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Weak Nuclear Forces cause the Strong Nuclear Force

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Abstract. We determine the strength of the weak nuclear force which holds the lattices of the elementary particles together. We also determine the strength of the strong nuclear force which emanates from the sides of the nuclear lattices. The strong force is the sum of the unsaturated weak forces at the surface of the lattices.

Keywords: strong force, weak force, nuclear lattice, muon neutrino mass.
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INTRODUCTION

After have explained the masses of the electron and muon and of the stable mesons and baryons with cubic lattices consisting of either photons or of neutrinos in [1], we can now determine the strength of the weak and the strength of the strong nuclear forces. Both are 70 years old puzzles. We will, in the following, use lattice theory to determine the strength of the weak force which holds the lattices of the elementary particles together. We will then show that the strong force between two elementary particles is nothing but the sum of the unsaturated weak forces emanating from the lattice points at the surface of the lattice. Consequently the strong force between two elementary particles is on the order of 10^6 times stronger than the weak force in the interior of the particles. The strong force is caused by the weak force.

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THE FORCE IN THE INTERIOR OF IONIC LATTICES

In order to determine the force in the interior of the cubic lattices with which we have explained the particle masses we will, as we have done before [2], use a classical paper by Born and Landé [3], (B&L), dealing with the potential and compressibility of regular ionic crystals. It is essential to realize that

- *for the existence of a cubic lattice it is necessary that the force between the lattice points has an attractive part and a repulsive part.*
- Otherwise the lattice would not be stable and collapse.

For the ionic crystals considered by B&L the Coulomb force between the ions is the attractive force, whereas the repulsive force originates from the electron clouds surrounding the ions. When the electron clouds of the ions approach each other during the lattice oscillations they repel each other. The magnitude of the repulsive force is not known per se and has to be determined from the properties of the crystal.

We will follow exactly the procedure in B&L in order to see whether their theory is also applicable to a cubic lattice made of neutrinos. In this case the Coulomb force is, of course, irrelevant. As B&L do, we say that the potential of a cell of the neutrino lattice has an attractive part $-\,\mathrm{a}/\delta$ and a repulsive part $+\,\mathrm{b}/\delta^{\mathrm{n}}$ with the unknown exponent n. δ is the distance in the direction between two neutrinos of the same type, either muon neutrinos and anti-muon neutrinos or electron neutrinos and anti-electron neutrinos.

The potential of a cell of an ionic cubic lattice is of the form

$$\phi = -\,\mathrm{a}/\delta + \mathrm{b}/\delta^{\mathrm{n}}\,, \tag{1}$$

Eq.(1) of B&L. The constant b is eliminated with the equilibrium condition $\mathrm{d}\phi/\mathrm{d}\delta = 0$. Consequently

$$\mathrm{b} = \frac{\mathrm{a}}{\mathrm{n}}\,\delta_0^{\mathrm{n}-1}\,, \tag{2}$$

where δ_0 is the lattice constant. The unknown exponent n of δ in Eq.(1) was determined by B&L with the help of the compression modulus κ which is known for ionic crystals. κ is defined by

$$\kappa = -\,1/V \cdot dV/dp\,. \tag{3}$$

The compression modulus of an ionic lattice is given by

$$\kappa = 9\,\delta_0^4/\mathrm{a}\,(\mathrm{n}-1)\,, \tag{4}$$

Eq.(4) in B&L. The interaction constant a of the Coulomb force in cubic ionic crystals resulting from the contributions of all ions on a single ion is given by Eq.(5) of B&L, it is

$$\mathrm{a} = 13.94\,\mathrm{e}^2 = 3.2161 \cdot 10^{-18}\,\mathrm{erg}\cdot\mathrm{cm}\,, \tag{5}$$

where e is the elementary electric charge. This equation is fundamental for the theory of ionic lattices and is based on an earlier paper by Madelung [4]. Consequently we find that

$$(\mathrm{n}-1) = 10.33\,\mathrm{r}_0^4/\mathrm{e}^2\kappa\,, \tag{6}$$

where $\mathrm{r}_0 = \delta_0/2$ is the distance between a pair of neighboring Na and Cl ions. For the alkali-halogenids, such as NaCl or KCl, B&L found that $\mathrm{n} \approx 9$. If $\mathrm{n} = 9$ is used in Eq.(4) to determine theoretically the compression modulus κ, then the theoretical values of κ agree, in a first approximation, with the experimental values of κ, thus confirming the validity of the ansatz for the potential in Eq.(1).

THE FORCE IN THE INTERIOR OF A NUCLEAR LATTICE

We now apply $\mathrm{n} - 1 = 10.33\,\mathrm{r}_0^4/\mathrm{e}^2\kappa$, Eq.(6), to the neutrino lattice of the elementary particles in order to determine the potential in the interior of the particles. We must use for r_0 the distance between two neighboring neutrinos in the lattice, which is equal to the range of the weak nuclear force. The range of the weak force is $1 \cdot 10^{-16}$ cm, according to Perkins [5], and so we have

$$\mathrm{r}_0 = 1 \cdot 10^{-16}\,\mathrm{cm}\,. \tag{7}$$

We have used this value of r_0 throughout our explanation of the masses of the elementary particles in [1]. We must, furthermore, replace e^2 by the interaction constant g_w^2 of the weak force which holds the nuclear lattice together. According to Perkins [5]

$$\mathrm{g}_w^2 = 4\pi\hbar\,\mathrm{c}\cdot 1.05 \cdot 10^{-2}\,(\mathrm{M}_W/\mathrm{M}_p)^2\,, \tag{8}$$

where M_W is the mass of the W boson, $M_W = 80.403\,\text{GeV/c}^2$, and M_p is the mass of the proton, $M_p = 0.938\,272\,\text{GeV/c}^2$. That means that

$$g_w^2 = 2.9976 \cdot 10^{-17}\,\text{erg} \cdot \text{cm}. \tag{9}$$

We must also use the compression modulus κ of the nucleon. The value of the compression modulus of the nucleon has been determined theoretically by Bhaduri et al. [6], following earlier theoretical and experimental investigations of the compression moduli of nuclei. Bhaduri et al. found that the compression modulus $K_A(N)$ of the nucleon ranges from 900 to 1200 MeV, or is 940 MeV or 900 MeV for particular sets of parameters. We determine κ of the nucleon with

$$\kappa = 9/\rho_{\#} K_{nm}\,, \tag{10}$$

from Eq.(1) in [6]. Bhaduri et al. write that "the compression modulus K_{nm} of nuclear matter is calculated by considering the nucleons as point particles", which they are not. Other assumptions are also sometimes made such as infinite nuclear matter, periodic boundary conditions, etc. Recent theoretical studies of the compressibility of "nuclear matter" [7,8,9] place the compressibility K_{nm} at values from between 250 to 270 MeV, not much different from what is was twenty years earlier in [6]. Considering the uncertainty of K_{nm} it seems to be justified to set, in the case of the nucleon, $K_{nm} = K_A$, where K_A is defined as the compression modulus for a finite system with A nucleons. It then follows from Eq.(10) with the number density $\rho_{\#}$ being the number density per fm^3, and with the radius of the nucleon $R_0 = 0.88 \cdot 10^{-13}$ cm, and with $1\,\text{MeV} = 1.6022 \cdot 10^{-6}$ erg that the compression modulus of the nucleon is

$$\kappa_n = 1.603 \cdot 10^{-35}\ \text{cm}^2/\text{dyn}\,, \tag{11}$$

if we use for $K_A(N)$ the value 1000 MeV. We will keep in mind that κ_n is not very accurate because $K_A(N)$ is not very accurate.

If we insert (7), (9), and (11) into $n - 1 = 10.33 r_0^4/e^2\kappa$ (Eq.6) we find an equation for the exponent n in the term b/δ^n of the repulsive part of the potential in a nuclear lattice

•

$$n = 1 + 2.164 \cdot 10^{-12} = 1 + \epsilon\,, \tag{12}$$

with $r_0^4 = O(10^{-64})$, $g_w^2 = O(10^{-17})$ and $\kappa = O(10^{-35})$.

That means that

the potential ϕ in the interior of an elementary particle is given by

$$\phi = -\frac{a}{\delta} + \frac{b}{\delta^{1+\epsilon}} = \frac{a}{\delta}\,[\frac{(\delta_0/\delta)^{\epsilon}}{n} - 1]\,, \tag{13}$$

which we can reduce with $n - 1 = \epsilon$, neglecting a term multiplied by $\epsilon^2 = O(10^{-24})$, using also $a = 13.94\,e^2$ and $1/n \cong (1-\epsilon)$, to

$$\phi \cong -\frac{a\,\epsilon}{\delta}\,[1 - \ln(\delta_0/\delta)] \cong -\frac{13.94\,g_w^2\,\epsilon}{\delta}\,[1 - \ln(\delta_0/\delta)]\,. \tag{14}$$

In equilibrium the value of ϕ in the nuclear lattice is about $g_w^2 \cdot \epsilon/e^2 \approx 2.7\cdot 10^{-10}$ times smaller than the corresponding electrostatic potential in an ionic lattice. A graph of the potential in Eq.(14) versus δ is shown in Fig. 1.

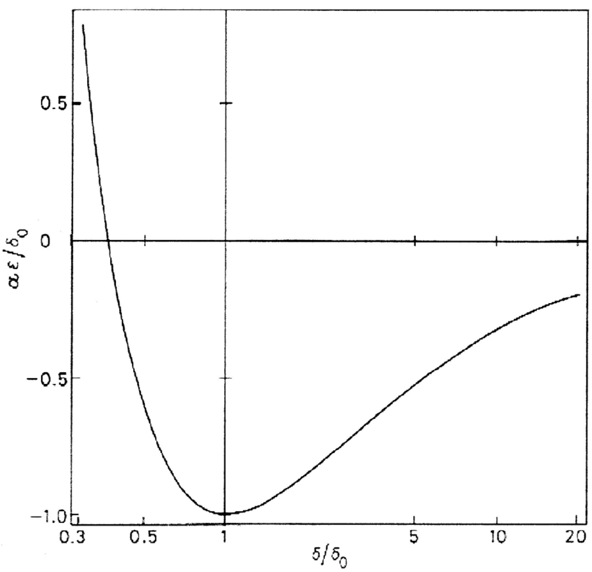

Fig.1: The potential ϕ of the weak force as a function of δ. After [2].

The minimum of the curve marks the equilibrium. From Eq.(14) follows with $F_w = d\phi/d\delta$ and $\delta = 2r$ that *the weak force in the interior of the nuclear lattice is*

$$F_w \cong \frac{3.485 \cdot g_w^2\, \epsilon}{r^2} \cdot \ln(\frac{\delta}{\delta_0}) . \qquad (\mathrm{dyn}) \tag{15}$$

For all distances $\delta > \delta_0$ the force F_w is attractive, for all distances $\delta < \delta_0$ the force is repulsive. The small value of $\epsilon \approx 10^{-12}$ means that small displacements $\delta/\delta_0 < 1$ of the neutrinos from their equilibrium position, which carry the neutrinos into the domain of their neighboring neutrino, cause a very strong repulsive force between both neutrinos.

We have thus determined the potential of the weak force in the interior of the lattice of the elementary particles with lattice theory. Let us consider how this was done.

- *Following exactly the procedure used by B&L to determine the potential in the interior of an ionic crystal,*

- *we have determined the potential in the interior of the lattice of an elementary particle by using the parameters of the nuclear lattice.*

As in an ionic lattice the potential in a nuclear lattice has an attractive and a repulsive part, as is necessary for the stability of the lattice. We have found that in equilibrium in a nuclear lattice the absolute values of the attractive and repulsive terms of the potential are very nearly the same, because ϵ is on the order of 10^{-12}.

THE MUON NEUTRINO MASS

One wonders, in view of the extraordinaryly small value of ϵ, whether the potential in Eq.(14) is not an academic result. It has to be shown that Eq.(14) is indeed relevant for elementary particles. We can show that the mass of the muon neutrino $m(\nu_\mu)$ depends on $\epsilon = n - 1 = 2.164 \cdot 10^{-12}$ and yields a correct mass $m(\nu_\mu)$ if only ϵ is on the order of 10^{-12}.

From the explanation of the $\pi^\pm$ mesons in [1] follows that the mass of the muon neutrinos is

$$m(\nu_\mu) = m(\bar{\nu}_\mu) \cong 50\,\mathrm{milli\,eV/c^2}, \tag{16}$$

Eq.(40) in [1]. One can, on the other hand, determine the mass of the muon neutrinos from the group velocity of the neutrino oscillations in their nuclear lattice. It follows from Eq.(26) of [1] that

$$\mathrm{m}(\nu_\mu) \cong \mathrm{r}_0^3\, \mathrm{c}_{44}\, / \mathrm{c}^2\,, \tag{17}$$

where c_{44} is one of the elastic constants of continuum mechanics, which is valid when $r_0 \to 0$. With the proper value of c_{44}, for details see http://arXiv: 0712.1849, we find that

$$\mathrm{m}(\nu_\mu) = 1.284 \cdot 10^{-34}\,\mathrm{gr} = 72.1\,\mathrm{milli\,eV/c^2} = \mathrm{m}(\bar{\nu}_\mu)\,. \tag{18}$$

The anti-muon neutrinos in the lattice move with the same group velocity as the muon neutrinos, so $m(\nu_\mu) = m(\bar{\nu}_\mu)$. The value of $m(\nu_\mu)$ in Eq.(18) differs by 50% from $m(\nu_\mu) \cong 50$ milli-eV/c^2 given by Eq.(16). We have thus learned that ϵ *must be on the order of* 10^{-12} to end up with a correct value of the muon neutrino mass $m(\nu_\mu)$.

To summarize: We have found that it follows from lattice theory that the value of the exponent $n = 1 + \epsilon$ in the repulsive term of the potential in the nuclear lattice leads to an, in the first approximation, correct value of the mass of the muon neutrino, albeit that ϵ is so extraordinarily small. We have thus confirmed the validity of the potential $\phi \cong -\, a/\delta + b/\delta^n = -\, a/\delta + b/\delta^{1+\epsilon}$. That means *we have found the potential of the weak force which holds the nuclear lattice together.*

THE STRONG FORCE BETWEEN TWO ELEMENTARY PARTICLES

Crucial for the understanding of the existence of a strong force between the sides of two cubic lattices is the observation that

- *the sides of two halves of a cubic lattice cleaved in vacuum exert a strong, attractive force on each other.*

It is an automatic consequence of lattice theory that

- *the weak force, which holds the lattice together, is accompanied by a strong force which emanates from the sides of the lattice.*

This seems to contradict the simple observation that two salt crystals stacked upon each other can be separated without any effort. This is only so because the surface of a cubic crystal cleaved in air oxidizes immediately, and then the sides do not attract each other any longer. The origin of the force emanating from the sides of a cubic ionic lattice is the Coulomb force between ions of opposite polarity, i.e. the force which holds the lattice together. The attractive force emanating from the side of a crystal cleaved in vacuum has a macroscopic value. The existence of this force has tangible consequences in space technology. The force between the sides of two cubic lattices was first studied by Born and Stern [11] (B&S).

If U_{12} is the potential between two halves of a crystal with the equal surfaces A, or the work that is necessary to separate the two halves of a cleaved crystal, then the capillary constant σ is given by Eq.(2) of B&S

$$\sigma = -\,U_{12}/A\,. \tag{19}$$

The capillary constant is, in the following, taken at zero degree absolute and against vacuum for the square outside area A of a cubic crystal. σ has been explained by B&S, but their formula cannot be used here because they use the value n = 9 of the alkali-halegonids. We will instead use Eq.(463) from Born [10] for the capillary constant σ_{100} of the (100) front surface of an ionic cubic crystal

$$\sigma_{100} = -\,\frac{e^2}{r_0^3}\,\frac{s_0(1)}{2}\cdot\Big[\,1 - \frac{1}{n}\,\frac{s_0(n)}{s_0(1)}\cdot\frac{S_0(1)}{S_0(n)}\,\Big]\,. \tag{20}$$

The sums $s_0(n)$ and $S_0(n)$ originate from the contributions of the different lattice points to the repulsive part of the potential. The sign of the second term on the right hand side in Eq.(22) comes from the repulsive part of the potential in Eq.(1). For the capillary constant in a nuclear lattice we set $e^2 = g_w^2$, $n = 1 + \epsilon$, (Eq.12), and $s_0(1) = -\,0.0650$ from [10] p.743. We find that $s_0(n) \cong s_0(1)$ since $n = 1 + \epsilon$ and $\epsilon \cong 10^{-12}$. Similarly we have $S_0(n) \cong S_0(1)$. Then we have

$$\sigma_{100} \cong \frac{0.065}{2}\,\frac{g_w^2}{r_0^3}\,\epsilon\,. \qquad \text{(dyn/cm)} \tag{21}$$

The work required to separate one half of a nuclear lattice from the other half is according to Eq.(19) given by

$$U_{12} \cong -\,\frac{0.065}{2}\,\frac{g_w^2\,\epsilon}{r_0^3}\cdot A\,. \tag{22}$$

We determine the area A with the number of the lattice points N in the cubic nuclear lattice

$$N = 2.854 \cdot 10^9\,, \tag{23}$$

from Eq.(15) in [1]. It follows that $A = (\sqrt[3]{N} \cdot r_0)^2$. The strong attractive force between the sides of two nuclear lattices is

$$F_s = \frac{dU_{12}}{dr} = -\frac{d\sigma}{dr} \cdot A = \frac{3 \cdot 0.065\, g_w^2\, \epsilon}{2\, r^4} \cdot A\,. \tag{24}$$

- *The force emanating from the front surface of a cubic nuclear lattice, the strong force, is*

$$F_s = \frac{0.0975\ g_w^2\ \epsilon}{r^4} \cdot (\sqrt[3]{N} \cdot r_0)^2\,. \qquad (\mathrm{dyn}) \tag{25}$$

The strong force depends, first of all, on the *weak interaction constant* g_w^2, and secondly on the number of lattice points on a side of the lattice, via $(\sqrt[3]{N})^2 = 2.012 \cdot 10^6$. The strong force is also inversely proportional to the *fourth* power of the distance between the particles.

The ratio of the entire force emanating from the surface of the lattice, which is six times Eq.(25), to the weak force between the lattice points, Eq.(15), is then

$$\frac{F_s}{F_w} = \frac{0.33 \cdot 10^6}{r^2/r_0^2 \cdot \ln(r/r_0)}\,, \tag{26}$$

or the strong force is on the order of 10^6 times larger than the weak force but the ratio is sensitive to the value of r/r_0.

To summarize: According to lattice theory

- *the existence of the strong nuclear force between two elementary particles is an automatic consequence of our explanation of the masses of the elementary particles with cubic nuclear lattices,*

held together by the weak nuclear force. The lattices we have used for the explanation of the masses of the particles consist of photons or neutrinos. That means:

We do not use hypothetical particles.

CONCLUSIONS

We have found long sought after answers to the questions what is the weak nuclear force and the strong nuclear force, and why is the strong force so much stronger than the weak? The strong force is nothing but the sum of the large number of unsaturated weak forces at the surface of the lattice.

In order to understand the origin of the strong nuclear force one has to understand the structure of the elementary particles, which we have explained in [1] with nuclear lattices. With this concept we can explain the masses of the particles and the spin of the particles. We have now also understood the strength of the weak force which holds the nuclear lattice together and the cause of the strong force between two nuclear lattices.

REFERENCES

[1] Koschmieder, E.L. http://arXiv.org:physics/0602037. (2006)

[2] Koschmieder, E.L. Nuovo Cim. **101A**,1017. (1989)

[3] Born, M. and Landé, A. Verh.Dtsch.Phys.Ges. **20**,210. (1918)

[4] Madelung, E. Phys.Z. **19**,524. (1918)

[5] Perkins, D.H. *Introduction to High-Energy Physics* Addison-Wesley. (1982)

[6] Badhuri, R.K. et al. Phys.Lett.B **136**,189. (1984)

[7] Müller, H-M. et al. http://arXiv.org:nucl-th/9910038. (1999)

[8] Vretenar, D. et al. http://arXiv.org:nucl-th/0302070. (2003)

[9] Dexheimer, V.A. et al. http://arXiv.org:0708.0131. (2007)

[10] Born, M. *Atomtheorie des festen Zustandes* Teubner. (1923)

[11] Born, M. and Stern, O. Sitzungsber.Preuss.Akad.Wiss. **33**,901. (1919)