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On the W-boson NN Interaction and the Extended Cluster Model of the Nucleus

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Abstract

The problem of the nuclear interaction is analyzed *ab initio*, using a physical model of low-energy nuclear phenomena rather than the usual approach of mathematical theory and nuclear parameters. The interaction model is an extension of the fully discrete model of the electron, derived from the Dirac equation. Here we show that a nuclear bond, mediated by the W^- boson, evolves naturally in a discrete physical model of the nucleon, in a framework of direct interparticle action. The new model naturally accounts for the uniquely stable two-, three- and four-body bound states, the abolition of free neutron ß-decay by the deuteron bond, ^{3}H and ^{3}He particle-stability and ^{3}H ß-instability. The model is qualitative and radical, and is supported by its congruence with light nuclear phenomena in the low-energy regime.

Key words: NN interaction; physical model; W^- boson; ß-decay; discrete spacetime; nuclear clusters.

1. Introduction

This is the second of two complementary communications on the nuclear many-body problem, in a fully discrete framework. The first introduced the extended cluster model (ECM) of nuclear structure [1] without dealing with the interaction itself. The components of the structure model are four nuclear clusters, viz the deuteron, the two three-body mirror nuclei and the alpha. The model distributes the nucleons of every $A > 4$ nuclide among from one to three of the four clusters. The model is simple and radical in a number of respects but it correlates remarkably well with several nuclear phenomena.

It is anticipated that an improved understanding of the nucleus will arise from a seamless merger of structure and the interaction so that each becomes a natural extension of the other; they should be of the one genre. Because the ECM diverges so profoundly from mainstream nuclear physics it is to be expected that its accompanying theory of the nuclear interaction should also differ fundamentally from current models. The interaction model of the four clusters of the ECM, which are the subjects of the present paper, is also a major departure from mainstream nuclear physics.

The traditional approach to the nuclear problem employs mathematical modeling within symmetry constraints in order to produce numerical predictions that are compared with the results of experimental measurements. In order to approximate the data, models are altered by way of adjustable parameters and other means. Wave functions, Hamiltonians and symmetry principles are selected for inclusion based mainly on intuition and the experience of the individual making the selection, simultaneous with the aim of keeping the model realistic. The exercise is chiefly concerned with putting the information into a mathematical form which is then used to predict quantifiable nuclear behavior. Issues that relate to the underlying physical behavior of the systems and their components, that give rise to the experimental results, are not normally part of the exercise.

Heisenberg is credited with the first attempt to explain the deuteron bond. [2] Following the quantum field theory concept that particles can be bound by a charge-exchange force, mediated by a charged particle, Heisenberg proposed that the electron could act as the intermediate particle between the proton and neutron. It was soon realized, however, that such a theory could not account for the properties of the nucleus and it was abandoned, but it set the course for much of the work that was to follow.

The modern approach to the nuclear force began in the 1980s with the introduction of the concept of effective field theory (EFT) and its application to low-energy quantum chromodynamics (QCD). [3–4] That long-awaited breakthrough was welcomed enthusiastically and is now generally considered to be the correct way forward. Prior to the introduction of QCD, theories centered around Yukawa's 1935 meson theory [5] and pion exchange, then in the 1960s, the discovery of heavy mesons [6-7] led to the one-boson exchange models. [8–9] Both are still employed to supplement QCD in models of the nuclear force, but it remains a challenge after 75 years. Progress towards its resolution has been uneven and recent theoretical achievements remain deficient. The theoretical description of the deuteron, the simplest bound nucleus, is ambiguous and incomplete and its experimentally determined properties are well beyond the accuracy of nuclear models. [10]

The nucleon vector analyzing power (*Ay*) in elastic nucleon-deuteron scattering at < 30 MeV for the incident nucleon, fails to fit the experimental data by as much as 30%. [11] A deficiency of a similar magnitude is found in *Ay* calculations in p-^{3}He scattering. [12] The *Ay* puzzle remains the greatest difficulty in understanding two- and three-body systems. [13] The problem has proved so intractable that it has been suggested that it will never be solved using any theoretical model of the two-nucleon force [14] and that the problem requires new physics. [15]

While attention was focused on the new approach afforded by EFT and QCD, a postulated but formerly unobserved nuclear particle, the W^- heavy gauge boson (**W**), was detected at CERN in 1983. [16-17] The **W** had been originally predicted in the 1930s by Fermi, [18] when it became part of his model of neutron ß-decay. Then in the 1960s it was incorporated as a component of the Standard Model; a significant prediction of which was confirmed by its observation in the 1980s.

The **W** is especially interesting because of its unique relation to the two components of the deuteron. Without external stimulus, its natural emission by an isolated neutron generates a proton. The **W** has one unit of negative charge and its measured mass (80.4 GeV) is well in excess of that of the nucleon (0.938 GeV). Consequently, it is a natural, short-range charge current of the nucleon. In addition to being a property of the nucleon in the low-energy sector its presence in large numbers, observed in colliding beam accelerators, has suggested that it plays an as yet unknown role in particle physics. [19]

For these reasons it is appropriate to re-analyze the problem *ab initio*, using a physical model of nuclear phenomena rather than a mathematical theory of nuclear parameters. The aim is a description of the interaction for each of the four nuclear clusters of the ECM which is (a) simple and clearly defined (b) economical of postulates and (c) in agreement with observations of undisturbed nuclear systems.

Here we show that when the isolated neutron is analyzed in the discrete model of sub-atomic particles [20] a two-body interaction evolves naturally which is able to bind the nucleons of the four clusters of the ECM. The model is fully congruent with observed particle-stability, the tendency to ß-decay and the relative strengths of the interactions of the four clusters.

The paper is divided into five parts. Part 2 deals with the interaction model, space and time discreteness, properties of the oscillation and special relativistic model constraint. In Part 3 the model is applied to neutron decay and the principle of the nucleon interaction is set out. In Part 4 the four cluster interactions are described and briefly compared. Part 5 is a summary of the paper.

2. The Nuclear Interaction Model

2.1 The discrete nucleon

The physical interpretation of the meaning of mathematical models and experimental results is not always simple or clear cut. The so-called unreal consequences of the Dirac equation for the electron are examples of the problems that can arise when trying to gain a physical understanding of the mathematics. The equation is regarded, rightly, as a high point of achievement in the development of quantum theory. But how are energy values of less than zero, the motion of the electron at the speed of light and an equal role for space and time in its description to be understood?

Dirac expressed the problem as follows: "These quantum equations are such that, when interpreted according to the general scheme of quantum dynamics, they allow as the possible results of a measurement of kinetic energy either something greater than mc^2 or something less than $-mc^2$". [21] The difficulty was immediately apparent. The negative energy solutions were a challenge to the physical relevance of the equations, which had to be rectified. The problem presented by the equations was seemingly physical, since the mathematics were entirely problem-free.

However, Dirac's response was to prove that by a unitary symmetry transformation negative energy solutions could be transformed into positive energy solutions with opposite charge and the same mass. [22] The strategy avoided the problem of an unreal physical interpretation of the original mathematics. The present approach assumes that the mathematics is sound and the physical interpretation is inappropriate; accordingly, the problem is reanalyzed physically rather than mathematically. The positive and negative energy states are given a logically equivalent, although novel, physical interpretation which when coupled with the oscillation of the Dirac equation has far-reaching consequences. It employs a transformation of mathematical opposites, as applied to physical quantities, expressed in the usual way by the use of the symbols (+) and (–), into physical opposites without a mathematical representation.

The model is founded on the transformation which is expressed as follows: The opposite of the energy of the physical or real electron is identical with the energy of the opposite of the real electron. The opposite of the real electron is the potential electron. According to this analysis the opposite of energy of any quantity is no energy by the same rationale as: the opposite of the photon is no photon because the physical opposite of light is dark. Energy of a magnitude less than zero is then interpreted to be the capacity or potential to subsequently achieve positive energy of that magnitude. In essence, we employ the ancient distinction between potential and actual that Aristotle applied to natural objects. [23]

The physical model consists of a coupling of the actual–potential interpretation of positive and negative energy states with a further element of the Dirac equation—the oscillation. The electron oscillates between an actual state of positive energy which is physically real and a state of immaterial potential of zero energy and, consequently, with no physical properties.

The concept of 'potential' as applied to an individual oscillating particle includes all of the contributions to interactions or quantum measurements that the particle could possibly make, in any basis in which it can participate. Accordingly, for example, the potential of a quantum system to appear as a wave or particle at a measurement is a component of the single potential of the bare system. The potential may actualize as a wave when detected with an antenna or a particle when detected with a particle detector. The indivisible potential is to appear or interact as either a wave or a particle at a single observation. In this example, the potential of the counterfactual outcome is retained through successive cycles of the oscillation, which accords with the postulate that possession of potential, generally, does not imply its actualization. Quantum wave functions are then understood generally as the calculus for predicting the statistics of the actualizations of immaterial potential.

The oscillation, which Dirac described as: "an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us", [21] when coupled with the actual–potential scheme is interpreted to render the quantum system fully discrete in space and time. The "regular motion which appears to us" is then an emergent manifestation of the underlying oscillation. Material discreteness of the particle follows from the interposition of immaterial pure potential between pairs of the serial actualizations which constitute the oscillating particle. Without energy and therefore without any properties, the system lacks all geometric relations during the potential phase of the oscillation. The zero-energy phase is a discrete vacuum to which only a single potential belongs. Being completely immaterial, the vacuum is devoid of matter, space and time.

2.2 Special relativity and model constraint

As Einstein pointed out, in the absence of matter there is neither space nor time. [24] In continuous physics that assertion is essentially physically inconceivable, but it is a necessary element of the discrete scheme. Following the completion of actualization, the oscillating nucleon consists entirely of immaterial potential because its energy has decayed to zero. Since space is simply the distance and direction that relate the matter particles of the universe and time is the set of temporal relations among their serial actualizations, there is neither space nor time for the nucleon other than when it is fully actual; then it possesses its classical properties, which include its geometrical relations with all the actualizations of the universe. The neutron occupies a position in space and time when it is fully actual, at which stage of the oscillation it is observable. Therefore, the process of actualization itself cannot conform to the spacetime symmetries of special relativity. The system is unobservable and reference frames are irrelevant because there is neither distance nor duration separating it from other actual particles or its own antecedent actualizations. For the nucleon, in the absence of matter there is neither space nor time.

For the oscillating nucleon, the Lorentz transformation is relevant at the instant of complete actualization, when the classical, material nucleon occupies a fixed position, its energy has decayed to zero and consequently the geometry of its spacetime relations is flat. It is at that stage of the oscillation that charged particles emit the photons that enable their observation. [20] It does not follow from this argument that special relativity is irrelevant to the actualization process—it is. The rules that relate to mass, the speed of light and the mass–energy transformation relation provide the special relativistic constraints on the model of the nucleon oscillation. Those three elements of special relativity concern the concept of mass. It is of interest that Einstein expressed the opinion that the new concept of mass is the most important result of special relativity. [25]

According to special relativity, mass limits the rate at which a particle can change its position; which in continuous physics is the speed at which it can move. A particle with mass cannot change its position as fast as a massless photon; which is interpreted to mean, it cannot overtake a photon that it has emitted. The difference between their speeds is absolute, irrespective of the speed of the charged particle. By contrast, the difference between the speed at which a proton and a **W** (each with mass) can move is relative; either may move faster than the other. In continuous terminology, the proton overtakes the **W** if the nucleon is to be in the neutron state at the completion of actualization. The nucleon may or may not overtake the **W** that it has emitted, which accords with the observation that the decay of the neutron at some instant following its isolation is a matter of chance.

According to this analysis, the nineteenth-century field theory that requires a particle to interact with itself, which is absolute, is rendered relative by the twentieth-century advent of special relativity. Indeed, there never was a consistent theory of the action of a particle on itself. In a theory of direct interparticle action a charged particle cannot interact with itself via its emitted electromagnetic boson—the photon. [26] By contrast, a nucleon can interact with itself via its emitted nuclear boson—the **W**. The relative–absolute distinction is an effect of the concept of mass, as understood in the theory of special relativity.

The speed at which a particle changes its position (moves), in the discrete scheme, is inversely related to the duration of its actualization. The zero-energy, nonlocal component of the oscillation makes no contribution to the duration of the journey of the particle, whether it has mass or not. The particle tunnels instantaneously from one locus to the next. [27-28] The photon, being the fastest moving component particle of the atom, therefore has the shortest duration of actualization, which follows from its being uniquely massless. Regardless of the energy of the photon, none is converted into mass during its serial actualizations between creation and annihilation. The actualization of a photon is the realization of a single potential. Therefore, there is neither co-actualization with an additional potential nor conversion of its energy into mass; the two are correlated. Of the oscillations of the three matter particles and two bosons of the low-energy atom only that of the photon occurs without co-actualization and without conversion of energy into mass, except at its annihilation by a charged particle when the double potential of the photon and the particle co-actualize and energy is converted into mass.

The electron, although without constituent parts, is expected to co-actualize with and therefore annihilate photons whether it is part of an atom or not. Co-actualization is thus correlated with the conversion of energy into mass. At actualization of each component particle of the atom (except the photon) a quasi-collision occurs between two potentials (viz. co-actualization) which results in the mass of the actual particle. The special relativistic mass–energy transformation is continually realized as part of the oscillation process of each of the components of the atom.

2.3 The nucleon oscillation

In the discrete model of subatomic particles,(20) the nucleon is postulated to consist of a two-phase oscillation between states of energetic actualization and zero-energy pure potential. The physical nucleon of classical physics with its usual properties is momentarily produced by the actualization phase of the oscillation. At the completion of actualization its energy decays to zero, which eliminates all its classical properties. Successive actual phases of the oscillation are separated from one another by the intervening nonlocal, immaterial phase of pure potential at zero energy. The classical nucleon with all its properties and geometric relations is thereby rendered discrete in space and time.

The nucleon potential begins to actualize at zero energy and therefore without geometric relations or any of its usual properties. The actualization is energetic and takes time. It culminates as an actual nucleon as it achieves the properties of mass, charge and internal and external geometric relations. The energy of the nucleon exclusively performs the work of the actualization of its potential. At the completion of actualization that phase terminates instantaneously and the nucleon is then once more in the potential phase of its oscillation, from which it again begins to actualize.

The two phases of the oscillation are analogous with the fermion–boson distinction. Just as in continuous theories, bosons are binding particles and fermions are matter particles, successive actual phases of the oscillation are fermionic and are bound by the intermediate potential phase, which is bosonic, and together they form the enduring nucleon. The bond locates each actualization of the nucleon in relation to its immediate antecedent; it acts as a nonlocal restraint on their geometric separations of space and time. Fig. 1 depicts the increasing energy with time of actualization (a) and the initially featureless gradual development of two consecutive actualizations (b). Two serial actualizations originate at t_0 and t_1 respectively and terminate instantaneously at t_1 and t_2. They are initially featureless, without a definite beginning in space or time (a). The energies of actualization rise from zero (E_0) at t_0 and t_1 and reach their maxima (E_m) at t_1 and t_2, when they decay to zero (b).

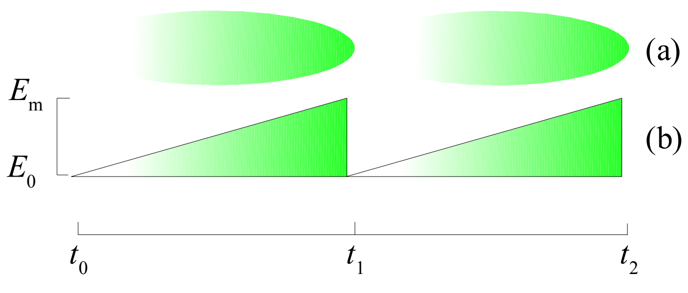

Figure 1. Energy and actualization.

3. Neutron Decay

At the level of the oscillating isolated nucleon, the low-energy phenomena of chief importance are ß-decay of the neutron and ß-stability of the proton. The final decay products of the neutron are a proton, an electron and an electron antineutrino. The Fermi picture of ß-decay is a two-step process. The first step consists in the decay of the neutron, the products of which are a proton plus the heavy gauge boson—the **W**. The second step is the decay of the **W** whose products are an electron plus an electron antineutrino. The complete, two-step process is ß-decay; here, the first step is referred to as neutron decay. Fig.2 depicts the discrete model of two-step ß-decay. Two serial neutron (N) co-actualizations are shown with a supervening **W** potential (grey oval, W). Neutron decay is shown encircled; the decay products being a proton (P) and a **W**. Following a single actualization,

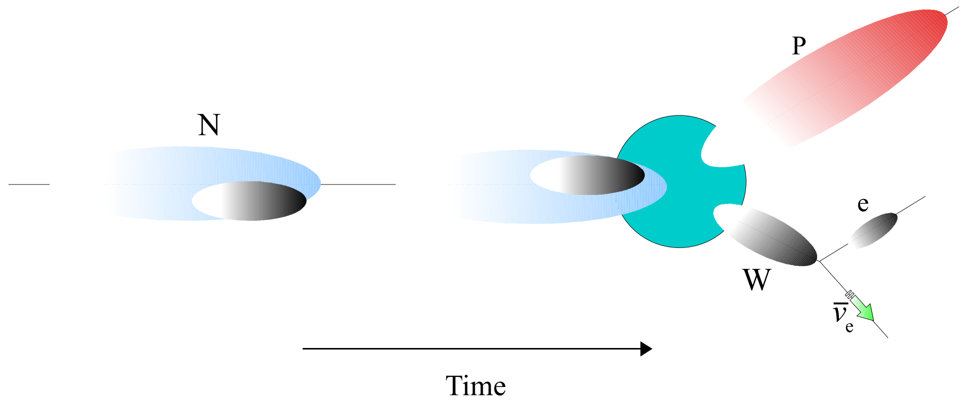

Figure 2. The discrete model of the Fermi picture of neutron ß-decay.

the **W** is shown to decay to an electron (e) and an electron antineutrino ($\bar{\nu}_e$), which are the products of ß-decay.

The isolated single neutron decays with a mean lifetime of 914 s. The zero-energy phase of the neutron oscillation consists of a double potential; one is that of a proton and the other is that of a **W**. There are just two possible outcomes for the actualization of the double potential of each oscillation of the isolated neutron. The first is co-actualization of the two potentials to form a neutron; the second is two separate actualizations, which is the first stage of neutron decay. The two alternatives are illustrated in Fig.2.

Separate or combined actualization of the neutron double potential, in the low-energy sector, is due to the interplay of the two counteracting properties of mass and charge. Mass is directly related to the duration of actualization and charge is the property that enables particles to exert forces on one another. For charges of opposite polarity the force is attractive. At the instantaneous termination of the actual phase of each oscillation, the two potentials of the neutron simultaneously begin to actualize. The mass difference of the **W** (the sum of the masses of its decay products) and the proton gives them different durations of actualization, which results in less than complete congruence of the development of their property of electric charge during the actualization of the neutron; thus, the mass difference tends to impede their co-actualization. Their opposite charges, by contrast, tend to facilitate co-actualization by the mutual attraction then annihilation of the charges of opposite polarity of the two actualizing potentials.

The counteracting effects of mass and charge mean that the nucleon self-interaction may or may not occur at each of its oscillations. There is no absolute rule that the fermion overtake its own boson if each particle moves in compliance with the principle of special relativity. The probabilistic nature of neutron ß-decay and the associated impossibility of predicting when an individual neutron will decay are consistent with a random hit-or-miss aspect of the coupling, consequent upon the interplay of mass and charge during the actualization of the double potential.

Following neutron decay, the **W** then decays by the same process, but without the randomness due to an interplay of counteracting effects. Its decay products are the electron and the electron antineutrino, whose mass difference is a factor of the order of 10^5. The mass difference of the decay products of the neutron (**W** and the proton) is less than $2x10^3$. However, the chief difference between the decay products of the neutron and those of the **W** is the absence of a charge effect for the latter. The **W** decays immediately following its single actualization because of the large mass difference and the absence of a counterbalancing charge effect between its two decay products—the negatively charged electron and the chargeless electron antineutrino.

3.1. The principle of the NN interaction

From the above analysis of neutron decay, it follows that the less than complete congruence of the actualization of the charges of the **W** and proton is ultimately due to their simultaneous origin in space and time coupled with their mass-induced different durations. If the geometric relationship of the **W** and proton actualizations were not constrained by their having a common origin in space and time, i.e. if the two were to begin separately while remaining propitiously related in space and time, the counteracting effect of the mass difference on the action of their actualizing charges could be removed. Consequently, the mutual attraction of their charges would be fully congruent, thus removing the tendency to undergo ß-decay. The smaller mass of the proton gives it a shorter duration of actualization than the neutron. If both began to actualize simultaneously, at the following pair of actualizations the proton would begin before that of the neutron. The duration of the **W** actualization is shorter than that of the proton, which is consistent with full congruence of their charges if the proton actualization begins before that of the **W**.

4. Cluster Interactions

4.1. The deuteron interaction

When a proton and neutron are suitably related in space and time, the zero-energy phases of the two oscillations may be analyzed as consisting of two potential protons and one potential **W**. As the three immaterial potentials actualize, the proton potential whose charge development is closest to being congruent with the charge development of the **W** will tend to co-actualize with it, due to the attractive effect of the opposite polarity of their charges. Under those conditions the proton tends to co-actualize with the **W** from the neutron. Thus, for the deuteron a bond is formed by a one-way, nonlocal transfer of the **W** from the neutron to the proton. The boson for the two-body nuclear system transfers without actualizing and therefore without undergoing decay. Thus, neutron decay occurs in the absence of ß-decay; which is depicted in Fig. 3. Four serial actualizations of two nucleons (*N*) are shown

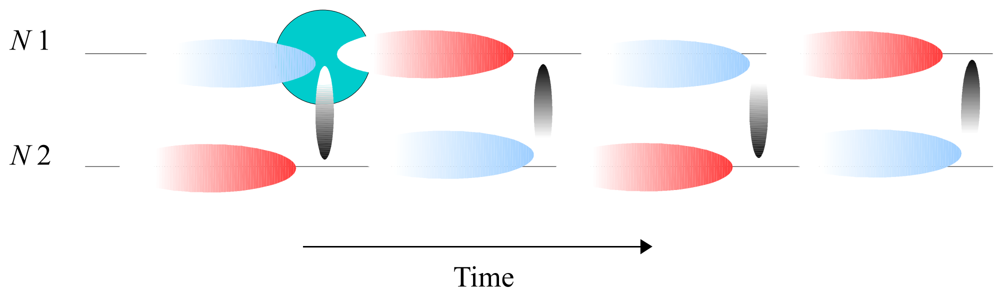

Figure 3.The deuteron NN interaction.

alternating between proton (P) and neutron (**N**) states following the one-way transfer of a **W** potential (grey oval) from neutron to proton. One of the four neutron decays is shown encircled. Each interaction is shown to draw the neutron closer to the proton in space but not in time.

The principle of the two-body bond of the deuteron is the same as the principle of the bond between the serial actual phases of the oscillation which gives rise to the endurance of the individual nucleon. An isolated proton consists of a series of discrete actualizations, each of which is bound to the source of the potential which it actualized, viz., its antecedent actualization. The bond between the two arises from the initial conditions that were founded by the first and thereby became part of the potential which effected the actualization of the properties of the second; the properties include geometric relations. The distance and duration that separate the two actualizations of the proton are the essence of the bond and are constrained by initial conditions.

The deuteron bond arises from the co-actualization of two potentials, one of which originates with each of the two nucleons. The initial conditions for the geometric relations of each actualising neutron were subject to initial conditions derived from both nucleons. Where and when the actualisation occurs is constrained by both nucleons The principle of the two-body interaction originates with the isolated neutron. The one-way transfer of a **W**, which switches both nucleon states, only originates with a nucleon in the neutron state and terminates with another in the proton state. Accordingly, the other two-body configurations (two neutrons or two protons) are unbound by the interaction.

4.2. The triton interaction

The zero-energy phases of the three oscillating nucleons of the triton may be analyzed as consisting of three potential protons and two potential **W**s. The global triton interaction, depicted in Fig. 4, consists of a series of two-body interactions plus a non-interacting, oscillating neutron; which like the isolated neutron, may either co-actualize with its own **W** or decay to a proton plus a **W** in which case the inevitable second stage of ß-decay follows. Four sets of three serial nucleon (*N*) actualizations are shown. Two of each set are in the neutron state (**N**) and one is in the proton state (P). One of the two neutrons co-actualizes with its own **W** potential (depicted as horizontal

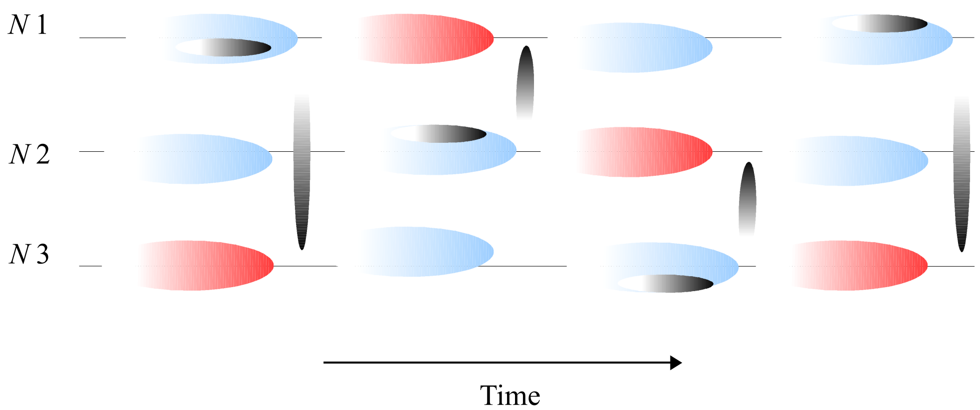

Figure 4. The triton NN interaction.

grey ovals superimposed on the neutron) which makes no contribution to the bond. The **W** potentials that transfer between nucleons are shown as vertical grey ovals, whose different lengths are an artifact of the flat two-dimensional figure. The global interaction is cyclical. Each interaction is shown to draw the two nucleons together in both space and time.

Each of the three nucleons in turn, is first the non-interacting neutron and then the initiator of the interaction. Because the global interaction binds two nucleons while each of the three completes a single oscillation, for one in three of its oscillations, each in turn is only bound to its own antecedent actualization. Being a neutron-excess nucleus, the non-interacting nucleon of the triton is always in the neutron state. The nucleon that co-actualizes with a **W** transferred from another nucleon co-actualizes with its own **W** at its next actualization.

Like the isolated single neutron, the non-interacting neutron of the triton provides the conditions for ß-decay, which is consistent with the observation that the triton undergoes ß-decay with a mean life of 3.5 years. It can be seen in Fig. 4 that two of the three nucleons are simultaneously actual, but they are in different quantum states. Thus, Pauli exclusion is naturally satisfied by the interaction. Unlike conventional nuclear theory, there are no three-nucleon interactions; only pairs are able to form a bond. The unbound neutron does not affect particle stability of the global interaction because its spacetime locus is constrained by its immediate antecedent neutron actualization, which is always bound to a proton. Thus, the discrete model of the triton is particle-stable and ß-unstable.

4.3. The ^{3}Helium interaction

When the triton decays to a ^{3}He nucleus the global potential phase consists of three protons and one **W**. The same two-body interaction binds the two protons and the single neutron. In the ^{3}He configuration, each nucleon in turn is in the proton state for two consecutive oscillations; hence the kinematics mirrors the triton interaction. The ^{3}He interaction is depicted in Fig. 5. Four sets of three

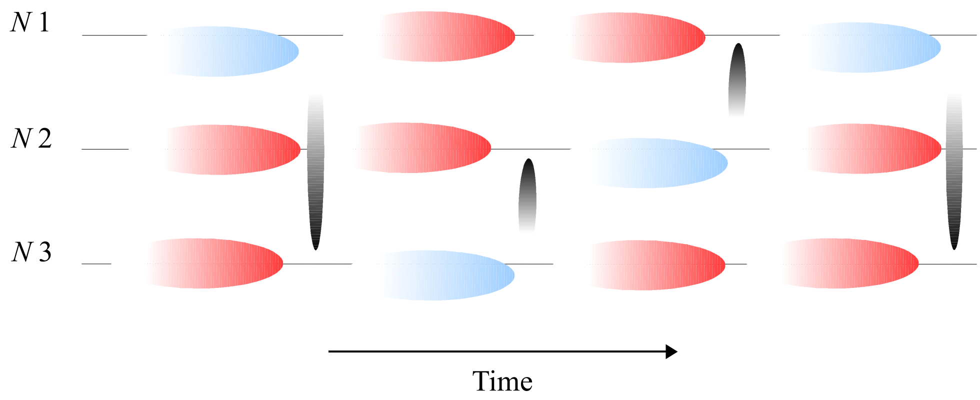

Figure 5. The ^{3}He NN interaction.

serial nucleon (*N*) actualizations are shown. Two of each set are in the proton state (P) and one is in the neutron state (**N**). One of the two protons does not interact, the other co-actualizes with a **W** potential (shown as vertical grey ovals, whose different lengths are an artifact of the flat two-dimensional figure) transferred from the neutron. The global interaction is cyclical. Each interaction is shown to draw the two nucleons together in both space and time.

Being a proton-excess nucleus, the non-interacting nucleon is always in the proton state. No nucleon has to co-actualize with its own **W** and therefore there is no tendency for ß-decay. The excess proton, like the excess neutron of the triton, is only bound to its own antecedent during one in three complete oscillations. Thus, the same principle gives particle stability to both three-body systems. Like the deuteron interaction which cannot bind two protons or two neutrons, the interaction cannot bind three protons or neutrons. The model of the three-body mirror nuclei is therefore consistent with the facts of light nuclear observations in the low energy sector. Pauli exclusion is also a natural consequence of the reaction, as seen in Fig. 5.

4.4. The alpha interaction

The addition of a neutron to the ^{3}He nucleus leads to the global interaction for the alpha particle by including the non-interacting proton of ^{3}He. The two-body interaction has evolved as the number of nucleons has increased from the deuteron to the four nucleons of the alpha. When the four nucleons are diagrammatically arranged so that they all engage in the global bond the interaction is as shown in Fig. 6. Four sets of four serial nucleon (*N*) actualizations are shown. Two of each set are in the

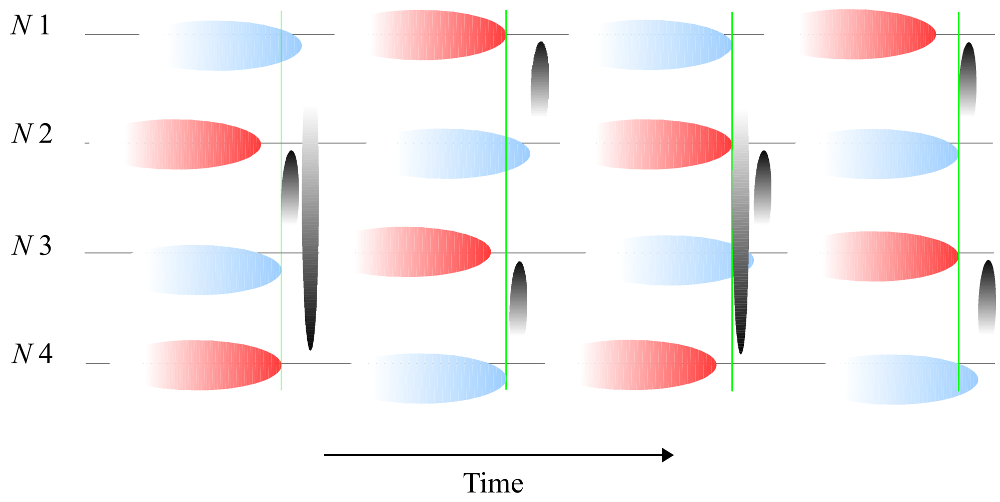

Figure 6. The ^{4}He NN interaction.

neutron state (**N**) and two are in the proton state (P). **W** transfers between nucleons are shown as vertical grey ovals, whose different lengths are an artifact of the flat two-dimensional figure. Of each set of four actualizations, two nucleons are in-phase earlier than the third and later than the fourth. The vertical lines show the phase relations and depict the sequence of boson transfers for each set. As in the three-body global interactions, the direction of boson transfers is in one direction since the global interaction is cyclical.

The fundamental principle of the interaction for the four clusters is the elimination of the effect of the mass difference between the neutron and proton which tends to counteract the attractive effect of the charges of opposite polarity. Like the two- and three-body interactions the principle is observed in every boson transfer of the alpha interaction.

Each nucleon of the alpha interacts at every oscillation, without reciprocal boson transfers between pairs, as is the case in the deuteron interaction. Unlike the two- and three-body interactions, the global alpha interaction transfers two bosons per set of four oscillations. Immediately following the interaction between two nucleons, each binds with one of the other two. The global interaction is tighter than the two- and three-body interactions in both time and space, which is consistent with it having the highest bond energy of the four clusters.

4.5. Some comparisons of the cluster interactions

Three characteristics of the interaction sequences stand out, as shown in Table I. First, the direction

Table I: Nuclear binding energies and the sequence of W transfers of each NN interaction

Nucleus	Binding energy (MeV)	Sequence of **W** transfers
^{2}H	2.224	1→2 ǀ 2→1 ǀ 1→2 ǀ 2→1†
^{3}H	8.481	1→3 ǀ 2→1 ǀ 3→2 ǀ 1→3
^{3}He	7.718	1→3 ǀ 3→2 ǀ 2→1 ǀ 1→3
^{4}He	29	3→2 ǀ 4→3 ǀ 1→4 ǀ 2→1 [a] 1→4 ǀ 2→1 ǀ 3→2 ǀ 4→3 [b]

† Numbers refer to nucleons depicted in Figs. 3 to 6;

→ indicates the transfer direction.

Transfer sequences for the four sets of each cluster are separated by vertical bars.

Each pair of [a] and [b] partners belong to a set of the four nucleons of the alpha. Each [a] transfer immediately precedes its [b] partner below.

of the ^{2}H interaction reverses with each boson transfer, in contrast with the other three which are cyclic and never reciprocate. The interaction is unique among the four in not drawing the nucleons together in time. The cyclic interactions are reminiscent of quantum spin which, contrary to classical spin, does not entail motion about a point or axis. Second, the sequences of the two three-body interactions are mirrors of one another. They are similar in both bond strength and interaction kinematics. Third, the ^{4}He interaction binds each nucleon during each set of boson transfers. The alpha interaction represents the completion of the neutron-engendered two-body interaction. There is no potential to bind an additional single nucleon, whether proton or neutron; there is neither a non-interacting nucleon nor a serial reversed boson transfer.

Each of the four interactions consists of serial discrete nucleon pairings that may be analyzed as quantum mechanical two-particle ensembles, the members of which occupy antisymmetrical quantum states. The model of the nuclear interaction is both consistent throughout and a natural manifestation of the Pauli exclusion principle as it applies both to individual particles and generally to the global interaction of the nucleus.

5. Summary

The discrete model of the nuclear force is radical, but it is also clearly defined, simple and consistent with observation. Its unification of the phenomena of the particle-stable two-, three- and four-body nuclei connects the theory with physical reality, which is indicative of its intrinsic value. The most radical element is its departure from both the Standard Model of particle physics and the doctrine of continuity, which are the usual foundations for particle theories. It is also radical because the nuclear force can be understood qualitatively, without symmetry laws or calculations of adjustable parameters and without the concepts of physically real fields, shells and orbits. The single heavy gauge boson-mediated interaction generates the four clusters of the ECM in compliance with the generalized Pauli principle. A later communication will deal with the extension of the same two-body model to cluster–cluster interactions in the formation of nuclear structure

The model provides a consistent explanation of neutron persistence and decay, at the level of the single particle and the four clusters of the ECM. The interaction naturally accommodates the only observed two-, three- and four-body bound states. A single principle underlies the endurance of the nucleon and the nuclear bond, and the process of its realization is a natural evolution of the model of the isolated neutron—nothing is put in by hand.

The **W** is given the role of a boson which mediates a bond between the components of stable matter, thus placing it on an equal footing with the photon and gluon. Each of the three bosons is then confined to a single sector of the atom, none needs the assistance of the others and quark confinement is allowed to remain absolute, in the low energy sector.

The present approach conserves the charge of the nucleus and couples the electromagnetic and weak forces via the two modes of action of electric charge. Charge annihilation and the short-range massive **W** provide the weak nuclear interaction, leaving the strong force in the quark–gluon sector. Charge-mediated annihilation of the infinite-range, massless photon that provides the electromagnetic interaction is not part of the theory. Although unified by their dependence upon electric charge, each is fully independent of the other. The model is crucially constrained by the special relativistic concepts of mass, the speed of light, the mass–energy transformation relation and the symmetries of flat space-time emerge in the classical part of the nucleon oscillation.

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References

1. P.J. Fimmel, Physics Essays **17,** 245 (2004).
2. W. Heisenberg, Z. Phys. **77**, 1 (1932).
3. S. Weinberg, Phys. Lett. B **251**, 288 (1990).
4. S. Weinberg, Nucl. Phys. B **363**, 3 (1991).
5. H. Yukawa, Proc. Phys. Math. Soc. Japan **17**, 48(1935).
6. A.R. Erwin, R. March, W.D. Walker and E. West, Phys. Rev. Lett. **6**, 628 (1961).
7. B.C. Maglic, L.W. Alvarez, A.H. Rosenfeld and M.L. Stevenson, Phys. Rev. Lett. **7**, 178 (1961).
8. R. Bryan and B.L. Scott, Phys. Rev. **177**, 1435 (1969.
9. M.M. Nagels, T.A. Rijken and J.J. de Swart, Phys. Rev. D **17**, 768 (1978).
10. M. Garçon and J.W. Van Orden, (preprint) nucl-th/0102049 (2001).
11. H. Witała, D. Hüber and W. Glöckle, Phys. Rev. C **49**, R14 (1994).
12. M. Viviani, A. Kievsky, S. Rosati, A.E. George and L.D. Knutson, Phys.Rev. Lett. **86**, 3742 (2001).
13. W. Glöckle, H. Witała, D. Hüber, H. Kamada and J. Golak, Phys. Rep. **274**, 107 (1996).
14. D.R. Entem, R. Machleidt and H. Witała, Phys. Rev. C **65**, 064005 (2002).
15. F. Sammarruca, H. Witała and X. Meng, Acta Physica Polonica B **31**, 2039 (2000).
16. G. Arnison, et al., (UA1-collab.) Phys. Lett. B **122**, 103 (1983).
17. M. Banner, et al., (UA2-collab.) Phys. Lett. B **122**, 476 (1983).
18. E. Fermi, Z. Physik, **88**, 161 (1934).

19. V.J. Stenger, Timeless Reality; Symmetry, Simplicity and Multiple Universes (Prometheus Books, New York, 2000).

20. P.J. Fimmel, (preprint) http://pjfimmel.id.au/OtEoME.pdf (2007)

21. P.A.M. Dirac, Theory of Electrons and Positrons. Nobel Lecture. 1933. (Nobel Lectures Physics 1922-1941. Elsevier, Amsterdam 1965), p. 330.

22. P.A.M. Dirac, The principles of quantum mechanics (Clarenden Press, Oxford, (1930) p. 255.

23. Aristotle, Physics Book III $200^{b}26$ - $201^{a}19$. Translated by R. Waterfield (Oxford University Press Inc. New York, (1999), p. 56.

24. A. Einstein, Relativity: The Special and the General Theory (Crown Trade Paperbacks, New York 1961), p. 51.

25. A. Einstein, *ibid*., p. 176.

26. J.A. Wheeler and R.P. Feynman, Rev. Mod. Phys. **21**, 425 (1949).

27. A.M. Steinberg, P.G. Kwiat and R.Y. Chiao, Phys. Rev. Lett. **71**, 708 (1993).

28. V. Laude and P. Tournois, J. Op. Soc. Am. B**16**, 194 (1999).