g_{00} c^2 \mathrm{d}t^2 - g_{11} \mathrm{d}r^2 - r^2 \left(\sin^2 \theta \mathrm{d}\varphi^2 + \mathrm{d}\theta^2\right). \tag{31}$$

We spread the field Equation (28) using the usual method [4] (pp. 716 to 717, 196 to 202), and replace the relevant quantities in them by Equations (29), (30) and (25), as well as introduce dimensionless quantities

$$x = \frac{2G_{\mathrm{N}} M_{\mathrm{N}}}{c^2 r}, \quad p = P \frac{8\pi G_{\mathrm{N}}}{c^4} \left(\frac{2G_{\mathrm{N}} M_{\mathrm{N}}}{c^2}\right)^2, \quad p_0 = \lambda \left(\frac{2G_{\mathrm{N}} M_{\mathrm{N}}}{c^2}\right)^2. \tag{32}$$

Then replace the relevant quantities in equations by them. Finally, we obtain the equations set of nuclear force fields follows

$$g_{00}'(x) = -\frac{g_{00}(x)}{x}\left[\left(\frac{\pm p(x) - p_0}{x^2} + 1\right) g_{11}(x) - 1\right], \tag{33}$$

$$g_{11}'(x) = -\frac{g_{11}(x)}{x}\left[\left(\frac{p(x) + p_0}{x^2} - 1\right) g_{11}(x) + \left(\frac{x g_{00}'(x)}{2 g_{00}(x)}\right)^2 + 1\right], \tag{34}$$

$$\pm p'(x) = -\frac{1}{2} x^2 \frac{g_{00}'(x)}{g_{00}(x)}\left[\frac{\pm p(x) + p(x)}{x^2} + \frac{1}{g_{11}(x)}\left(\frac{x g_{00}'(x)}{2 g_{00}(x)}\right)^2\right], \tag{35}$$

$$D'(x) = \frac{2G_{\mathrm{N}} M_{\mathrm{N}}}{c^2 x^2} \sqrt{g_{11}(x)}\,. \tag{36}$$

where the symbol "±" take "+" when $g_{00}'(x) \geq 0$, and take "−" when $g_{00}'(x) < 0$, Equation (36) is to calculate the distance from the edge of the nuclear force field to a sphere with a curvature radius of *r*.

5. Mesons and Their Physical Quantities at the Edge of the Nuclear Force Field

Firstly, at the edge of the nuclear force field, the distance $D(x_0) = 0$, the potential is zero, and from Equation (12), $g_{00}(x_0) = -1$.

We also assume that fluctuations in vacuum energy cause the appearance and disappearance of virtual mesons. The reaction chain that produces virtual mesons is

$$\mathrm{N} \to \mathrm{N}' + \mathrm{m}\,. \tag{37}$$

where the N and N' represent separately the baryons before and after reaction; the m represents the virtual meson. When the fluctuation energy is the threshold energy *e* of the reaction, the kinetic energy in the centre-of-mass systems is zero, that is, generated virtual meson does not have the radial motion relatived to the baryon, and which is the virtual meson on the boundary of the nuclear force field, and so its potential energy is zero. Because in laboratory system before reaction and the centre-of-mass system after reaction, the Lorentz invariant $\left(E_{total}^2 - p^2c^2\right)$ is equal, so there is

$$\left(e + M_{\mathrm{N}}c^2\right)^2 - e^2 = \left(mc^2 + M'_{\mathrm{N}}c^2\right)^2. \tag{38}$$

where the M_{N} and M'_{N} represent separately the masses of baryons before and after reaction, m represents the mass of virtual meson. Calculating the threshold energy e from this equation, then, based on the conservation of energy before and after the reaction, the kinetic energy of the system after the reaction can be calculated. Perhaps due to rapid radiation of virtual mesons in all directions, the baryon is actually stationary, and the virtual mesons carry away all the kinetic energy of the reaction. Therefore, the kinetic energy and total energy of a virtual meson at the edge is

$$T_0 = \frac{c^2}{2M_{\mathrm{N}}}\left(m + M'_{\mathrm{N}} - M_{\mathrm{N}}\right)^2, \qquad E_0 = T_0 + mc^2. \tag{39}$$

We assume that the meson "sea" is a kind of fluid composed of point virtual mesons, which pressure P at the edge comes from localized collisions between virtual mesons, so

$$P = \frac{1}{3}\sum_n \frac{P_n^2c^2}{E_n}\delta^3\left(x - x_n\right) = \frac{1}{3}\left(\frac{E_0}{mc^2} - \frac{mc^2}{E_0}\right)\frac{\lambda c^4}{8\pi G_{\mathrm{N}}}. \tag{40}$$

(Refer to reference [4], p. 56). Dimensionless pressure (lowercase p) is

$$p = \frac{1}{3}\left(\frac{T_0 + mc^2}{mc^2} - \frac{mc^2}{T_0 + mc^2}\right)p_0. \tag{41}$$

The edge of the meson "sea" is a two-dimensional curved surface embedded in four-dimensional space-time, and vice versa. The Gaussian two-dimensional curvature [4] (p. 10 and 162) is

$$\frac{1}{r_{\mathrm{B}}^2} = -\frac{R}{2} = -\frac{4\pi G_{\mathrm{N}}}{c^4}\tilde{T}_\mu^\mu \to -\frac{4\pi G_{\mathrm{N}}}{c^4}\tilde{T}_i^i, \quad \mu = 1,2,3,4;\ i,j = 1,2 \tag{42}$$

After the $\tilde{T}_{ij}$ of Equation (28) reducing to $\tilde{T}_i^i$ by g^{ij}, and replacing the same quantity in Equation (42) by it, that equation becomes

$$\frac{1}{r_{\mathrm{B}}^2} = \frac{4\pi G_{\mathrm{N}}}{c^4}\left(\tau_0 + \frac{\lambda c^4}{4\pi G_{\mathrm{N}}}\right). \tag{43}$$

where the τ_0 is the kinetic energy density of the meson "sea" at the edge, as shown in Equation (24), but it is much smaller than the second term in parentheses, and if omitting it, there is

$$r_{\mathrm{B}} = \frac{1}{\sqrt{\lambda}} = \frac{\hbar}{mc}. \tag{44}$$

Equation (44) is only approximate. In order to find a more refined curvature radius of edge sphere, replacing τ_0 in Equation (43) by $\tau_0 = \rho_0 T_0/m$, and ρ_0 taking Equation (15), the results are

$$r_{\mathrm{B}} = \frac{1}{\sqrt{\lambda\left(1+\frac{T_0}{2mc^2}\right)}} = \frac{2G_{\mathrm{M}}M_{\mathrm{N}}}{c^2\sqrt{\left(1+\frac{T_0}{2mc^2}\right)p_0}} \tag{45}$$

$$x_0 = \sqrt{p_0\left(1+\frac{T_0}{2mc^2}\right)}. \tag{46}$$

By equating $\tau_0 = \rho_0 T_0/m$ with Equation (24), and replacing the relevant quantity, we obtain

$$\left(\frac{p(x_0)-p_0}{x_0^2}+1\right)g_{11}(x_0)-\frac{4G_{\mathrm{N}}M_{\mathrm{N}}}{\hbar c^2 x_0}\sqrt{mT_0}\sqrt{g_{11}(x_0)}-1=0. \tag{47}$$

Solving this equation can determine the value of $g_{11}(x_0)$ at the edge.

6. Solving Field Equations of Nuclear Forces

We have already determined G_{p} value of π-p field in Equation (7). For other baryonic-meson fields, there may be differences in the intensity of the interaction, and the value of their G_{N} may differ from the G_{p}, and G_{p} value also may not be accurate. But Equations (33), (34), (36) and their initial values are independent of G_{N} or G_{p}. For the convenience of calculation, we take $G_{\mathrm{N}} = \mathrm{G}_{\mathrm{p}}M_{\mathrm{p}}/M_{\mathrm{N}}$, so $\mathrm{G}_{\mathrm{N}}M_{\mathrm{N}} = \mathrm{G}_{\mathrm{p}}M_{\mathrm{p}}$, which is regarded as a constant throughout the entire series of strong interactions, but a single M_{N} does not change its value. In addition, when determining the initial conditions of the field equations, we will apply the virtual processes. Due to the conservation of charge, there are no corresponding virtual processes for $\mathrm{p}\pi^+$, $\mathrm{n}\pi$, $\Lambda\pi$, $\Lambda\mathrm{K}^-$, but these processes can be achieved through experiments. Due to nuclear forces are independence with the charge, we consider them equivalent to $\mathrm{p}\pi$, $\mathrm{n}\pi^+$, $\Lambda\pi^+$, $\Lambda\mathrm{K}^+$ processes, respectively. Therefore, the former can use the initial conditions of the latter.

In Equations (32), (39), (46), (47) and (41), inputing the mass values of mesons and baryons respectively to calculate $p_0, T_0, x_0, g_{11}(x_0), p(x_0)$, and using them as well as $D(x_0)=0$, $g_{00}(x_0)=-1$ as initial conditions to solve Equations (33)-(36). And using the equation which is derived from (23) combined with (33) and (12), to calculate the field strength and potential, this equation is

$$E = \frac{c^4}{4G_{\mathrm{N}}M}\varepsilon(x),\quad \varepsilon(x) = -\frac{x}{\sqrt{g_{11}(x)}}\left[\left(\frac{\pm p(x)-p_0}{x^2}+1\right)g_{11}(x)-1\right], \tag{48}$$

But Equations (33)-(36) are nonlinear, we can only use computer for numerical solutions. For the $\mathrm{p}\pi^0$ field, some calculation results are listed in **Table 1** and **Table 2**, and **Figure 1** and **Figure 2** depict the curve behavior of field strength and potential data.

Some numerical solutions for several meson fields are listed in **Table 2**.

From **Table 2**, we can see that there are more or less differences in the data of different baryonic meson fields, they can be divided into three categories: N π, Λ π, and Λ K. If ignoring the small differences, the fields in the same class are the same.

Table 1. Some data of the π^0-meson field of proton.

x	r/fm	d/fm	g_{00}	g_{11}	p	ε	φ/c^2
281	1.43650	0	−1	66.8057	3.8×10^{-3}	−0.1543	0
0.77963	0.53951	2.03573	−0.08315	0.62145	0.45301	-2.2×10^{-64}	−0.45843
0.39618	1.06168	1.47147	−0.17853	2.67361	0.17782	−0.79782	−0.41073
0.537	0.78327	1.82017	−0.09789	1.00228	0.38140	−0.55799	−0.45105
0.77964	0.53950	2.03574	−0.08315	0.62144	0.45302	0.91613	−0.45843
1.0	0.42062	2.12379	−0.10261	0.48163	0.47988	1.13740	−0.44870
2.0	0.21031	2.25114	−0.17506	0.25468	0.75137	3.16424	−0.41247
13	0.03236	2.31664	−0.98740	0.03022	208.944	75.3145	−0.00630
14	0.03004	2.31703	−1.06404	0.02752	269.105	85.2575	0.03202
10^7	4.2×10^{-8}	2.32007	-1.3×10^6	5.8×10^{-10}	7.4×10^{21}	4.3×10^{11}	659257
10^{11}	4.2×10^{-12}	2.32007	-2.0×10^{10}	3.2×10^{-15}	1.3×10^{35}	1.8×10^{18}	9.8×10^9

Where 1 fm = 10^{-15} m.

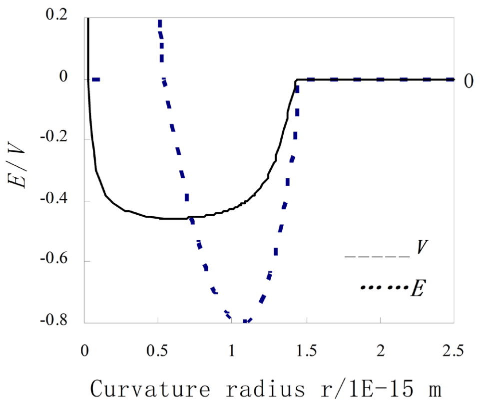

Figure 1. The field strength E and potential V of pπ^0-field vary with radius r.

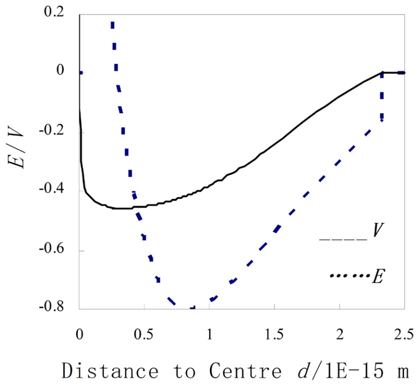

Figure 2. The field strength E and potential V of pπ^0-field vary with distance d.

These two images are generated from a large amount of data using Excel software, with a size of approximately 30 KB. Where the unit of field strength E is $c^4/4G_P M_p$, the unit of potential V is c^2.

Table 2. Some data of several baryonic meson fields.

Type	location	Radius/fm	g_{00}	g_{11}	p	ε
$P\pi^0$	On the boundary of the field	1.43650	−1	66.8057	3.83×10^{-3}	−0.15430
	Strongest field strength	1.06168	−0.17853	2.67361	0.17782	−0.79782
	The potential valley	0.53951	−0.08315	0.62145	0.45301	0
$n\pi^0$	On the boundary of the field	1.43653	−1	66.8917	3.83×10^{-3}	−0.15419
	Strongest field strength	1.06179	−0.17851	2.67395	0.17780	−0.79784
	The potential valley	0.53960	−0.08313	0.62138	0.45301	0
$p\pi^{+/-}$	On the boundary of the field	1.38878	−1	65.9656	4.16×10^{-3}	−0.16065
	Strongest field strength	1.02570	0.17877	2.71100	0.19125	0.82482
	The potential valley	0.52089	0.08328	0.62217	0.48450	0
$n\pi^{+/-}$	On the boundary of the field	1.38782	−1	63.6421	4.31×10^{-3}	−0.16377
	Strongest field strength	1.02298	−0.17949	2.6434	0.19051	−0.82419
	The potential valley	0.51853	−0.08366	0.62423	0.48461	0
$\Lambda\pi^0$	On the boundary of the field	1.33993	−1	16.1011	1.81×10^{-2}	−0.35530
	Strongest field strength	0.94948	−0.26231	2.37083	0.18181	−0.73865
	The potential valley	0.42837	−0.12630	0.73250	0.43485	0
$\Lambda\pi^{+/-}$	On the boundary of the field	1.29516	−1	16.0373	1.95×10^{-2}	−0.36842
	Strongest field strength	0.91818	−0.26301	2.37188	0.19428	−0.76367
	The potential valley	0.41405	−0.12658	0.73273	0.46494	0
ΛK^0	On the boundary of the field	0.35569	−1	13.5635	0.30461	−1.47803
$\Lambda\overline{K}^0$	Strongest field strength	0.25630	−0.29068	2.35803	2.46624	−2.70604
	The potential valley	0.11463	−0.14015	0.73896	5.88206	0
$\Lambda K^{+/-}$	On the boundary of the field	0.35853	−1	13.5505	0.30001	−1.46717
	Strongest field strength	0.25805	−0.28993	2.34787	2.43745	−2.68424
	The potential valley	0.11555	−0.14024	0.73898	5.78783	0

Where 1 fm = 10^{-15} m, and the term “strongest” usually refers to nuclear attraction, the same applies below.

7. Discussions

7.1. On the Spatiotemporal Properties of Nuclear Force Fields

First $G_N/G = 1.7 \times 10^{38}$, it is thus clear that the nuclear force is indeed more stronger than the gravitation. From Table 1 we know, the curvature radius of the edge spherical surface of the $p\pi^0$-field is 1.43650×10^{-15} m. But the numerical solutions from

(33) to (36) show that the radius (distance) of the nuclear force field is approximately 2.32007×10^{-15} m (see **Figure 2**), and the ratio of the edge spherical area to the square of the radius (distance) is about 1.5π, which is much smaller than 4π. And from **Table 1**, it can be seen that the metric tensor components g_{00} and g_{11} of the $p\pi^0$-field are not constants and vary greatly. These indicate that the nuclear force field is short-range and powerful, and space-time is highly curved.

7.2. The Potential and Field Strength Curves of Nuclear Force Fields

From **Table 1** and **Figure 1**, it can be seen that at the edge of the $p\pi^0$-field, the field strength is $E = -0.1543004\ c^4/4G_pM_p$, and the potential is zero; At the transition point of positive and negative field strengths, the spherical curvature radius $r = 0.53951$ m, which is about 0.28×10^{-15} m away from the centre of the nucleus, the field strengths in area larger than this distance are less than zero, and in area smaller than this distance, the field strengths are greater than zero, and rise sharply, forming a strong repulsive core; At the transition point of positive and negative potentials, the radius of curvature of the sphere is $r = 0.03236 \times 10^{-15}$ m, which is about $r = 0.03236 \times 10^{-15}$ m away from the centre of the nucleus, the potentials in the region larger than this distance are less than zero, while the potentials in the region smaller than this distance are greater than zero and rise sharply; When r approaches zero, both the field strength and potential tend towards positive infinity. It can be seen that nuclear forces are a kind of short-range van der Waals type force.

In nuclear physics, the nuclear force potential is often treated as a square potential well. As shown in **Figure 1**, when using the spherical curvature radius as the horizontal coordinate variable, the negative potential curve is very close to the square potential well, but the depth is deeper than the average depth usually calculated. At the neighborhood of edge, because of the distance become longer, when using the distance as the horizontal coordinate variable, the slope of the potential curve is very small, unlike a square potential well, as shown in **Figure 2**.

7.3. About the Helium Nucleus Field

From the curve of binding energies of atomic nuclei knowing: at ${}^{4}_{2}\mathrm{He}$, ${}^{8}_{4}\mathrm{Be}$, ${}^{12}_{6}\mathrm{C}$, ${}^{16}_{8}\mathrm{O}$, ${}^{20}_{10}\mathrm{Ne}$, ${}^{24}_{12}\mathrm{Mg}$, the average binding energy of nucleon in each nucleus exhibits a maximum value, which show these nuclei have the stable internal structure. In these nuclei, the ${}^{4}_{2}\mathrm{He}$, *i.e.* the helium nucleus, is the lightest, its structure is the simplest, and the nucleon numbers of other nuclei are just some integral multiples of the ${}^{4}_{2}\mathrm{He}$, as if they are made up of some ${}^{4}_{2}\mathrm{He}$. All these show the ${}^{4}_{2}\mathrm{He}$ is the construction unit of stable nuclei. Therefore, its matter must be in the potential valley of the unit, the field strengths are zero, and will form a spherical shell distribution with a spherical cavity appearing in the central region. Similar to Newton's gravitation or Birkhoff's theorem in General Relativity [4] (p. 391), it is known that the field strength inside a central spherical cavity is zero. Therefore, in the ${}^{4}_{2}\mathrm{He}$, the field strengths are zero everywhere, like the disappearance of nuclear forces, and space-time is a flat structure.

Next, we will study the external fields of $^4_2\mathrm{He}$.

The $^4_2\mathrm{He}$ contains two protons and two neutrons, or say four nucleons. If neglecting nucleons' binding energies and the mass difference between them, the mass of $^4_2\mathrm{He}$ is four times the nucleon mass M_N, *i.e.* $4M_N$. The field of $^4_2\mathrm{He}$ is generated by four nucleons, which is still a π-meson field, the field equations described should still be (33)-(36). Due to the short-range nature of nuclear force, at the edges of each nucleon's fields in the $^4_2\mathrm{He}$ they do not affect each other and maintain the potential of the single nucleon's edge, which can serve as the potential at the edge of the $^4_2\mathrm{He}$ field, and also has the form of the Yukawa potential. According to Equations (2) and (14), there is

$$4G_N M_N \frac{e^{-\sqrt{\lambda_{He}}r_{He}}}{r_{He}} \equiv G_N M_N \frac{e^{-\sqrt{\lambda}r_N}}{r_N}. \tag{49}$$

where subscripts He and N represent the quantities of helium nuclei and single nucleon, respectively. By comparing the two sides of Equation (49), we can obtain the curvature radius r_{He} of spherical surface of edge of the $^4_2\mathrm{He}$ field and its spatial constant λ_{He}, which are respectively

$$r_{He} = 4r_N,\ \lambda_{He} = \lambda/4^2. \tag{50}$$

They are 4 times and $1/4^2$ times the size of the nucleon field, respectively, so $x_{He} = 2G4M_N/c^2 r_{He}$ and $x_{Si} = 2GM_N/c^2 r_{Si}$ are equal. According to Equations (50) and (32), the constant p_0 of both is also the same. By applying the method of finding the edge values of the nucleon field, it is known that for these two fields, the initial conditions of the field equations are the same, so, their solutions $g_{00}(x)$, $g_{11}(x)$ and potential $\varphi(x)$ are the same. Therefore, if using x for space coordinate, the field outside the surface of the $^4_2\mathrm{He}$ is like a single nucleon field.

7.4. Size of Helium Nucleus

Above, we have clarified that matter of $^4_2\mathrm{He}$ are in the potential valley, and also have clarified that its external fields correspond to a single nucleon field. Therefore, the x on the surface of matter of $^4_2\mathrm{He}$ is equal to the x at the potential valley of the nucleon field, *i.e.*

$$\frac{2G_N 4M_N}{c^2 R_{HeS}} = \frac{2G_N M_N}{c^2 r_{NV}}, \tag{51}$$

where the R_{HeS} represents the curvature radius of surface of the helium nucleus, r_{NV} is the spherical curvature radius at the potential valley of the π-meson field. So, we obtain the spherical curvature radius of the surface of $^4_2\mathrm{He}$ from Equation (51) as

$$R_{HeS} = 4r_{NV}. \tag{52}$$

7.5. Nuclear Forces Saturation and Radius of Atomic Nuclei

Previously, we have clarified that the $^4_2\mathrm{He}$ is stable construction unit for atomic nuclei, In order to achieve stability, every four adjacent nucleons in a nucleus (which may be common) form many structures like ${}_{2}^{4}\mathrm{He}$, entire atomic nucleus seems to be composed of numerous interlaced ${}_{2}^{4}\mathrm{He}$, and the density of matter is the same as that of the ${}_{2}^{4}\mathrm{He}$, which is independent of the mass number of nucleus. This is what is commonly referred to as the saturation of nuclear forces. Because the nuclear force is a van der Waals type force and the nucleons are in potential valley, if a nucleon is perturbed and leaves the equilibrium position, there will be nuclear attraction or repulsion force pulling the nucleon back to the equilibrium position, and saturation is stable.

The traditional radius formula for atomic nuclei requires a radius constant obtained from experimental measurements, it is a semi empirical formula. Below, we will explore the nuclear radius formula derived from full theory.

Due to the nucleus as if is filled with many ${}_{2}^{4}\mathrm{He}$, its space-time is like that inside ${}_{2}^{4}\mathrm{He}$, which is a flat space-time, the calculation of distance and volume is much simpler. So for a nucleus with a mass number $A \geq 4$, their matter density is the same as that of the ${}_{2}^{4}\mathrm{He}$, there is

$$\frac{AM_{\mathrm{N}}}{R^{3}} = \frac{4M_{\mathrm{N}}}{R_{\mathrm{HeS}}^{3}}, \tag{53}$$

where R is defined as the radius of the surface of the nuclear matter. Combining the formula (52), from the formula (53), we gain the radius formula of nuclei are

$$R = r_{0}A^{1/3}, \quad r_{0} = 4^{2/3}r_{\mathrm{NV}}, \tag{54}$$

where r_{NV} is the spherical curvature radius at the potential valley of the π-meson field, which can be derived from our theoretical data. Atomic nuclei are generally composed of protons and neutrons, and according to Table 2, the data for several π-meson fields are slightly different. Based on them, the range of r_0 we calculated is 1.30660 - 1.35971 × 10^{-15} m, with an average value of $r_0 = 1.32 \times 10^{-15}$ m, which are within the range of different measured values (1.2 - 1.5 × 10^{-15} m, average $r_0 = 1.35 \times 10^{-15}$ m), and both average values are almost the same. However, now R and r_0 are all derived from theory, and (54) is no longer a semi-empirical formula.

7.6. The Binding Energies of Atomic Nuclei

Binding energy is another important characteristic of atomic nuclei. Why are the average binding energies of nucleons in almost all atomic nuclei around 8 Mev? It is difficult to explain using classical mechanics alone, and we are trying to combine the quantum properties of nucleons to seek answers to the problem. The rigorous formula for the uncertainty relationship in quantum mechanics is

$$(\delta x)^{2} \cdot (\delta p)^{2} \geq \frac{\hbar^{2}}{4}, \tag{55}$$

where $\delta x \equiv \pm\sqrt{\overline{(\Delta x)^{2}}}$ and $\delta p \equiv \pm\sqrt{\overline{(\Delta p_{x})^{2}}}$ are the standard deviations, which express respectively the statistic scopes of uncertainties in x and corresponding momentum p_x. When nucleons combine to form an atomic nucleus, they are confined within a small spatial range in potential valleys. It is easy to prove from

Equation (54) that the average radius of the confined space for one nucleon is r_0, and the maximum linear range for positional uncertainty is $\delta x = 2\pi r_0$, From (55), the corresponding range of momentum uncertainty can be determined as the minimum value, *i.e.* $\delta p = \pm\hbar/4\pi r_0$. From the formula of Special Relativity

$$p^2c^2 = T\left(T + 2M_{\mathrm{N}}c^2\right), \tag{56}$$

deriving the relationship between the change in kinetic energy δT and δp, and replacing T and δp in it by $T = -U = \left(1+g_{00}\right)M_{\mathrm{N}}c^2/2$ and $\delta p = \pm\hbar/4\pi r_0$, we obtain the range of uncertainty in kinetic energy as

$$\delta T = \pm\frac{c\hbar\sqrt{\left(1+g_{00}\right)\left(5+g_{00}\right)}}{4\pi r_0\left(3+g_{00}\right)}, \tag{57}$$

where g_{00} takes the value at the potential valley. When nucleons combine to form atomic nuclei, they enter a potential valley and release potential energy to gain kinetic energy. Equation (57) represents the range of uncertain kinetic energy for each nucleon in the potential valley. $\delta T < 0$ represents the amount of uncertain kinetic energy that each nucleon can release, causing the nucleus to form a stable state with lower energy. It is the formula for the release of binding energy for each nucleon. $\delta T > 0$ indicates the amount of allowed increase in the kinetic energy of each nucleon in a stable atomic ucleus. When a nucleon absorbs energy equal to its binding energy and forms a critical state, it is possible to escape from the nucleus or release the obtained energy back to a stable state with lower energy.

When A nucleons combine to form an atomic nucleus, the resultant momentum is zero. According to the Lorentz invariant of the A particles system [6]

$$\left(\sum_{i=1}^{A} E_i\right)^2 - \left(\sum_{i=1}^{A} p_i\right)^2 c^2 = M_A^2c^4, \tag{58}$$

The combined (unchanged) mass is

$$M_A = A\left(M_{\mathrm{N}} + U + T + \delta T\right) = A\left(M_{\mathrm{N}} + \delta T\right). \tag{59}$$

The masses in Equation (59) are represented by the energies they contain, such as proton mass M_{p} = 938.2796 MeV, the same below. When nucleons combine to form an atomic nucleus, they release binding energy, $\delta T < 0$, it can be seen from (59) that the atomic nucleus exhibits mass loss. As mentioned earlier, nuclear matter is in potential valley, where the g_{00} is the same as that in the potential valley of nucleon field. According to the data of several π-meson fields in **Table 2**, the range of binding energy released by each nucleon is calculated from Equation (57) to be $\beta = |\delta T|$ = 8.41 - 8.75 MeV, average β = 8.62 MeV. The β calculated from the mass loss of medium mass nuclei with mass numbers of 40 - 120 are β = 8.50 - 8.79 MeV, with an average β = 8.67 MeV. The difference calculated by the two methods is less than 1%, and both average values are almost the same.

7.7. About Meson-Baryon Resonance

According to the scattering of π-mesons by nucleons, when the nucleons absorb π-mesons with kinetic energy of about 190 MeV, the π-N system immediately forms Δ (1232) resonances (also known in some works as Δ (1234) or Δ (1236), also known as a resonant particle), then which rapidly decays out of π-meson with the largest scattering cross-section. When the energy range of the incident photons is between 300 MeV and 350 MeV, the photoproduction of π-mesons from the nucleons also exhibit a similar peak cross-section. Both indicate the strongest interaction between π-meson and nucleon in resonances system. According to the idea that nuclear forces are realized through nucleon radiating and absorpting mesons, we imagine that when one baryon absorbs a meson of certain kinetic energy, they immediately form coupling state with strongest nuclear force, *i.e.* resonances. The kinetic energy and potential energy of the meson in it are the same as those of the virtual meson in the strongest nuclear force, and its kinetic energy is provided by the kinetic energy of the incident particle and the potential energy released by itself. Let the masses of meson and baryon be m and M_N, respectively. the potential energy of virtual meson can be obtained from Equation (12), and the number density of virtual mesons can be obtained from Equation (15). Then, the kinetic energy of virtual meson in the nuclear force field can be obtained from Equations (24), (32), (48) and (14). They are respectively

$$U=-\frac{1}{2}\left(1+g_{00}\right)m\,, \tag{60}$$

$$T=\frac{E^2}{\lambda c^4}m \quad \text{or} \quad T=\frac{\varepsilon^2}{4p_0}m\,, \quad p_0=0.08276034\times\left(m/m_{\pi^0}\right)^2. \tag{61}$$

where g_{00} and field strength E or dimensionless field strength ε take the values at the strongest nuclear field strength, Equations (60) and (61) represent the potential and kinetic energy of meson in resonances. According to the Lorentz invariants (58) and (56), the (invariant) mass of the resonances is

$$M_r=\sqrt{\left(M_N+m+U+T\right)^2-T\left(T+2m\right)}\,. \tag{62}$$

Respectively replacing corresponding terms in Equation (62) by the masses of baryons and mesons and at the strongest nuclear force the potential and kinetic energy of the virtual meson which are calculated using Equations (60) and (61), the (invariant) mass of resonances can be calculated. If no other particles appear simultaneously, the (constant) masses of the meson-baryon system are equal before and after resonances formationing. Based on this, the laboratory kinetic energy of the incident meson can be calculated, and the result is as follows

$$T_i=\frac{1}{2M_N}\left[M_r^2-\left(M_N+m\right)^2\right]. \tag{63}$$

For example, Δ^{++} Resonances, it is a coupling state where π^+-meson strongly interact with proton to form the strongest nuclear force, denoted as (π^+p)*. According to Table 2, at the location of the strongest nuclear field strength, g_{00} = −0.178774, and dimensionless field strength $\varepsilon = -0.8248197$. From Equations (14), (60), (61), (62), and (63), it can be calculated that $U = -57.3080$ MeV, $T = 268.213$ MeV and $M_r = 1230.48$ MeV, and the laboratory kinetic energy of the incident π-meson that forms this resonances is $T_i = 187.75$ MeV.

The same method can be used to calculate other possible meson—baryon resonances. Several calculation results are now listed in Table 3, and provide several explanations and discussions as follows.

Table 3. Some resonances of the meson-baryon.

Resonances	Conformation	Radius/fm	Masses/MeV	Sources	Incident energy of γ/π (MeV)
Δ^{0+}	$(\pi^0 p)^*$	1.06168	1222.35	$\gamma + p$	327.07
Δ^{00}	$(\pi^0 n)^*$	1.06179	1223.71	$\pi^- + p$	178.89
Δ^{++}	$(\pi^+ p)^*$	1.0257	1230.48	$\pi^+ + p$	187.75
Δ^{-+}	$(\pi^- p)^*$	1.02578	1230.48	$\pi^- + p$	187.75
Δ^{+0}	$(\pi^+ n)^*$	1.02298	1231.59	$\gamma + p$	339.16
Δ^{-0}	$(\pi^- n)^*$	1.02298	1231.59	$\pi^- + n$	187.46
Σ^{00}	$(\pi^0 \Lambda)^*$	0.94948	1384.21		
Σ^{+0}	$(\pi^+ \Lambda)^*$	0.91818	1392.24		
Σ^{-0}	$(\pi^- \Lambda)^*$	0.91818	1392.24		
Ξ^{00}	$\left(\bar{K}^0 \Lambda\right)^{\cdot}$	0.2563	1893.38		
Ξ^{-0}	$(K^- \Lambda)^*$	0.25805	1888.56		

Where 1 fm = 10^{-15} m.

1) The experiment identified four π-N resonances, namely: Δ^{++}, Δ^0, Δ^+, Δ^- (This article badges which as Δ^{++}, Δ^{-+}, Δ^{+0}, Δ^{-0}). We calculate their masses to be 1230.48 MeV and 1231.59 MeV respectively, which are within the standard mass range of 1230 - 1234 MeV determined in the experiment. However, according combination pathway of π and N, they should increase two kinds of Δ^{00} and Δ^{0+}. We calculate their masses respectively are 1222.35 MeV and 1223.71 MeV. If there are no selection rules to restrict, the π-N resonances are divided into six structures from four charge states: Δ^{++}, (Δ^{-+}, Δ^{00}), (Δ^{+0}, Δ^{0+}), Δ^{-0}. The resonances formed by different π mesons and baryons have slight differences in mass. Only when small mass differences can be ignored, they can be considered as different isospin components of the same resonances.

2) The Σ^{00}, Σ^{+0}, Σ^{-0} listed in Table 3 are the coupling states where π-mesons interact with Λ hyperon to form the strongest nuclear force. Their masses calculated by us are the same or very close to the standard masses ($M^0 = 1382.0 \pm 2.5$ MeV, $M^+ = 1382.3 \pm 0.4$ MeV, $M^- = 1387.5 \pm 0.6$ MeV) of the Σ (1385) series (with a difference of less than 0.7%), they should be the Σ (1385) series, which express that π-mesons can not only serve as mesons in the nucleon field, but also as mesons in the hyperon field.

3) The Ξ^{00} and Ξ^{-0} listed in Table 3 are the coupling states formed by the inter-

action between K-mesons and Λ-hyperon to form the strongest nuclear force. The difference between their masses calculated by us and the standard masses of Ξ (1820) of 1823 ± 6 MeV is only about 3%, and they may be Ξ (1820) series.

4) The resonances masses in Table 3 are calculated based on the strongest nuclear field strength and where virtual meson data. The results are consistent with the experiment, indicating that human can achieve the strongest nuclear force using observable mesons, and demonstrating the true existence and function of virtual mesons.

7.8. About Basic Baryons and Composite Hyperons

Hyperons and nucleons are collectively called as the baryons. Although hyperons may decay into other baryon and meson, their lifetimes are generally about 10^{14} times that of resonances, and they belong to stable composite particles. Therefore, we assume that the hyperons are formed by the stable combination of mesons and baryon. In terms of field, this means that the mesons are in the potential valley of the baryon, and they combine to form stable hyperons. According to the essence of nuclear forces, these mesons should be able to serve as mesons in the nuclear force field, and in potential valley the field strength is zero. From Equation (61), it is known that their kinetic energy are zero. So the size of the binding energy released by each meson in hyperon system and the mass of composite system are respectively

$$b_i = \frac{1}{2}\left(1+g_{00}\right)m_i , \tag{64}$$

$$M_{\mathrm{c}} = M_{\mathrm{N}} + \sum_{i=1}^{n}\left(m_i - b_i\right). \tag{65}$$

where M_{N} and m_{i} are the masses of the baryon and the i-th meson, respectively. g_{00} is taken as the value at the potential valley of the baryon field, and the sum covers all the combinational mesons. Through calculation and comparison, we cannot find any particles that can combine to form Λ-hyperon, which should be a fundamental hyperon. But it is discovered that Σ-hyperons are composed by π-meson and Λ, Ξ-hyperons are composed by K-meson and Λ, while Ω-hyperon is composed by K^- and $\overline{\mathrm{K}}^0$ mesons with Λ. So, Λ is a basic hyperon, also is a basic baryon, while other hyperons are composed by mesons and basic hyperon Λ. The detailed information of the composite hyperons determined by our calculations is shown in Table 4.

The zero-subscripts in the table indicate that the mesons are in the potential valley of field of hyperon Λ. The calculation of binding energies and combination masses are based on Equations (64), (65) and Table 2 data, calculation masses differ very little from the standard masses determined by the experiment (except for Ξ the difference is about 6%, the rest are below 0.5%). The calculation method is also simple. If according to the theories of Fermi, Yang Zhenning, and Marshak *et al.*, the π-meson and K-meson are considered the bound states of $\left(\mathrm{N}\overline{\mathrm{N}}\right)$ and $\left(\mathrm{N}\overline{\Lambda}\right)$ respectively, the fundamental baryon and the combination mode of the hyperons determined by us are the same as those assumed by the Sakata model

[7], and we also add a Ω^- -hyperon and its combination mode.

Table 4. The composite hyperons.

Hyperons	Compound Way	Radius/fm	Binding Energy/MeV	Compound Mass/MeV	Standard Mass/MeV
Σ^0	$(\pi^0\Lambda)_0$	0.428371	58.96	1191.6	1192.47
Σ^+	$(\pi^+\Lambda)_0$	0.414051	60.95	1194.22	1189.37
Σ^-	$(\pi^-\Lambda)_0$	0.414051	60.95	1194.22	1197.35
Ξ^0	$(K^0\Lambda)_0$	0.114625	213.96	1399.31	1314.9
Ξ^-	$(K^-\Lambda)_0$	0.115551	212.22	1397.05	1321.32
Ω^-	$(K^-K^0\Lambda)_0$	0.114625 - 0.115551	426.1	1680.8	1672.2

Where 1 fm = 10^{-15} m.

8. Conclusion

The results of the discussion on nuclear forces in the article are consistent with experimental results, except for the nuclear space-time structure that needs to verify, demonstrating that General Relativity can unify the description of nuclear force and universal gravitation. Therefore, General Relativity enters a new field, which is not only a macroscopic theory of gravitation, but also the theoretical foundation of microscopic nuclear force. The successful interpretation and calculation of nuclear binding energy in the text indicate that although General Relativity and quantum theory are both independent, they can complement each other in the microscopic field.

Data Availability

Data will be made available on request.

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Conflicts of Interest

Cangqi Wen independently completes the research and paper writing of this project, without the participation of any other individuals or organizations, and this article has no interest relationship with anyone else.

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Appendix

A For nucleus with mass numbers of 40 - 120, the deviation of the average binding energy of the nucleon calculated from the mass loss is $\sigma = 8.4 \times 10^{-2}$ MeV, relative deviation of 1%, and the deviation of the average mass of nucleons is 3×10^{-6}, which can be regarded as a constant. We use this deviation of binding energy to estimate how much the ratio of nuclear force mass to inertial mass may deviate from 1. From Equation (6), it can be obtained that $\sum_i \mu_i \Big/ \sum_i M_i = 1 \pm \sigma \big/ \bar{M} \varphi$. When a nucleon enters the potential valley, it releases binding energy. The average depth of the nuclear potential well is about 50 MeV. Therefore, $\sum_i \mu_i \Big/ \sum_i M_i = \mu_i / M_i = 1 \pm 0$ $\left(< 2 \times 10^{-3} \right)$, which has no evident deviation from 1. It can be seen that the mass of nuclear force is equal to the mass of inertia, and its accuracy is very high.

B The representation of field potential. According to the Schwarzschild metric, the Newtonian potential can be represented by the time component of the metric tensor. It can be seen that the field potential should generally be a second-order tensor, denoted as $\varphi_{\mu\nu}$. We generalize the relationship between potential and vector field strength as

$$\varphi_{\mu\nu;\lambda} = -\zeta_{\mu\nu} E_{\lambda} .$$

where $\varphi_{\mu\nu;\lambda}$ represents the covariant derivative of $\varphi_{\mu\nu}$ with respect to coordinate λ, and $\zeta_{\mu\nu}$ is a tensor. For the spherically symmetric field, the unique non-zero component of the above equation is

$$\varphi_{00;1} = -\zeta_{00} E_1 .$$

The left side of the equation is the gradient of the tensor potential change, based on the relationship between field potential and field strength, under static spherical symmetry, the right side of the equation corresponds to vector field strength, $\zeta_{00} = 1$. Expanding the equation above and replacing the relevant quantities by Equation (22) in the main text, we obtain

$$\varphi_{00,1} = \frac{g_{00,1}}{g_{00}} \varphi_{00} + \frac{c^2 g_{00,1}}{2 g_{00}} \xi_{00} .$$

Now φ_{00} is unique non-zero component, denote it as φ, and solving this equation, we obtain the field potential as

$$\varphi = -\frac{1}{2}\left(1 + g_{00}\right) c^2 .$$