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Weak Interaction and the Mechanisms for Neutron Stability and Decay

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Abstract

Purpose – The decay of the neutron is well known from the perspective of empirical quantification, but the ontological explanations are lacking for why the neutron should be stable within the nucleus and unstable outside. A theory is developed to explain the reasons for decay of the free neutron and stability of the bonded neutron. **Method –** The Cordus theory, a type of non-local hidden-variable (NLHV) design, provided the mathematical formalism of the principles for manipulating discrete forces and transforming one type of particule into another. This was used to determine the structures of the W and Z bosons, and the causes of neutron decay within this framework. **Findings** - The stability of the neutron inside the nucleus arises from the formation of a complementary bound state of discrete forces with the proton. The neutron is an intermediary between the protons, as the discrete forces of the protons are otherwise incompatible. This bond also gives a full complement of discrete forces to the neutron, hence its stability within the nucleus. The instability of the free neutron arises because its own discrete field structures are incomplete. Consequently it is vulnerable to external perturbation. The theory predicts the free neutron has two separate decay paths, which are mixed together in the β- process, the first determined by the local density of the fabric, and the second by the number of neutrinos encountered. The exponential life is recovered. The internal structures of the W bosons are determined. **Implications –** The W bosons are by-products from the weak decay process, and do not cause the decay. The weak decay is shown to be in the same class of phenomenon as annihilation, and is not a fundamental interaction. **Originality –** A novel theory has been constructed for the decay process, using a NLHV mechanics that is deeper than quantum theory. This new theory explains the stability-instability of the neutron and is consistent with the new theory for the stability of the nuclides.

Keywords: weak interaction; ontological; W boson; neutrino; nuclear polymer

1. Introduction

The beta decay process and the existence of the neutron and neutrino are well-established by a large body of empirical evidence. However the situation is less clear from the perspective of physical realism, as an ontologically satisfactory explanation of the decay processes has been elusive. There are unanswered questions at the foundational level: *Why does the free neutron need to decay? Why is the neuron stable in the nucleus, but unstable on its own?* The present paper addresses these questions, and shows that a specific non-local hidden-variable (NLHV) design has the ability to solve these issues.

2. Background

2.1 Existing Approaches

The discovery of beta minus decay (Rutherford, 1911) was an historically important step for fundamental physics, because from it two new particles were inferred, the neutron (Chadwick, 1932), and the neutrino (Fermi, 1934; Pauli, 1930; Wilson, 1968). The empirical aspects of the beta and other decays have been extensively studied since, resulting in a comprehensive knowledge of the quantitative properties (life, binding energy, daughter products, and decay channels) for the whole table of nuclides. This table represents an aggregation of an enormous body of empirical knowledge. However the theoretical explanations have not kept pace. All the models of the nucleus, which are primarily the shell model (Ivanenko, 1985), liquid-drop model (Gamow, 1930), and semi-empirical mass formula (SEMF) for binding energy (Weizsäcker, 1935) have been in existence for some time. However none is particularly effective. The models are contrived, requiring variables to be included for the sake of accommodating the empirical data rather than on the basis of theory. They also require extensive tuning of their multiple coefficients, and even then their fit is poor. The liquid-drop model and SEMF come closest to providing an underlying set of mechanics for the nuclides, but even this is arbitrary in places. As a whole these models are incapable of explaining the simplest features in the table such as the existence of multiple stable isotopes, or why any one isotope series begins and ends where it does.

The neutron has some important but obscure part to play in nuclear structure: this is evident from observing that no stable nuclide exists with more protons (p) than neutrons (n), $_{2}He_{1}$ being the exception. It is also apparent from the table of nuclides that the neutron can be stable within the nucleus, though instability arises when there are too many neutrons in the nucleus, and the single isolated neutron is intrinsically unstable as the β- decay shows. This inconsistent stability-decay behaviour of the neutron is difficult to reconcile with existing theories.

While quantum chromodynamics (QCD) describes the neutron as comprising three quarks, the equations of QCD have not been solved, from first principles, for this particle. Consequently the nature of the bound state is imperfectly understood. This situation has been partly compensated by the development of numerical methods, in the form of non-perturbative lattice QCD, that give excellent quantitative solutions (Bazavov et al., 2010). Lattice QCD is able to quantify many aspects of nucleon behaviour (Fodor, 2012), such as the binding of the quarks (Brown & Rho, 1979), and the approximate masses of the particles (Dürr et al., 2008). It also makes quantitative predictions of the transitions between the hadrons in the early Universe or in neutron stars (Aoki, Endrodi, Fodor, Katz, & Szabo, 2006). These quantitative methods provide insights into the behaviour of quarks, but fall short of ontological explanations of *how* the stability/decay arises. The stability of the neutron in the deuteron is usually attributed to binding energy, i.e. the mass of the deuteron is *less* than that of its decay products. Hence decay is prohibited by energy conservation. However this still does not explain the nature of how binding energy arises or how the stability operates. Likewise, it is reasonable to accept that energy considerations allow the free neutron to decay, but this does not explain *how* it does or why it has such a long life. Consequently, although quantitative descriptions of the neutron are well-developed within quantum theory, there is a deep ontological deficiency in the understanding of how the neutron decays and how this affects the nuclides. There is value in exploring whether alternative theoretical frameworks are able to challenge quantum theory in this area.

3. Methodology

3.1 Purpose

The purpose of this paper was to explore the reasons for the stability of the neutron *inside the nucleus,* and for the instability of the *free* neutron, based on a novel alternative mechanics for fundamental physics. This also takes in an explanation of the W bosons, and the role of the neutrino-species. The work builds on a prior conceptual theory for the beta decays (D. J. Pons, A. Pons, D., & A. Pons, J., 2014).

3.2 Approach

The Standard Model and existing models of the nucleus are all based on the assumption that matter comprises zero-dimensional (0-D) points. Since no theory built on this premise has been able to explain the nuclides, it is worthwhile looking at alternative approaches. Specifically, it is possible that physical realism is not fundamentally point-based. In which case the deeper physics would, by the principle of requisite variability, comprise particles with internal functionality. This prospect is explored here. The specific starting design is the Cordus theory (Pons, Pons, Pons, & Pons, 2012), which is a non-local hidden-variable (HNLV) design with the addition of discrete fields. The core idea is that matter and photons are not 0-D points but rather have two reactive ends, some short distance apart and connected by a fibril. The fibril itself does not interact with other matter or fields, but the reactive ends do. The reactive ends emit discrete forces that travel down flux lines in three orthogonal directions hence hyperfine emission directions (HED). The combination of internal structure and external discrete fields is called a *particule* to differentiate it from the 0-D point (Dirk. John. Pons, Arion. D. Pons, & Aiden. J. Pons, 2014). The pattern of emission of discrete forces is proposed to characterise the type of particule, and the discrete forces themselves make up the electro-magneto-gravitational forces and the strong force. While this *particule* structure was initially conjectural, it turns out to be a robust idea with wide-ranging relevance. It has successfully provided explanations based on physical realism for many phenomena, including resolving wave-particle duality at a proposed deeper level and recovering basic optical laws of reflection and refraction (Pons et al., 2012). It has also made meaningful contributions to a new understanding of matter-antimatter (Dirk. J. Pons, Arion. D. Pons, & Aiden. J. Pons, 2014b) and the annihilation process (Dirk. J. Pons, Arion. D. Pons, & Aiden. J. Pons, 2014a), as well as applications in cosmology (Pons & Pons, 2013; D. J. Pons, A. Pons, D., & A. Pons, J., 2013a). Thus the initial conjecture, while designed to solve wave-particle duality, has demonstrated excellent external construct validity. Nor need there be any disquiet about this mechanics being based on a hidden variable solution. While it is true that the Bell type inequalities (Bell, 1964; Groblacher et al., 2007; Leggett, 2003) preclude *local* hidden-variable solutions, the *non-local* types are not excluded (De Zela, 2008; Laudisa, 2008). Instead the only real objection that can be made against the NLHV sector is that it is historically unproductive: it has been difficult to find candidates solutions in this area other than the de-Broglie-Bohm pilot-wave theory (Bohm & Bub, 1966; de Broglie, 1925), which has progressed poorly. The present solution is a different concept and in no way similar to that theory.

As the Cordus theory shows, it is feasible to conceive of a new mechanics for the deeper level of physics, and as anticipated (Colbeck & Renner, 2011), this does not involve quantum theory. Thus within the Cordus theory particles are not points, locality fails, and quantum mechanics is re-interpreted as a statistical approximation to a deeper and faster determinism, consistent with earlier expectations (Einstein, Podolsky, & Rosen, 1935). This yields a solution grounded in physical realism, as opposed to the stochastic abstraction of quantum theory. There is therefore no reason to believe that quantum theory is the only way to conceptualise fundamental physics.

The concept has been extended into a theory that explains nuclear structure, starting from the nuclear force, which is explained as a synchronous interaction between discrete fields (D. J. Pons, A. D. Pons, & A. J. Pons, 2013c). It explains why each individual nuclide (H to Ne) is stable, unstable, or non-existent (D. J. Pons, A. D. Pons, & A. J. Pons, 2013b), identifies why the isotope series start and end where they do, explains the anomalous trends in the lifetimes, and explains the main structural features such as the deviation from the proton (p) = neutron (n) line and the stable isotopes and isotones. This level of explanation is not provided by any other nuclear theory. Other parts of the Cordus theory have identified how the beta decay process operates, and this has been used to propose a specific NLHV structure for the neutrino species (Dirk. J. Pons, Arion Pons, D., et al., 2014). Thus it has been possible to answer the question of how the neutron decays into three independent particles, e.g. β- decay to a proton, electron, and antineutrino.

3.3 Method

The problem of the stability/instability of the neutron was approached using the discrete force emission principles of this theory, i.e. hyperfine-emission-direction (HED) mechanics (Dirk. J. Pons, Arion Pons, D., et al., 2014) (Dirk. J. Pons, Arion. D. Pons, et al., 2014a). This is a mathematical formalism of the principles for manipulating discrete forces and transforming one type of particule into another. This is referred to as a remanufacturing process, as the discrete forces are usually conserved, the exceptions being the mass-energy equivalences of pair production and annihilation (Dirk. J. Pons, Arion. D. Pons, et al., 2014a) where the sum of discrete forces is not conserved, but these are not of concern here. A core principle of this theory is that a particule is defined by the pattern of discrete forces it emits, and therefore changes to the discrete forces cause the particule to change its nature. The pattern of discrete forces is represented in HED notation, which indicates the number of discrete forces in each of three orthogonal spatial directions [r, a, t], their charge (negative: x^1, positive: x_1) and matter-antimatter hand (antimatter uses underscore, e.g. $x_{\underline{1}}$). The HED mechanics may be considered a discrete-field hidden-variable equivalent of Feynman diagrams.

The underlying principles of the Cordus nuclear theory, which are noted as lemmas, are summarized below, from (Dirk. John. Pons et al., 2014):

1) ‘The HED mechanics require the discrete forces to be conserved, rearranged, or even transformed, during transmutation and decay processes. Thus all discrete forces have to be accounted for, though they can be changed into other types as the annihilation theory shows.

2) The HED mechanics allow a charge- and hand-neutral complex of discrete forces to be added to any particule. This neutral complex comprises $x_{\underline{1}.1}^{1.\underline{1}}$ where x is one of the HED axes. The complex is represented symbolically by ↑↓ where ↑= $x_{\underline{1}}^1$ and ↓= $x_1^{\underline{1}}$. Being charge- and hand-neutral, this complex has no net energy. It is analogous to QM’s idea of a vacuum fluctuation. Note that neither a single discrete force (say) x^1 nor a single pair (say)↑ may be added to a particule ex vacuua: all such additions must be neutral as regards *both* charge and hand.

3) The structure ↑↑↑ = [$r_{\underline{1}}^1$. $a_{\underline{1}}^1$. $t_{\underline{1}}^1$] corresponds to a pair of photons, alternatively an electron-antielectron pair (Dirk. J. Pons, Arion. D. Pons, et al., 2014a). This set of discrete forces may be added to a particule as part of energy absorption.

4) The application of HED mechanics to a particule, or assembly of particules, is best understood as a remanufacturing process. The discrete forces are permitted to change to other axes (HEDs), and separate/combine into other groupings, and thereby redefine the identity of the particule. ‘

Next the HED mechanics are used to infer the structures of the W bosons, from the known products of the decay processes. Thereafter the reasons are sought for the stability of the neutron *inside the nucleus* and the instability of the *free* neutron.

4. Results

4.1 Discrete Force Structures of the Neutron

Prior work identified the hidden structures and discrete forces of the neutron as shown in Figure 1.

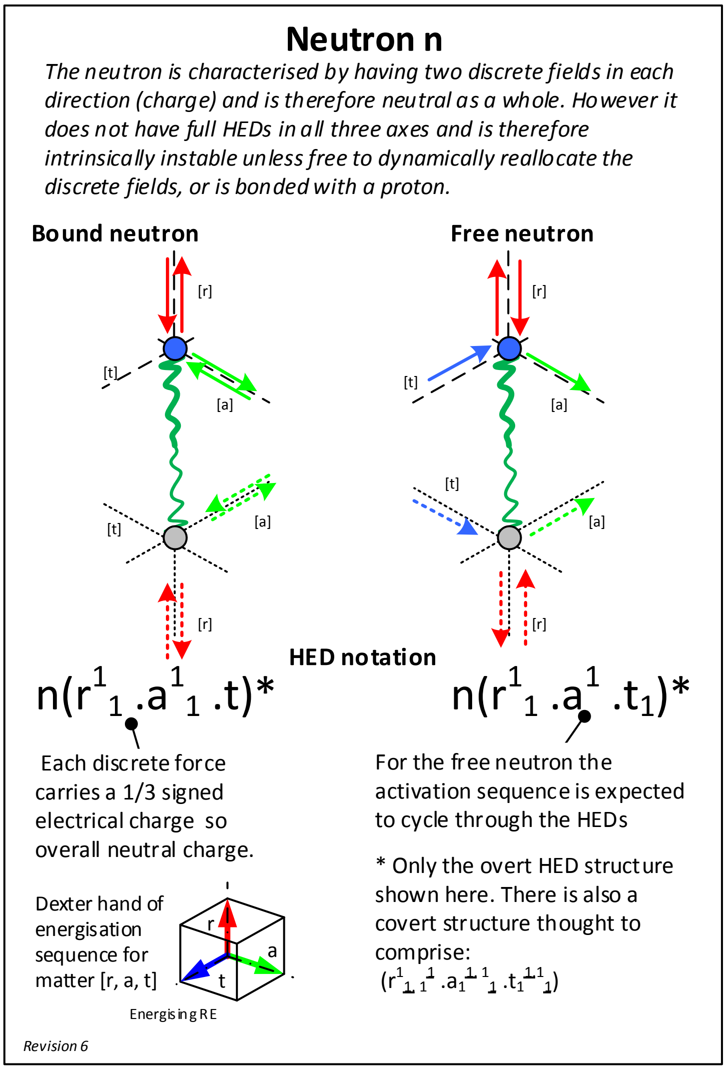

Figure 1. Proposed internal and external (discrete force) structures of the neutron. From (Dirk. J. Pons, Arion Pons, D., et al., 2014) reproduced by permission

The discrete force structures are represented in HED notation as follows (Dirk. J. Pons, Arion Pons, D., et al., 2014):

$$
\begin{aligned}
&n(udd) = \\
&n[u(r_1{}^1{}_{\underline{1}}\,.a_1\,.t_1{}^{\underline{1}}) + d(r^1{}_1{}^{\underline{1}}.a^1{}_{\underline{1}}\,.t) + d(r^1{}_1{}^{\underline{1}}.a^1{}_{\underline{1}}\,.t)] \\
&= n(r_1{}^{11}{}_{\underline{1.}}{}_1{}^{\underline{1}}\,.a_1{}^1{}_1{}^{\underline{1.}}{}^1{}_{\underline{1}}\,.t_1{}^{\underline{1.}1}{}_{\underline{1}}) \\
&= n[(r_1{}^1\,.a_1{}^1\,.t) + (r^1{}_{\underline{1.}}{}_1{}^{\underline{1}}\,.a_1{}^{\underline{1.}}{}^1{}_{\underline{1}}\,.t_1{}^{\underline{1.}1}{}_{\underline{1}})] \\
&= n[(r_1{}^1\,.a_1{}^1\,.t) + (r\uparrow\downarrow\,.a\uparrow\downarrow\,.t\uparrow\downarrow)] \\
&= n(r_1{}^1\,.a_1{}^1\,.t)^*
\end{aligned} \quad (1)
$$

There are two components here: *overt* and *covert*. The overt discrete forces are those that are displayed outside the particule and make up the electrostatic fields and bonding interactions. In this case the component $n(r_1{}^{1}\ .a_1{}^{1}\ .t)$ contains the overt fields. The covert discrete forces are the component that is completely balanced in *both* charge and matter-antimatter species. This means that they are neutral and do not respond to the electrostatic force. Charge neutrality means that there are as many superscripts as subscripts in the HED notation, and matter-antimatter species neutrality is evident in symmetry of the underscore parts in the HED notation. Thus the predicted covert part is $(r^1{}_{\underline{1}.}{}_1{}^{\underline{1}}\ .a_1{}^{\underline{1}.\ 1}{}_{\underline{1}}\ .t_1{}^{\underline{1}.1}{}_{\underline{1}})$. The combination of charge and species neutrality means this component is not evident except by its effect on mass (Dirk. J. Pons, Arion Pons, D., et al., 2014). It is proposed, see later, that the free neutron shifts its discrete forces around to avert decay. Consequently the bound and free states of the neutron are predicted to be slightly different, see Figure 1.

4.2 Weak Interaction and W bosons

Next it is shown that the bosons may be understood as transitional assemblies of discrete forces. The specific area under examination are the W bosons as they are involved in the neutron decay.

4.2.1 W^- boson

The emission or absorption of a W^+ or W^- boson changes the electric charge and spin, and changes the quark flavour type. In the conventional description, β- decay involves a d quark in the neutron emitting a W^- boson and thereby converting itself into a u quark, to make a proton. The W^- boson then quickly decays into an electron and an antineutrino. Thus:

$$d => u + e + \underline{v} \text{ with } e + \underline{v} = W^- \tag{E2}$$

The track of the W boson is empirically visible in high-energy impacts. By comparison the Z boson does not change the charge, hence *neutral current interaction*, but can change spin. The bosons, which have been inferred from experimental observation, are heavy: they have mass much greater than the proton. The Z boson decays into various different particle-antiparticle pairs, such as the neutrino and the complementary antineutrino. Higher energy Z bosons may decay into higher generation neutrino-antineutrinos, and have shorter lives.

HED notation was used to estimate the basic structure of the W^- boson. First, express the d quark in HED notation, then add two neutral complexes each of $\uparrow\downarrow = x_{\underline{1}}{}^{1}{}_1{}^{\underline{1}}$. These may be considered structural contributions from the fabric (vacuum fluctuations), rather than energy per se. The design necessitates these to provide for the requisite output discrete forces. Then starting with d, rearrange to extract the u quark structure and the W^- transitional assembly:

$$\begin{aligned}
& d[(r^1.a.t)+(r_1{}^{\underline{1}}.a^1{}_{\underline{1}}\ .t)] + [\downarrow_1{}^{\underline{1}}].[\uparrow^1{}_{\underline{1}}] + [\downarrow_1{}^{\underline{1}}].[\uparrow^1{}_{\underline{1}}] \\
& => O[(r^1{}_1{}^{\underline{1}}.a_1{}^{\underline{1}}.t)+(r_1{}^{\underline{1}}.a^1{}_{\underline{1}}\ .t) + (r.a.t)[\downarrow].[\uparrow^1{}_{\underline{1}}] + [\downarrow].[\uparrow^1{}_{\underline{1}}] \\
& => O[(r_1.a_1.t) + (r^1{}_{\underline{1}}.a.t_1{}^{\underline{1}}) + (r^{1.\underline{1}}.a^{\underline{1}.\ 1}{}_{\underline{1}}.t^1{}_{\underline{1}})] \\
& => u[(r_1.a_1.t) + (r^1{}_{\underline{1}}.a.t_1{}^{\underline{1}})] + W^-(r^{1.\underline{1}}.a^{\underline{1}.\ 1}{}_{\underline{1}}.t^1{}_{\underline{1}}) \\
& => u[(r_1.a_1.t) + (r^1{}_{\underline{1}}.a.t_1{}^{\underline{1}})] + e(r^1\ .a^1\ .t^1) + \underline{v}(r.^{\underline{1}}\ .a_{\underline{1}}{}^{\underline{1}}\ .t_{\underline{1}}) \\
& => u + e + \underline{v}
\end{aligned} \tag{E3}$$

So the W^- is identified as:

$$W^-(r^{1.\underline{1}}.a^{\underline{1}.\ 1}{}_{\underline{1}}.t^1{}_{\underline{1}}) \tag{E4}$$

This correctly predicts the negative charge of the boson, and produces electron and antineutrino structures consistent with those previously found.

4.2.2 W^+ boson

The empirical evidence is that the W^- and W^+ bosons have the same mass but opposite charge. The Cordus theory therefore predicts that the W^+ should have a HED structure comprising charge-inversion of the W-. However this may be proved the long way instead. The W+ boson is associated with the following process:

$$\begin{gathered}
u => d + \underline{e} + v \\
\text{with } \underline{e} + v = W^+
\end{gathered} \tag{E5}$$

Now apply HED notation to estimate the basic structure of the W^+ boson, starting with the u quark in HED notation. This design requires the addition of external energy, provided by a ↑↑↑ energetic structure. This is consistent with the observation that the u [2.3 E6 eV/c^2] has a lower mass than the d [4.8 E6 eV/c^2]. From this perspective the added energy ↑↑↑ goes into the creation of new discrete force structures, rather than radiation or thermal agitation (heat). Then rearrange to extract the d quark structure and the W^- transitional assembly:

$$
\begin{aligned}
& u[(r_1 .a_1 .t)+(r^1_{\underline{1}} .a.t_1^{\underline{1}})] +[\uparrow^1_{\underline{1}}].[\uparrow^1_{\underline{1}}].[\uparrow^1_{\underline{1}}] \\
& => O[(r_1 .a_1 .t)+(r^1_{\underline{1}} .a.t_1^{\underline{1}}) + (r.a.t)] +[\uparrow^1_{\underline{1}}].[\uparrow^1_{\underline{1}}].[\uparrow^1_{\underline{1}}] \\
& => O[(r_1 {}^1_{\underline{1}}.a_1 .t)+(r^1_{\underline{1}} .a.t_1^{\underline{1}}) + (r.a.t)] +[\uparrow].[\uparrow^1_{\underline{1}}].[\uparrow^1_{\underline{1}}] \\
& => O[(r^1.a.t)+(r_1^{\underline{1}} .a^1_{\underline{1}}.t) + (r_{\underline{1}.\,1}{}^1.a_{\underline{1}}.t_{\underline{1}.}{}^1{}_1)] \qquad \text{(E6)} \\
& => d[(r^1.a.t)+(r_1^{\underline{1}} .a^1_{\underline{1}}.t)] + W^+(r_{\underline{1}.\,1}{}^1.a_{\underline{1}}.t_{\underline{1}.}{}^1{}_1) \\
& => d[(r^1.a.t)+(r_1^{\underline{1}} .a^1_{\underline{1}}.t)] + \underline{e}(r_{\underline{1}}.a_{\underline{1}}.t_{\underline{1}}) + v(r_1{}^1.a.t^1{}_1) \\
& => d + \underline{e} + v
\end{aligned}
$$

So the W^+ is identified as:

$$W^+(r_{\underline{1}.\,1}{}^1.a_{\underline{1}}.t_{\underline{1}.}{}^1{}_1) \qquad \text{(E7.1)}$$

which may be rearranged to make its complementarity to the W- more explicit:

$$W^+(r_{\underline{1}1} .a_{\underline{1}.1}{}^1 .t_{\underline{1}}{}^1) \qquad \text{(E7.2)}$$

Thus the W^- and W^+ are indeed charge-inversions of each other, as expected.

4.2.3 Z boson

The Z boson (91.2 GeV) does not transform quarks, but instead is conventionally proposed to be the mechanism for momentum transfer between particles. This is thought to be the mechanism for elastic scattering of neutrinos, the transfer of the Z boson being referred to as a *neutral current interaction*. Neutrinos are otherwise not expected to interact electromagnetically (via photons). The decay products of a Z boson are a fermion and the corresponding antifermion: electron-positron, neutrino-antineutrino, quark-antiquark. It is possible to express each of these pairs in HED notation, but it is not possible to infer the Z structure due the lack of unique outcomes. The method suggests that the Z may comprise:

$$\uparrow\downarrow +\uparrow\downarrow+\uparrow\downarrow => Z(r_{\underline{1}.1}{}^{1.\underline{1}}.a_{\underline{1}.1}{}^{1.\underline{1}} .t_{\underline{1}.1}{}^{1.\underline{1}}) \qquad \text{(E8)}$$

with a different residual in each case.

4.2.4 Interpreting the Weak force

The Cordus theory explains the W boson as a transitional assembly in the remanufacture of the nucleon, one that contains all the discrete forces that are surplus to the primary quark transformation. The theory accepts that the W and Z bosons can be considered temporary particules, but denies them a *causal* role in flavour-changing. From this point of view they are not so much particles with distinct static identities that *cause* change in quarks, but are instead dynamically changing waste streams. The reasons that quarks change, is driven by forces arising from within the nucleus, or the isolated neutron, and the bosons are the secondary response of those systems.

This also means that the Cordus theory denies the *weak interaction* as a fundamental force/interaction, and instead explains it as merely a remanufacturing of NLHV structures under the influence of the synchronous interaction (strong force). Thus according to the Cordus theory there are only four, not five, fundamental interactions: electrostatic, magnetic, gravitational, and synchronous (Pons et al., 2013c). In this theory the experience of force is caused by prescribed displacement of the reactive end under the loading of incoming discrete forces. In contrast the weak decay is a remanufacturing of internal structures, and does not involve prescribed displacement of reactive ends, other than internal re-arrangements of discrete forces. Hence it is not considered a force interaction in this perspective. It is instead classified as one of the remanufacturing processes, alongside photon emission/absorption, annihilation, and pair creation. Also unique to the Cordus theory, and falsifiable, is the prediction that the electro-magneto-gravitational interactions apply for discoherent matter, and the synchronous interaction for coherent (Pons et al., 2013c). Thus the theory provides force unification, though in a different way to that attempted by quantum mechanics.

Why are the bosons so heavy? From the Cordus perspective the reason they have high mass is that (a) they emit many discrete forces, and more speculatively (b) their fibrils operate at a high frequency to service the overloaded HED structures. Higher energy bosons are known to decay faster. This is explained as the decay process needing *cycles* of activity, not time per se (Pons et al., 2013a). Higher energy particules have higher frequency (from the de Broglie relationship), hence more frequent emission of discrete forces, and can accomplish the necessary disassembly process steps in less time. In this theory time is fundamentally the local frequency oscillations of particules.

4.3 Mechanisms for Neutron Stability in the Nucleus

It is readily apparent in the Cordus theory why the neutron is stable in the atom: because it forms a complementary bound state with the proton:

$$n(r\,.a_1{}^1\,.t_1{}^1) + p(r_{1.1}{}^1\,.a_1\,.t_1) \Rightarrow O(r_{1.1}{}^1\,.a_{1.1}{}^1\,.t_{1.1}{}^1) \quad \text{(E9)}$$

Here the O assembly is the deuteron, and only the overt structures are shown. Thus the discrete forces of the neutron combine with those of the proton, to create an assembly that has better completeness, and consistency, of discrete forces in each of the three axes, see Figure 2. The synchronous interaction holds the structure together. The result is greater stability, i.e. resistance to being perturbed into separation. This idea permits an explanation of many features of the nuclides, including relative stabilities, existence and non-existence of nuclides (H to Ne) (Pons et al., 2013b). This also explains why the neutron is necessary in the nucleus, as evident in no stable nucleus having fewer neutrons than protons (with exceptions). The reason is because proton-to-proton bonds cannot achieve an outcome with balanced discrete forces. The exceptions are H and He, and the Cordus theory explains those anomalies too (Pons et al., 2013b). Having the ability to explain the nuclides demonstrates the potential of the hidden-variable sector.

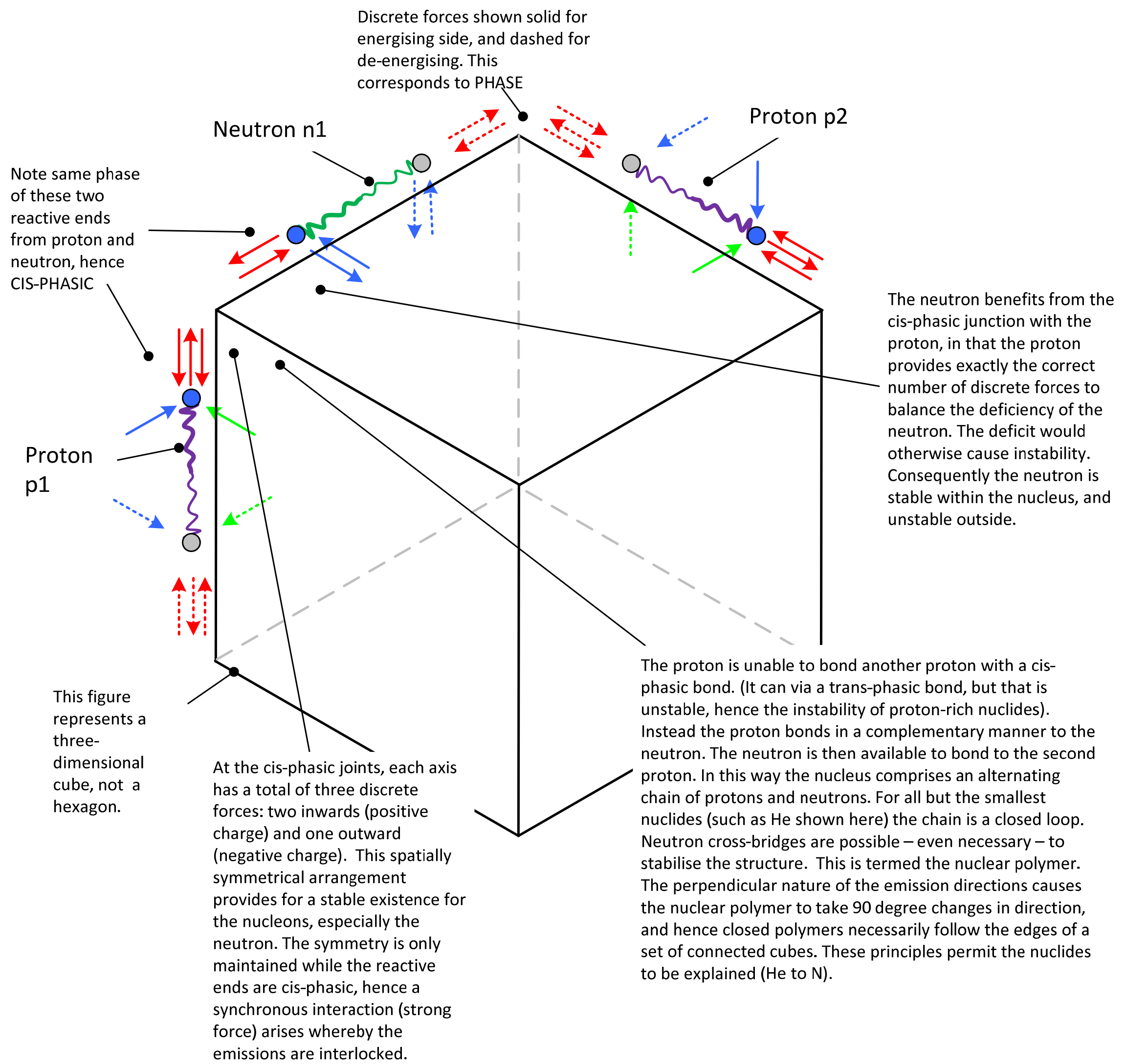

Figure 2. Proposed nuclear structure of $_2H_1$. A single neutron bonds at both ends to a proton. The role of the neutron is as an intermediary, as the discrete forces of the proton are otherwise mutually incompatible for same-phase (cis-phasic) bonds. This bonding arrangement also results in a full complement of discrete forces at each end of the neutron, and this is proposed as the reason for its stability within the nucleus. Image adapted from (Pons et al., 2013b)

4.4 Mechanisms for Decay of the Free Neutron

In β- decay the neutron decays into n => p + e + $\underline{v}_e$. Why does the neutron need to decay at all? Given that it is stable in the nucleus of the atom, why does it decay outside? The conventional answer is in terms of energy. The deuteron (one proton and a neutron) has a total mass slightly less than that of its separate constituents of a proton and the decay products of the neutron. Specifically, the binding energy of the **np** deuteron is 2.2 MeV, whereas the energy yield in decay of the neutron is the lesser amount of 0.78 MeV, hence decay is not preferred. However there is currently no explanation for *how* the energy effect works. Also, the energy effect does not explain quark flavour changes via the W^- and W^+ interactions, where changes occur *despite* appreciable differences in mass. The Cordus theory provides another way to answer these questions.

4.4.1 Why is the free neutron unstable?

With the Cordus theory it is apparent why the neutron on its own has stability problems. Its HED structure n(r $.a_1^1$ $.t_1^1$) is unbalanced, in that there is no discrete force pair in the [r] axis. Thus it fails a stability criterion for completeness. It is anticipated that the neutron can momentarily remedy this by dynamic reallocation of discrete forces to different HEDs, e.g. n(r^1 $.a_1$ $.t_1^1$) at the next frequency cycle of energisation. However that action may mean that some of the HEDs carry only a single discrete force, which is inappropriate for an uncharged particule. Thus this evasive behaviour unbalances the charge neutralisation requirement, making the neutron unstable in this configuration too. It is conjectured that dynamically changing between these various HED layouts n(r $.a_1^1$ $.t_1^1$) <=> n(r^1 $.a_1$ $.t_1^1$) prevents instability. So in this theory the neutron is vulnerable to two different forms of instability, depending on its structure, and it can stave off demise by rapidly changing between these structures before the decay processes can start.

4.4.2 Decay and stability

In the Cordus theory decay simply corresponds to disassembly of the discrete force structure. That which is preserved in disassembly (except in annihilation) is the net number of discrete forces, and the hand, and these can be distributed into the disassembly products in a different way to the original input particules. The Cordus theory suggests three mechanisms for stability. First, particules are *actively attracted* into assembly relationships with certain other particules by the HED negotiation process. That in turn is driven by mutual satisfaction of HED compatibility or completion of missing HEDs. Second, particles are *held* in such assembly positions by the ongoing synchronous emission of discrete forces (Pons et al., 2013c). Furthermore, synchronous assemblies provide *protection* against external disruption. The protection arises because (a) in cisphasic bonds the particules can project a more complete external presence of their discrete fields so are less vulnerable to the internal instability caused in response to externally imposed fields, or (b) in transphasic situations the particules look after the re-energisation locations in the absence of each other thereby protecting against external interference. The perturbation is proposed to originate in the ceaseless discrete forces of other particules in the accessible universe, which makes up the fabric of space (Pons et al., 2013a). Perturbation can also arise from the intrusion of a third particule with its own stronger field system, i.e. high energy impact. Once in such a synchronous assembly, particules tend to stay there, whereas non-assembled particules get buffeted by the external perturbations and are thereby randomly moved and actively drawn to other situations. So stability at this level can be understood in terms of interlocking of discrete-forces.

4.4.3 Decay initiated by perturbation from the fabric

When the neutron is bonded into the deuteron, its discrete forces are complemented by those of the proton. Thus the synchronous interaction keeps the neutron and proton bonded together. However the free neutron does not have this protection, and instead exists in what is conventionally termed the space-time of the universe. Except that the Cordus theory replaces the concept of space-time and instead proposes that the universe is filled with a fabric comprising the discrete forces of all the other particules in the accessible universe (Pons & Pons, 2013), and that time is an emergent property of matter (Pons et al., 2013a). This fabric becomes the external environment to the free neutron. The neutron must conduct its evasive actions within this environment, and it is proposed that irregularities in the fabric impose perturbations on the neutron. These disturbances might include a particular combination of discrete forces from the fabric, or bonding situations, or external fields, or impact with another particule. These create externally imposed *constraints* on the discrete force emissions of the neutron. They fix certain HED directions of the neutron, and prevent their dynamic movement to other directions. This compromises the neutron's dynamic adjustment, and the remanufacturing (beta decay) process is initiated as an escape mechanism. Hence a *perturbation-constraint mechanism of decay*.

Under this theory, the neutron itself is not unstable: it does not have any internal mechanism favouring decay. It has no internal timer counting down. Quite the opposite, it has an adequate compensatory mechanism of dynamically adjusting its structure, by which it may stay stable indefinitely. It only decays because the external environment overwhelms it. This does not happen inside the deuteron because the highly ordered nature of the assembled discrete forces provides a synchronous interlock force that is much larger than the usual fabric perturbations.

4.4.4 Why the Exponential distribution?

The life of the neutron is commonly represented as an exponential density distribution with mean of 15 min (or half-life 10 min). However the use of a *mean* implies a determinism and central tendency that does not exist. It is true that for a *normal* distribution the mean represents a 'true' estimate of the central tendency. This is because the sum of multiple density distributions will tend towards a *normal* distribution, regardless of the density distributions of the individual variables. Not so the exponential distribution, which has no mechanism for dispersal around a central tendency. Consequently the neutron decays with equal probability anywhere between zero and infinite time. The 'mean' value only becomes apparent when the outcomes of many individual neutrons are aggregated. Thus instead of talking about the mean lifetime of the neutron, it is more interesting to ask why the chance of failure is a uniform distribution over time. Which is to say, why is time not a variable?

The empirical evidence of exponential lifetime suggests that the mechanism that drives the failure of the neutron *cannot* be time-dependent, and the Cordus theory offers an explanation for that mechanism. It predicts that the degradation of the free neutron is a random encounter with the fabric. Therefore a logical consequence of this theory is that the decay initiation is a *uniform* random variable with time. The fabric provides an equal chance of decay at any time, i.e. a constant hazard rate. (The hazard rate is the probability that the system will fail in the next time interval, given that it has survived up to the beginning of that time interval.) The decay rate is then dependent on the density of the fabric at that locality. Thus the theory predicts that decay should proceed quicker in situations of greater fabric density, e.g. higher gravitation or higher acceleration, relative to other locations. This is because the neutron encounters more fabric, and hence more opportunity to be disturbed. This means that decay rates are not constant. This may seem an unorthodox prediction, but it is essentially the same as saying that decay rates are subject to time-dilation (Pons et al., 2013a), which is not controversial. Of course this also means that decay rates would have varied as the universe expanded, due to reducing fabric density, but this is not expected to change decay rates as time also flowed faster in the Cordus interpretation (Pons et al., 2013a) and there is no other contemporary location from which to observe. Thus the relativity of simultaneity is involved.

4.4.5 Neutrino induced decay

A second mechanism is proposed for decay of the neutron. This occurs when a neutrino-species strikes a nucleus and precipitates decay. That this inverse decay process occurs is not controversial, since it is used as the basis of neutrino detection. The evidence from neutrino detectors incontrovertibly shows that neutrino-species loading changes decay rates, at least in chlorine and gallium. The impact of a neutrino (or antineutrino) into a proton or neutron creates a temporary assembly structure which subsequently decays. It is those decay products that are detected. Doubtlessly that process generalises to other elements, so the only residual ambiguity is what proportion of decays of the *free neutron* (as opposed to the neutron within the nucleus) are caused by neutrinos, and what are due to fabric perturbation. This means that the neutron is proposed to have two separate decay paths, which are mixed together in what is perceived as the β- process. The first is determined by the local density of the fabric, and the second by the number of neutrinos encountered. This neutrino induced decay process is explored further in a companion paper, with the basic idea being that there exists an inverse decay channel n + v => p + e where v is the neutrino.

5. Discussion

This work makes a number of novel conceptual contributions. The first is a theory for the decay of the free neutron. It explains (a) the stability of the neutron inside the atom, (b) its instability outside, and (c) why the decay lifetime has an exponential density distribution rather than any other shape. A second contribution is the exclusion of the weak interaction from the fundamental forces/interactions. The conventional concept that the bosons change the flavour of the quark is not supported, i.e. the bosons are not the cause or the mechanism for the change. Instead they are merely the by-products and waste process stream from the remanufacturing process. In this way they are the same class of phenomenon as annihilation (Dirk. J. Pons, Arion. D. Pons, et al., 2014a, 2014b). This also means that, under this framework, unification of the forces is achieved in a hierarchical manner, with the synchronous (strong) interaction being the only force within coherent matter, and the electro-magneto-gravitational interactions being the forces for discoherent matter. Elsewhere the theory explains how this may be achieved, starting from the fundamental level of discrete forces (Pons et al., 2013c).

A third contribution is the provision of a new explanation for the initiators of decay in the free neutron. It is suggested that the neutron has two separate decay paths, which are mixed together in the β- process, with the first being determined by the local density of the fabric, and the second by the number of neutrinos encountered. Inter alia this implies that decay rates are situational variables as opposed to being strictly constant.

At present the mechanics of this theory are qualitative. This is because it is a *gedanken* experiment. The current absence of a mathematical formalism is not a failing of the theory, but simply a consequence of having started with a design rather than mathematical method, and the recent origin of the theory. Future research is intended to address the mathematical representation.

6. Conclusions

A novel conceptual theory explains the causes of neutron stability and decay processes. This theory is based on a NLHV design, and the explanations are given in terms of the discrete fields predicted by the Cordus theory. This is significant since the explanations are given from a basis of physical realism and entirely independent to quantum theory.

The Cordus theory explains the stability of the neutron inside the nucleus as arising from the formation of a complementary bound state with the proton. More specifically that the protons and neutrons form a chain or *nuclear polymer*. The role of the neutron is as an intermediary between the protons, as the discrete forces of the proton are otherwise mutually incompatible for same-phase (cis-phasic) bonds. This bonding arrangement also results in a full complement of discrete forces at each end of the neutron, and this is proposed as the reason for its stability within the nucleus.

The instability of the free neutron arises because its discrete field structures are incomplete. Consequently it is vulnerable to external perturbation by other discrete fields. The theory proposes that the free neutron has two separate decay paths, which are mixed together in the β- process, with the first being determined by the local density of the fabric, and the second by the number of neutrinos encountered. The exponential life has been recovered.

The internal structures of the W bosons have been determined. The weak decay is shown to be in the same class of phenomenon as annihilation, and is not a fundamental interaction -hence also irrelevant to the unification of the forces. The W bosons are merely by-products from the weak decay process, and are not the cause or the mechanism for the change. Consequently the conventional concept that the bosons change the flavour of the quark is not supported.

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