Structure of the neutrino and antineutrino

Pons, D.J. [1]

Abstract

The neutrino is involved in many of the unsolved areas of fundamental physics and cosmology, and therefore a better understanding of the causes of its behaviour is useful. This paper develops a conceptual theory for the internal structure of the neutrino, particularly the arrangement of its discrete field structures. The model is created using the concept of the cordus hyff emission directions (HEDs). Using the known quark composition of the neutron and proton, and the existing cordus models for their discrete field structures, and using the beta decay processes, we determine the discrete field structure of the neutrino by a reverse-engineering process. The structure of the neutrino in HED notation is found to be $v(r_1{}^1 .a .t_1{}^1)$ *or variants thereof, and the antineutrino to be* $\underline{v}(r_{\underline{1}}^{\underline{1}} .a .t_{\underline{1}}^{\underline{1}})$ *etc. The results are consistent whether using beta - decay, beta +, or electron capture. The results suggest that the neutrino is not its own antiparticle. Consequently neutrinoless double beta decay is predicted to be infeasible. The model predicts the neutrino has zero nominal mass, though a dynamic noise-mass is expected. The reasons why the neutrino moves at the speed of light are explained, and involve the engagement of its field structures, which are incomplete, with the fabric (spacetime). The gravitational bending of its trajectory is explained, even for a massless neutrino. This explanation requires the abandonment of both locality and the invariance of the vacuum-speed of light. The model also explains why neutrinos are always found with left-spin-hand, and antineutrinos with right, and suggests that the opposite structures are fundamentally unavailable. By moving away from the 0D point assumption of orthodox physics, cordus is able to generate a novel and radical model of the neutrino, and ground its behaviour in physically realistic interpretations.*

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1 Introduction

Neutrinos are the most enigmatic of particles. They are very light, or even massless, and do not interact much with matter, so they might be considered inconsequential. Yet they are useful in ways both practical and theoretical:

- They are probes for the interior of stellar objects, since they are not appreciably blocked by the outer layers of stars, nor interstellar dust.
- A more fundamental use is probing the theoretical validity of the standard model of particle physics. The properties of neutrinos,

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[1] *Please address correspondence to Dr Dirk Pons, University of Canterbury, Christchurch, New Zealand. Copyright D Pons 2011.*

particularly mass and handedness, might point to a different physics at work.

- If the behaviour of neutrinos and antineutrinos is different, then it could help explain why CP violation occurs, and explain why there is more matter than antimatter in the universe.
- Neutrinos are an integral part of the weak interaction, and understanding neutrinos could help better understand that effect.
- They are also important in theories of cosmology, for example some string theories propose superluminal sterile neutrinos, which if detected could help confirm that theory.
- Neutrinos may be involved in the dark matter problem.

So the neutrino is implicated as being involved in many of the unsolved areas of fundamental physics and cosmology, and therefore a better understanding of its behaviour would be useful. Unfortunately, the theory of neutrinos is incomplete, and empirical measurement is challenging because their low interaction with matter makes them difficult to detect.

This paper develops a qualitative conceptual theory for the internal structure of the neutrino. It is worthwhile attempting this for the potential to extract the mechanisms of causality, i.e. how internal structures cause the observed external behaviour. The idea is based on an extension of the cordus conjecture, which proposes a particular internal structure for particles. By comparison, conventional physics takes the premise that fundamental particles are zero-dimensional points. Thus the cordus approach is unorthodox, and results in a solution that cannot be contemplated from the conventional paradigm of quantum mechanics (QM) and the standard model.

2 What we know about neutrinos

In the standard model the neutrino is a neutral particle (zero charge). There are three generations in total: electron neutrino v_e, muon neutrino v_u, and tau neutrino v_t. For each there is known to be an antimatter version: the relevant antineutrino. These three generations are suggested by the lifetimes of the Z boson, and while it is satisfying to have three generations as also seen in quarks, it is uncertain whether this is a fundamental limit.

The neutrino does not interact much with other matter, thus does not appear to respond to the strong force, though it does to the weak: indeed it practically defines the weak interaction. It does appear to respond to gravity. Whether it reacts electromagnetically is uncertain.

Neutrino hand

Empirical results suggest that neutrinos always have left-handed helicity (spin relative to velocity), and antineutrinos have right-handed helicity. Hence also chirality, which is related to helicity by the frame of reference of the observer.

Whether right-spin-handed neutrinos even exist is uncertain. Some theories predict they do. (Note that spin-hand/helicity is not the same as the cordus ma hand concept [1].)

Neutrino mass

Whether or not neutrinos have mass is uncertain. In the standard model of quantum mechanics it was initially believed that neutrinos would be massless, because they are all left-spin-handed. No right-spin-handed neutrinos have been detected. This absence plus the requirement for conservation of angular momentum at formation, requires the left-handed neutrino to travel at the speed of light, and for the neutrino to be massless. Thus they *should* not respond to gravitation, i.e. not interact with the hypothesised Higgs boson. However there is now evidence for a small mass, see *oscillation* below, and this is something of a challenge for the standard model, e.g. [2].

How the mass might arise is uncertain. Since neutrinos are always left-handed, there does not seem to be an easy way for the Higgs boson to provide mass, unless right-handed neutrinos (and left-handed antineutrinos) are added to the Standard Model. However, these *sterile neutrino* particles have not been observed. Another conjecture is that the neutrino is its own antiparticle and thereby obtains mass through the Majorana effect. However the magnitude of this is doubtful. So the question of neutrino mass, and the mechanisms thereof, is still an open question.

Neutrino oscillation

The neutrino may change generation ('flavour' or state) while in transit, and this is termed oscillation. The conventional explanation is that the three states, which have different masses, are in coherent superposition within any one neutrino.[2] The phases of the various states are believed to be slightly different, so that the neutrino periodically advances through a harmonic mixture of all these states. Neutrinos are difficult to detect, and the various generations are detectable differently. Thus oscillation explains why neutrinos are often missing when measurement is attempted. In turn, oscillation is generally interpreted as requiring different mass, more specifically superposition between three different mass states, and therefore neutrinos should not be massless.

Neutrino creation and detection

Neutrinos are created in the decay of subatomic particles, e.g. in the sun, nuclear reactors, and particle accelerators. They are also regularly created by impact of cosmic rays (typically fast protons) into the atmosphere, and travel some distance into the earth because of their low interaction with matter.

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[2] This is an odd theory, for several reasons. First, quantum superposition usually refers to two states, not three of appreciably different mass. Second, the periodicity in the neutrino model is in contrast to the randomness that quantum mechanics otherwise associates with superposition.

Neutrinos interact little with matter, so detection is more difficult than other particles. Methods include watching for secondary photons (Cherenkov radiation) in a tank of water or volume of plastic (neutral current interaction), or for radioactive breakdown products in substances like chlorine or gallium.

3 Method

We start by adopting the cordus conjecture [3]. This provides a set of general principles governing the internal structure of subatomic entities. Cordus proposes that the particle is *not* a zero-dimensional point (as orthodox physics asserts) but rather a two-ended internal structure. We call this a cordus 'particule'.[3] This idea has been used to create a novel model of the internal structure of the photon. It is a radical idea that goes to the roots of fundamental physics, and is unorthodox in that it bypasses the conceptualisation of quantum mechanics (but accepts much of its mathematical machinery). Cordus has already been used to resolve wave-particle duality [4], explain entanglement, redefine locality [5], quantise the field forces, and explain a unified electricity-magnetism-gravitation [6].

Cordus has also described the internal structure of quarks and nucleons [7], electrons [8], and differentiated between matter and antimatter [1]. It has also been used to describe a detailed internal mechanics for the process of electron-antielectron annihilation [9], and is therefore able to show how the mass structures of those particules transform into the energy structures of the photon. The key to understanding annihilation proved to be a better model of the discrete field structures for particules: both their physical structure and their basic mechanics. The concepts here were hyffon pulses, hyff threads, reactive ends, and fibrils. Also crucial was a better understanding of the fundamental difference between matter and antimatter, which was identified as a special handedness characteristic called *ma*. This also explained why parity violation occurs at sufficiently small scales (but is not evident at larger).

A subsequent development was to create a new system modelling method to *represent* the annihilation process [10]. Specifically, Feynman diagrams are incapable of representing the crucial internal variables, because naturally those diagrams are also premised on the zero dimensional point assumption. A new representation was therefore developed, one more suitable for capturing the critical process variables. This is called *HED notation* [10]. The name arises since it models the three *hyff emission directions* (HEDs) that are presumed to exist at each of the two reactive ends of a particule, and how those HEDs are filled with hyffons (discrete

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[3] The cordus conjecture is that all particles, e.g. photons and electrons, have a specific internal structure of a *cordus,* comprising two *reactive ends*, with a *fibril* joining them. The reactive ends are a small finite *span* apart, and energised (typically in turn) at a frequency, at which time they behave like a particle. When energised they emit a transient force pulse along a line called a *hyperfine fibril (hyff),* and this makes up the field. We call this a cordus 'particule', and stress it is very different to the zero-dimensional point assumed by conventional physics.

field elements). The HEDs are geometric axes: [r], [a], and [t] and aligned with the movement/spin of the particule. A summary of the HED notation is shown in Figure 1 by application to the electron and antielectron (positron).

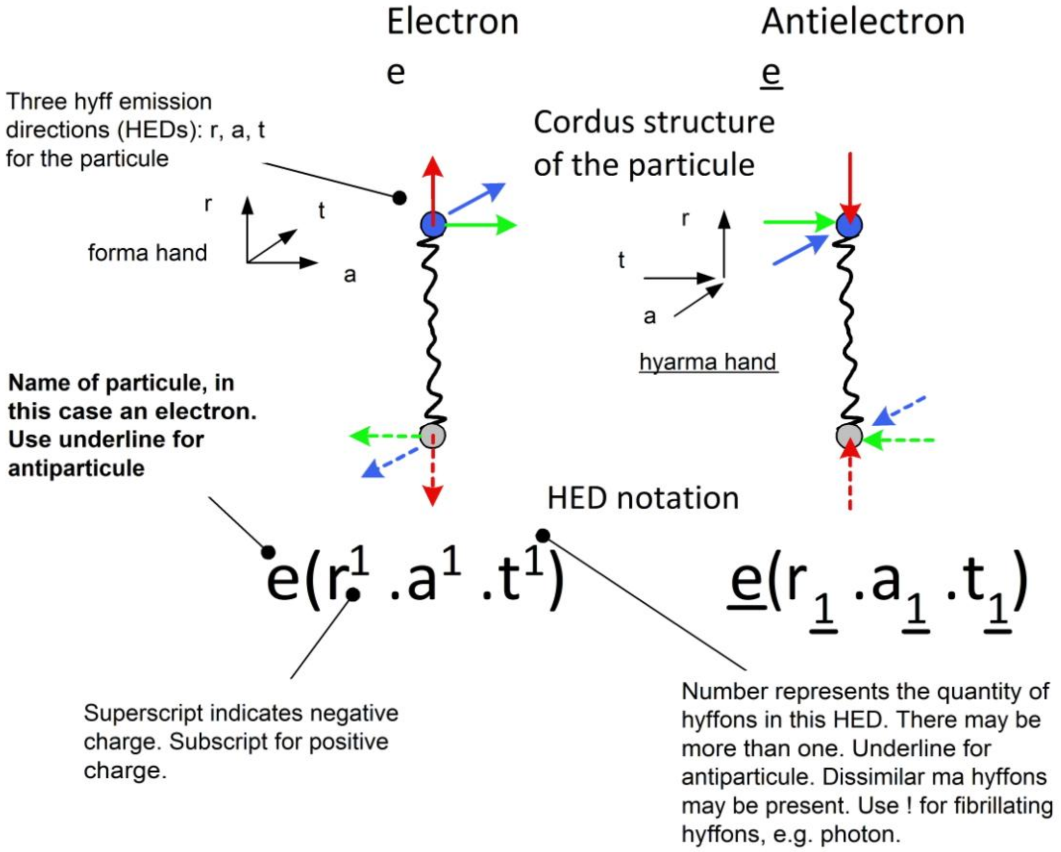

Figure 1: The cordus structure comprises two reactive ends, connected by a fibril, with hyffons (discrete field components) in three orthogonal directions. The diagram shows the physical structures, and underneath is the shorthand HED notation. Both the electron and antielectron are shown, the difference being identified as primarily the hand of the HED (forma for matter, and hyarma for antimatter), and secondarily the direction of the hyffons relative to their base, hence charge. Thus the HED notation differentiates charge and hand.

Note that we use underscore to represent antimatter. For details about the photon hyff structure, its fibrillating nature, and how it differs from all the matter and antimatter particules, see [8].

Our method is then to apply the HED notation to known interactions involving neutrinos, and thereby reverse-engineer the HED structure for the neutrino (and antineutrino). In the process we need to make some assumptions, which we mark as lemmas e.g. Ma.6, and we collect these at the end.

4 Neutrino structure

Our approach is to start with the known quark composition of the neutron and proton, convert those into HED notation and substitute into the beta decay process, assuming equifinality. We have some initial assumptions to guide us in this task, and we make several additional assumptions that we mark as lemmas.

4.1 Neutron structure

We know that the neutron comprises quarks: udd. We also know the charges of those quarks are -2/3 u and +1/3 d. We have previously identified the cause of fractional charge of quarks as selective activation of the three orthogonal HEDs [7]. We express those quarks in HED notation as:

u Quark $u(r_1 .a_1 .t)$

and

d Quark $d(r^1 .a .t)$

Colour

The allocation of the hyffons to specific HEDs [r,a,t] is nominal at this stage. We simply allocate them in the order of the HEDS. They can subsequently change to another vacant HED, and we believe that this corresponds to the known phenomenon of colour-change, see Ma.6.3. In this cordus interpretation, colour refers to the pattern of energisation of HEDs, i.e. directional charge. The three HEDs provide three combinations, hence the three colours. This cordus concept also explains why there are only three colour charges, no more or less: because there are only three geometric directions. It also explains why colour is only seen in fractional charge situations: because there are no free HEDs in unit-charge particules.

Confinement

We are not saying that the neutron necessarily consists of uud quarks at the fundamental level. Those are only the convenient transient (unstable) breakdown shapes taken: the accessible HED structures that the energy can take. Just because quarks appear at the breakdown of the neutron does not mean that the neutron originally comprised three intact quarks glued together. Anyway, and contrary to how they are popularly represented, quarks do not appear as discrete observable particles. They have not been observed on their own. Instead they are only inferred as the internal components of hadrons, and this is termed 'confinement'.

In this interpretation of the cordus principles, the neutron consists of an assembly of hyffons, and those assembly relationships are the reality. A high energy impact can deform those relationships so the hyffons dynamically regroup into quark structures.

At the same time, the number of same-hand hyffons evident in the output quarks is understood to represent the number of hyffons in the original neutron (which is assumed to likewise consist of one hand), see Ma.6.6. Therefore we assume that the neutron comprises the same numbers of hyffons as evident in its production of quarks, even if it does not actually consist of discrete quarks.

Thus the internal structure of the neutron is surmised to be:

$$n(r\ .a_1^{1}\ .t_1^{1})$$

A similar logic provides the HED structure of the proton as:

$$p(r_{1.1}^{1}\ .a_1\ .t_1)$$

As noted above, the allocation of hyffons to particular HEDs is nominal. Though in this case the specific n and p structures proposed above are complementary in an assembly, in the sense of adding to where the other is weaker.

4.2 Beta- decay and the antineutrino ($\underline{v}$) HED structure

In β- decay, or electron emission, the free-neutron decays, after a relatively long life, into a proton, electron, and an electron antineutrino:

$$n \Rightarrow p + e + \underline{v}_e$$

This process is known, and we assume there is no other missing component. B- decay occurs spontaneously in nuclei that have too many neutrons relative to protons, i.e. the process is a consequence of a need to enhance nuclear stability.

We now represent this with HED notation. All the HED structures are now known, so the only unknown in the beta decay process is the antineutrino.

We start with the derived neutron HED structure:

$$n(r\ .a_1^{1}\ .t_1^{1})$$

Assume that the proton is the nearest accessible structure, and we know its HED structure: $p(r_{1.1}^{1}\ .a_1\ .t_1)$. A free neutron is not obliged to arrange its hyffons in a complementary way to the proton to which it was formerly associated, so it can rearrange its hyffons (by colour change $|_{\%}$ Ma.6.3) to be more consistent with the proton-outcome of its upcoming metamorphosis state:

$$n \Rightarrow n(r\ .a_1^{1}\ .t_1^{1})|_{\%} \Rightarrow n(r_{1.1}^{1}\ .a_{.}^{.}\ .t_{.}^{1})$$

Add to the neutron the charge-neutral incipient hyffon-antihyffon twin-pairs (↑ = $x_{\underline{1}}^{1}$ and ↓ = $x_1^{\underline{1}}$), see Ma.6.7. These are as required to form the proton structure. In this case we place the unused other pairs outside the brackets until we decide where to assign them. Then expand the internal pairs to create a transitional assembly ‘O’ (Ma.6.8):

$$n => O(r_{1.1}^{1}\ .a\downarrow_{\cdot}^{\cdot}\ .t_{\cdot}^{1}\downarrow)_{\uparrow\uparrow} => O(r_{1.1}^{1}\ .a_{1}^{\underline{1}}\ .t_{1}^{1.\underline{1}})_{\uparrow\uparrow}$$

Next, partition off the proton HEDs and place the remaining hyffons into a secondary structure O_1 (see Ma.6.6.5):

$$n => p(r_{1.\,1}^{1}\ .a_{1}\ .t_{1}) + O_{1}(r_{\cdot}^{\cdot}\ .a_{\cdot}^{\underline{1}}\ .t_{\cdot}^{1.\underline{1}})_{\uparrow\uparrow}$$

Consider fragment O_1 and bring the other hyffon-antihyffon pairs into the brackets to form the next heaviest structure, which is the electron. The target is $e(r^1\ .a^1\ .t^1)$, so simply place a ↑ wherever a hyffon is missing. Note that in the process we also consume the previous pairs. Then expand:

$$n => p(r_{1.\,1}^{1}\ .a_{1}\ .t_{1}) + O_{1}(r_{\cdot\uparrow}^{\cdot}\ .a_{\cdot\uparrow}^{\underline{1}}\ .t_{\cdot}^{1.\underline{1}})$$

$$n => p(r_{1.\,1}^{1}\ .a_{1}\ .t_{1}) + O_{1}(r_{\underline{1}}^{1}\ .a_{\underline{1}}^{1.\underline{1}}\ .t_{\cdot}^{1.\underline{1}})$$

Then partition off the electron HEDs, and place the remaining hyffons into another secondary composite structure, O_2:

$$n => p(r_{1.\,1}^{1}\ .a_{1}\ .t_{1}) + e(r^{1}\ .a^{1}\ .t^{1}) + O_{2}(r_{\underline{1}}\ .a_{\underline{1}}^{\underline{1}}\ .t_{\cdot}^{\underline{1}})$$

The remaining O_2 structure appears to have a basic stability because it is all the same hand. We already have the proton and electron from the expression, so we identify the O_2 as the antineutrino:

$$n => p(r_{1.\,1}^{1}\ .a_{1}\ .t_{1}) + e(r^{1}\ .a^{1}\ .t^{1}) + \underline{v}(r_{\underline{1}}\ .a_{\underline{1}}^{\underline{1}}\ .t_{\cdot}^{\underline{1}})$$

Dynamic neutrino structures

The allocation of hyffons to specific HEDs is not known with certainty. If we assume a different layout of the neutron e.g. $n(r_1^1\ .a_1^1\ .t)$, and proton e.g. $p(r_{1.\,1}\ .a_1^1\ .t_1)$, then the predicted layout of the antineutrino also changes.

However this is not a problem, because the structure is assumed to be dynamic anyway, i.e. the hyffons can relocate to other HEDs (colour change, Ma.6.3). The main variants are of the following types: $\underline{v} = v(r_{\underline{1.1}}^{\underline{1.1}}\ .a\ .t) = \underline{v}(r^{\underline{1}}\ .a_{\underline{1}}\ .t_{\underline{1}}^{\underline{1}}) = \underline{v}(r\ .a_{\underline{1}}^{\underline{1}}\ .t_{\underline{1}}^{\underline{1}}) = \underline{v}(r!\ .a_{\underline{1}}^{\underline{1}}\ .t_{\underline{1}}^{\underline{1}})$

Since the antineutrino is a free particule, it can (and must) rearrange its hyffons to suit its needs (constraints). The stability lemmas [work in progress] suggest its closest stability is to concentrate its hyffons on the [r] and [t] HEDs, and then move on the fabric. Therefore the HED structure of the antineutrino is inferred to be:

Antineutrino: $\underline{v} = \underline{v}(r_{\underline{1}}^{\underline{1}}\ .a\ .t_{\underline{1}}^{\underline{1}})$

This is shown in Figure 2.

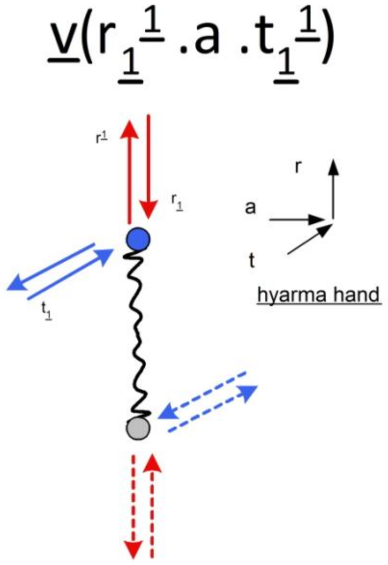

Figure 2: The cordus structure for the antineutrino, specifically the $\underline{v}(r_{\underline{1}}^{\underline{1}}$ *.a .*$t_{\underline{1}}^{\underline{1}})$ *variant. The diagram shows the HED notation and the proposed physical field structures.*

Other variants are possible.

By the matter-antimatter cordus lemmas [1], the neutrino is the corresponding mirrored HED structure:

Neutrino v = $v(r_1^{\ 1}$ .a .$t_1^{\ 1})$

This is shown in Figure 3.

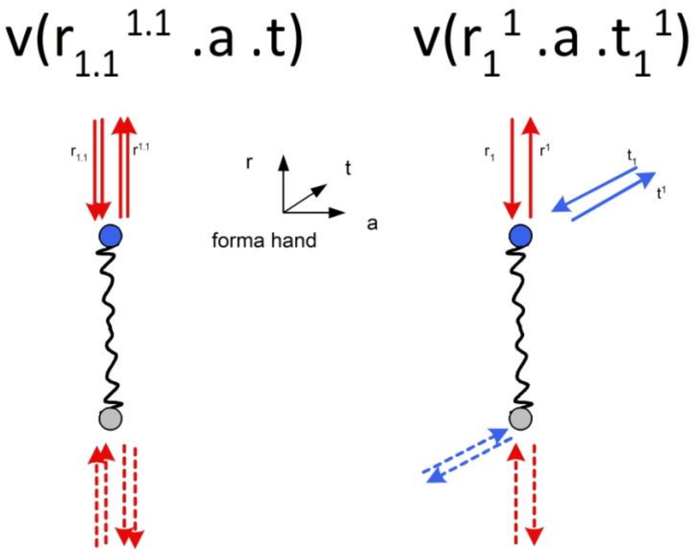

Figure 3: The cordus structure for the neutrino, specifically the $v(r_{1.1}^{\ 1.1}$ *.a .t) and* $v(r_1^{\ 1}$ *.a .*$t_1^{\ 1})$ *variants. The diagram shows the HED notation and the proposed physical field structures.*

Thus we have inferred the discrete field structures of the neutrino and antineutrino. Next we check the neutrino structure by analysing the β+ process.

4.3 Beta+ decay and the neutrino (v) structure

Derivation of neutrino structure

β+ decay, also called positron emission, occurs in proton rich nuclei and involves the conversion of an energetic proton into a neutron, antielectron (positron) and neutrino:

$$p + \text{energy} => n + \underline{e} + v_e$$

We represent this in HED notation to derive the structure of the neutrino. First, we note that the addition of energy, in the form of a photon, does not change the HED structure but simply puts more energy into the system, hence higher frequency:

$$p(r_{1.\,1}^{\;1}\ .a_1\ .t_1) + y(r!.a.t) => p(r_{1.\,1}^{\;1}\ .a_1\ .t_1)|_{+}$$

where $|_{+}$ denotes an energetic state and y is a photon. Then we add incipient hyffon pairs to accommodate the known requirements for the neutron. We are unsure at this stage whether to add a full set of hyff, or a single twin, hence the optional designation (↑↑or↓) (Ma.6.7.6). We also include a colour change $|_{\%}$:

$$p(r_{1.1}^{\;1}\ .a_1\ .t_1)|_{+\%} => O(r_{1.1}^{\cdot}.a_1^{1}.t_{1\uparrow})(\uparrow\uparrow\text{or}\downarrow)$$

$$=> O(r_{1.1}^{\cdot}.a_1^{1}.t_{1.\underline{1}}^{1})\ (\uparrow\uparrow\text{or}\downarrow)$$

Extract the neutron:

$$P => n(r\ .a_1^{1}\ .t_1^{1})\ + O_1(r_{1.1}\ .a_{.}\ .t_{.\underline{1}}^{\cdot})(\uparrow\uparrow\text{or}\downarrow)$$

Add incipient hyffon pairs in preparation for the antielectron. Note that we have added a full set of pairs now, i.e. we decided to use (↑↑ rather than ↓:

$$p => n + O_1(r_{1.1\uparrow}\ .a_{\uparrow}\ .t_{.\underline{1}}^{\cdot}) => n + O_1(r_{1.1.\underline{1}}^{\;1}\ .a_{\underline{1}}^{1}\ .t_{.\underline{1}}^{\cdot})$$

Extract the antielectron, and place the remaining hyffons into a secondary composite structure, O_2:

$$p => n(r\ .a_1^{1}\ .t_1^{1}) + \underline{e}(r_{\underline{1}}\ .a_{\underline{1}}\ .t_{\underline{1}}) + O_2(r_{1.1}^{\;1}\ .a^{1}\ .t)$$

Identify the O_2 as the neutrino:

$$p => n(r\ .a_1^{1}\ .t_1^{1}) + \underline{e}(r_{\underline{1}}\ .a_{\underline{1}}\ .t_{\underline{1}}) + v(r_{1.1}^{\;1}\ .a^{1}\ .t)$$

Rearrange the hyffons for the free neutrino:

$$\text{Neutrino } v = v(r_{1.1}^{\;1.1}\ .a\ .t)$$

This is consistent with the outcome from the β- analysis.

Explanation for the input energy

An interesting feature of this model is that it gives another explanation of why the β+ process involves extra energy at the outset. If we aggregate all the incipient hyffon pairs into a superstructure then we obtain:

$$p|_{y\%} => O(r_{1.1\uparrow}{}^{\cdot}.a_{1\uparrow}{}^{1}.t_{1\uparrow}) => n + \underline{e} + v$$

The interesting part is the substructure with the hyffon pairs:

$$O_3(r_{\uparrow}{}^{\cdot}.a_{\uparrow}.t_{\uparrow}) => O_3(r_{\underline{1}}{}^{1}.a_{\underline{1}}{}^{1}.t_{\underline{1}}{}^{1})$$

We recognise this $O_3(r_{\underline{1}}{}^{1}.a_{\underline{1}}{}^{1}.t_{\underline{1}}{}^{1})$ structure from the annihilation model for positronium: it is equivalent to two photons, see Ma.4.2 [10]. It has vertical separation of the hyffons by hand, and thus the potential to create an independent electron and antielectron, which can exist enduringly (hence require energy).

This confirms that input energy is required for the β+ process. Thus we can explain *why* additional energy is required. Moreover, we now have an explanation for exactly *how* that energy feeds into the process: it creates new hyffon field structures.

Comparison with β- decay

By comparison the β- process has an aggregated superstructure of:

$$n => O(r_{1.1\uparrow}{}^{1}\ .a_{\downarrow\uparrow}{}^{\cdot}\ .t^{1}{}_{\downarrow}) => p + e + \underline{v}$$

The substructure with only the hyffon pairs is:

$$O_3(r_{\uparrow}\ .a_{\downarrow\uparrow}\ .t_{\downarrow}) => O_3(r_{\underline{1}}{}^{1}.a_{1.\underline{1}}{}^{1.\underline{1}}.t_{1}{}^{\underline{1}})$$

This does not correspond to photons, but is instead a set of balanced pairs of hyffons. There is no vertical separation of the hyffons by hand, so the structure cannot form stable particules, and consequently it needs no permanent energy allocation.

4.4 Electron capture

In electron capture a proton absorbs an electron and converts to a neutron, emitting a neutrino. This occurs in nuclei that have more protons than required for a stable state. Representing this in HED notation:

$$p + e => n + v$$

$$p(r_{1.1}{}^{1}\ .a_{1}\ .t_{1}) + e(r^{1}\ .a^{1}\ .t^{1}) => O(r_{1.1}{}^{1.1}.a_{1}{}^{1}.t_{1}{}^{1})$$

$$=> n(r\ .a_{1}{}^{1}\ .t_{1}{}^{1}) + O_1(r_{1.1}{}^{1.1}.a_{.}{}^{\cdot}.t_{.}{}^{\cdot})$$

$$=> n(r\ .a_{1}{}^{1}\ .t_{1}{}^{1}) + v(r_{1.1}{}^{1.1}.a_{.}{}^{\cdot}.t_{.}{}^{\cdot})$$

So the neutrino emerges as before. The method correctly identifies that it is the neutrino rather than antineutrino that is involved.

Electron capture may involve one of the atom's own inner electrons, in which case there may be a cascade of consequences as the other electrons adjust, and this may result in a photon being emitted or an electron (Auger electron).

Electron capture is known to occur when there is insufficient energy for decay via positron emission. We have already explained why β+ decay requires more energy - it needs a net increase in field structures to form the antielectron. The bigger open question is then: Why does the decay not *always* prefer the electron capture route?

The answer may be that the electron capture conserves the total mass of the atom, whereas β+ decay is a way of achieving all those some outcomes and *also* getting rid of unwanted energy in the process. We have encountered a similar idea elsewhere in the cordus conjecture: that a structure that cannot contain the energy it is given is in trouble if it cannot find a way to get rid of it, hence also photon emission.

4.5 Alpha decay

Alpha decay involves a cluster of two protons and two neutrons (i.e. helium nucleus) being ejected from a larger nucleus. It does not involve neutrinos, and it is easy to see why: it does not involve any internal reassembly of the protons or neutrons. It is primarily a decay caused by instability of the bonds within the nucleus. In terms of the cordus explanation both the strong interaction (or residual strong force) that binds the nucleons, and the weak interaction (W and Z bosons) are different manifestations of the a single HED mechanics.

5 Discussion

5.1 What has been achieved?

We have used the beta decay outcomes to determine the HED field structure of the antineutrino:

Antineutrino: $\underline{v} = \underline{v}(r_{\underline{1}}^{\underline{1}} .a .t_{\underline{1}}^{\underline{1}})$ etc

And the neutrino:

Neutrino $v = v(r_1{}^1 .a .t_1{}^1)$ etc

We propose the structure is dynamic, and that several variants may exist. All of these variants have the same number of hyffons: two negative and two positive, of 1/3 charge each. The cordus structure of the neutrino is therefore neutral regarding charge. We can now use this information to explain other behaviours of the neutrino.

HED notation for common particles

The HED notations for several common particules are given below.

Matter (forma)		*Antimatter (hyarma)*
Electron $e(r^1 .a^1 .t^1)$		Antielectron $\underline{e}(r_{\underline{1}} .a_{\underline{1}} .t_{\underline{1}})$

Matter (forma)		*Antimatter (hyarma)*
Proton $p(r_{1.1}^{1}\ .a_{1}\ .t_{1})$		Antiproton $\underline{p}(r^{\underline{1.1}}\ .a_{\underline{1}}^{\underline{1}}\ .t^{\underline{1}})$
Neutron $n(r\ .a_{1}^{1}\ .t_{1}^{1})$		Antineutron $\underline{n}(r\ .a_{\underline{1}}^{\underline{1}}\ .t_{\underline{1}}^{\underline{1}})$
U Quark $u(r_{1}\ .a_{1}\ .t)$ Charge +2/3		AntiU Quark $\underline{u}(r^{\underline{1}}\ .a^{\underline{1}}\ .t)$ Charge -2/3
D Quark $d(r^{1}\ .a\ .t)$ Charge -1/3		AntiD Quark $\underline{d}(r_{\underline{1}}\ .a\ .t)$ Charge +1/3
Neutrino $v(r_{1}^{1}\ .a\ .t_{1}^{1})$		Antineutrino $\underline{v}(r_{\underline{1}}^{\underline{1}}\ .a\ .t_{\underline{1}}^{\underline{1}})$
Photon y(r! .a .t) or y(¦r¦ .a .t) The photon has no hand		

We provide, in the HED concept, a physical and geometric interpretation for the QCD concept of 'colour'. Existing quantum theory depends on the 0D point-construct and denies the existence of internal structures to particles. Hence it cannot conceive of a physical interpretation to an internal variable such as 'colour', so it remains only an abstract mathematical concept. Cordus manages to ground the concept back into the physical domain.

5.2 Implications

Neutrino not its own antiparticle

The first implication is the neutrino is *not* its own antiparticle. The reason is that it cannot be converted to an antineutrino solely by the addition of ↑or ↓ hyffon-antihyffon pairs.

Thus the neutrino is not a Majorana fermion. By implication *neutrinoless* double-beta decay will not occur by annihilation. The idea behind neutrinoless double-beta decay is that two neutrons decay simultaneously, producing two antineutrinos. If one antineutrino was able to spontaneously convert into a neutrino, then perhaps the two might annihilate, hence neutrinoless decay. This is currently an area of active research for physics, partly because it may allow the mass of the neutrino to be determined. Cordus suggests that the *mutual annihilation* pathway is verboten, though this does not preclude other ways of disposing of the antineutrinos.

Neutrino speed

We can anticipate why the neutrino travels at the speed of light. A neutrino structure of $v(r_{1.1}^{1.1}\ .a\ .t)$ or $v(r_{1}^{1}\ .a\ .t_{1}^{1})$ does not have hyff in all HEDs, and therefore does not meet all the stability criteria. Its only option is to move on the fabric [11]. This is the same basic model for how the photon moves [8]. We suggest that the neutrino fills its [a] axis by interacting with the hyffons of the fabrics, thereby obtaining a dynamic stability. A comparison of the photon and neutrino HED structures is shown in Figure 4.

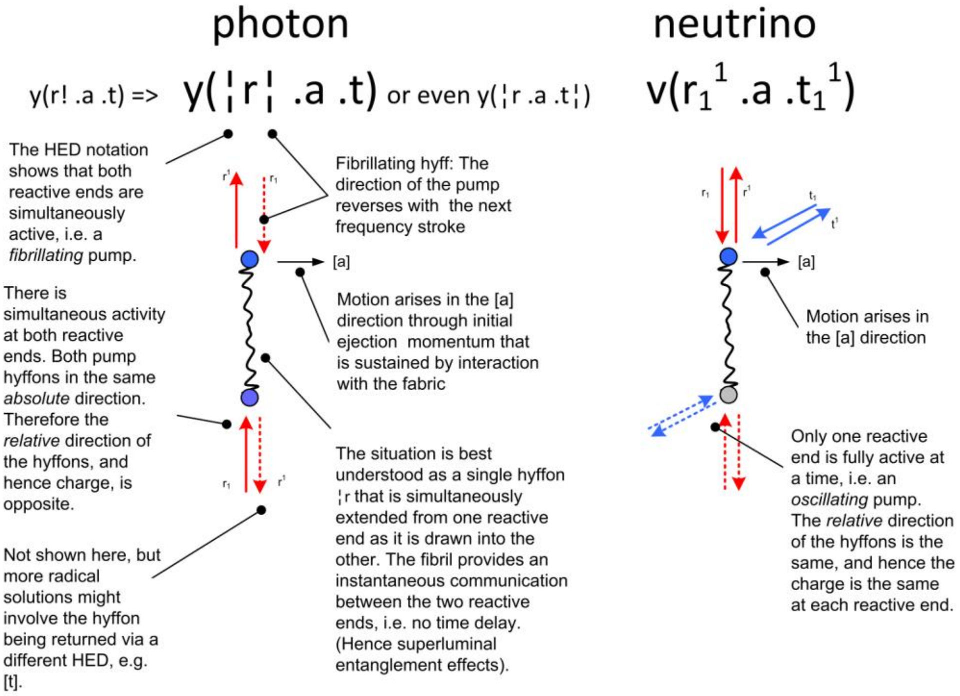

Figure 4: The cordus HED structures for the photon and neutrino. In both cases there are unfulfilled HEDs, and it is proposed that this feature drives the movement of these particules, though we acknowledge that the specific mechanisms are still sketchy.

This also implies that the speed of the neutrino will be dependent on the density of the fabric. In particular, it should slow down in locations where gravitation is stronger or matter is denser. Hence the neutrino appears to show refraction-like behaviour in matter. The Mikheyev–Smirnov–Wolfenstein effect, whereby the oscillation of neutrinos between generations is different in matter and the vacuum [12], may have a related causality.

Spin-hand

The neutrino is only left-spin-handed. This is strange, because it is the only fermion with this property. All neutrinos are left-spin-handed, and all antineutrinos are right-spin-handed, or at least that is what empirical results suggest. In a QM context left-hand means that the spin of the particle (by the right-hand grip rule) is in the opposite direction to the motion. We use the term ‘left-spin-hand’ to show that the concept is related to spin, not the ma-hand [1].

Plain ‘spin’ is an overloaded concept that should not be used without clarification. To explain the neutrino spin-hand, we first need to reconceptualise 'spin'. In this particular case we interpret the neutrino 'spin' as angular momentum, SPIN-M. This suggests that the neutrino always and only has angular momentum in one direction, and the antineutrino in the other. With the cordus model we can start to see why.

Quantum mechanics recognises that particles have intrinsic angular momentum, even when stationary. Cordus provides a physical interpretation of the particule spinning on the spot. Furthermore, that spinning is driven by the energisation sequence, which in turn is linked to the ma-hand.

Unlike the photon which has no ma-hand, the neutrino has a ma-hand, i.e. it has an energisation sequence for its hyff. Nominally the sequence is [r], [a], [t], and these axes are arranged in the forma hand, with the antineutrino taking the hyarma hand. The peculiar spin arrangements of the neutrino and antineutrino arise because of the combination of three factors: the need for the particule to spin, its need to move in the [a] direction, and the handedness of the energisation sequence of the HEDs, see Figure 5.

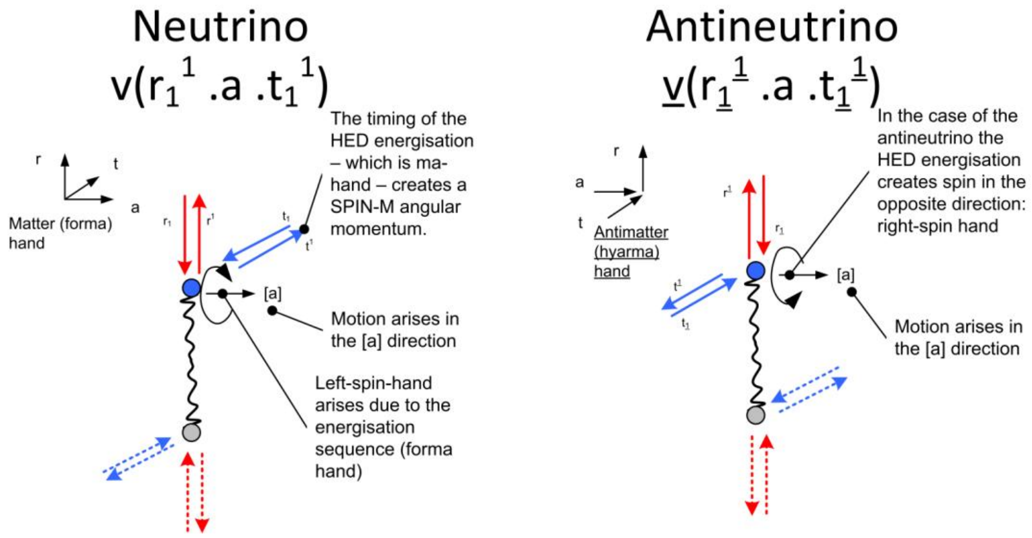

Figure 5: The cordus spin model for the neutrino and antineutrino. In both cases the particule needs to move (for stability) and therefore its spin is limited to the [r,t] plane. The ma-hand, which distinguishes between matter and antimatter, controls the energisation sequence of the HEDs, and hence the direction of spin. Thus, unlike other particules that are stable when stationary, the neutrino species have their spin direction determined by their ma-hand.

Thus it is proposed that the spin of the neutrino works like this: the energisation of the HEDs creates a spin (SPIN-M). However the stability requirement forces the neutrino to move: we nominally reserve the axial [a] axis for that. Therefore the spin is constrained to the [r,t] plane. The forma hand constrains that spin to be clockwise (i.e. left-spin hand).

The antineutrino spins in the opposite direction, anticlockwise or right-spin-hand for the same reasons. It is the change in hand, from forma to hyarma, that creates this difference.

Cordus predicts that we would see a similar spin effect in other particules, except that none move at the speed of light and therefore are not constrained to arrange their spin relative to their motion, or keep the [a] axis free for motion. The only other particule that moves at c is the photon, and it does not have any hand and therefore the effect does not arise there at all.

The explanation and the diagram were given in terms of the $v(r_1{}^1 .a .t_1{}^1)$ HED variant. What happens with other variants such as $v(r_{1.1}{}^{1.1} .a .t)$? We cannot be entirely sure, but there does not seem to be any reason why the explanation would not still hold. We acknowledge that we have not detailed the yet deeper mechanisms for how spin arises, but it is clear enough that spin does arise.

This cordus model therefore predicts that neutrinos are all left-spin-handed, and that there are no right-spin-handed neutrinos or left-spin-handed antineutrinos. If this is true, then it would have serious consequences for those theories that depend on such particles.

Neutrino mass

The cordus model for gravitation is that the sequential energisation of the HEDs creates a torsional pulse that is transmitted outwards, and this creates gravitational attraction [6]. Activation of the three HEDs seems necessary for an enduring mass or gravitational effect. The neutrino does not have the necessary complete HEDs to offer its own gravitation: a similar situation to that of the photon.

Therefore the gravitation part of the cordus model predicts that the neutrino has no nominal mass, based on its lack of the necessary structures. The stability part of the cordus model also predicts a massless neutrino, based on its speed being that of light.

However, 'mass' may not be everything that it seems to us. In particular, both the photon and neutrino make up for their incompletely energised HEDs by moving in the fabric. Thus they temporarily *do have* full HEDs, albeit only instantaneously. Therefore it is possible that they also do have an instantaneous mass and gravitation. While it may register as mass, it would however not be an enduring mass. We conceptualise it rather as *noise-mass*, i.e. an artefact of the propagation process. So it is possible to conceive of the neutrino having zero nominal mass, though a small dynamic localised noise-mass.

This may sound weird, but the MSW effect [12] predicts something similar: it models the situation as the neutrino obtaining an 'effective mass' (by a 'forward scattering' process) when propagating through matter.

Cordus is more radical still, in suggesting that 'mass', 'gravitation' and 'gravitational trajectory-bending' could be subtly independent effects [8]. Specifically, with the cordus conjecture it is possible to envisage gravitational bending of the neutrino locus occurring without the particule needing to have mass of any kind. The gravitational bending might instead be explained as the gradient in the fabric density near a large mass, the same explanation as previously given for the photon [8]. The fabric is slightly denser on the side of the neutrino nearest the mass, so a frequency cycle on that side accomplishes a slightly lesser displacement, i.e. the speed of light is slightly slower, thus bending the trajectory.

Furthermore, neutrinos are thought to exhibit refraction-like behaviour in their passage through matter. This cordus model readily accommodates this refraction, i.e. neutrinos should slow down in denser materials.[4]

Trajectory-bending reconceptualised as a non-mass effect

Thus mass may not be required for trajectory-bending effects. Indeed, optical refraction is a trajectory-bending effect that *does not* require the photon particule to have mass, though it is dependent on the density (including gravitational field) of the fabric medium.

Reconceptualising the trajectory-bending of neutrinos as a fabric effect rather than gravitation is unconventional. This has the profoundly radical implication that the vacuum-speed of light is variable, i.e. that the speed of light is not only dependent on the amount of matter that it passes through, the absence of which is conventionally the 'vacuum', but on the gravitational fields from neighbouring areas. Thus cordus also upsets the orthodox idea of 'locality' [5]. By comparison, physics currently conceptualises the speed of light as only determined by the local density of matter, and hence invariant in the vacuum. Cordus suggests the vacuum-speed of light is not invariant, but dependent on the density of the fabric. The fabric is the irregular mesh of background hyffons of (potentially) all the other particules in the universe [11]. This also gives a better model for time, and is consistent with the observation that time runs slower (dilation) for bodies that are accelerating or in higher gravity.[5]

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[4] Superluminal neutrinos are not naturally predicted by cordus, but it could nonetheless accommodate them. One possible cordus explanation is tunnelling at generation change (i.e. skipping interactions when there is no activity in the particule). Another might be an initial transient non-orthogonality between the [r][t] plane and the direction of propagation. These might be transients caused by the creation mechanism, i.e. the neutrino settles down later. Or it may simply be that the neutrinos are released late in the process. There could be other explanations, since moving away from the 0D point premise opens up a lot of other alternatives. However it is too early to be definitive as the empirical evidence is limited.

[5] Cordus explains this as the reactive ends of the particules in the body encounter the fabric at a greater rate (acceleration) or density (higher gravity). For a moving particule like the neutrino in a gravitational field, this means that it progresses a smaller displacement along its trajectory at each frequency cycle. For a stationary particule in higher gravitation, the increased fabric density compromises the hyff emission process and slows the re-energisation of the reactive ends, which then slows the frequency of the cordus.

Why are neutrinos so unreactive?

The cordus explanation for why neutrinos react little with matter is that their frequency is too low. That plus their motion. Reactivity between particules requires that their reactive ends be in the same place and phase at a moment in time. The fast motion of the neutrino, and the presumed relatively large span of its cordus (span is inversely related to frequency or mass [13]) makes co-location difficult. In a similar way long-wavelength radio waves have greater penetration (less engagement with matter) than visible light.

What happens in neutrino detectors?

The neutrino detectors are, according to the cordus interpretation, operating by an occasional impact of a neutrino (or antineutrino) into a proton or neutron. The injection of its hyffons into the target creates a temporary assembly structure which subsequently decays. It is those decay products that are detected.

Differentiation between neutrino and neutron

The neutrino and neutron have nominally similar HED structures:

Neutrino $v(r_1{}^1 .a .t_1{}^1)$

Neutron $n(r .a_1{}^1 .t_1{}^1)$

Both have two hyffons of each charge. Furthermore, we have already anticipated that hyffons may change to free HEDs. So what is the fundamental difference between these two particules?

One difference is obviously the mass. Our current working model is that the neutron is a complex assembly that includes hidden *internal* hyff that we do not see overtly externalised, but which nonetheless contribute to the propagation of external EMG hyffons (Ma.6.9). This explains why the neutron has a higher frequency and mass than the neutrino despite the same *nominal* HED structure.

The neutrino is, by comparison, a minimalist particule: it has the cordus structure and a functional ma-hand system, but not a lot of energy. It is possible, though not our currently preferred working model, that adding energy to the neutrino might convert it into a neutron. Instead we suspect that the neutrino *is* making a complete disclosure of all its hyffons, and no amount of additional energy would make it into a neutron.

From the cordus perspective, a fundamental particule is one that overtly displays all its hyffons. Examples would then be the photon, electron, and neutrino, for the matter (forma) hand. Assembly particules can cloak their balanced hyffons and thus appear to have greater frequency and mass than their external HED structure suggests. Examples would be the quarks, proton, neutron, and all higher assemblies thereof. So in the cordus interpretation the quark is probably *not* a fundamental particule, but can be expected to have a deeper sub-structure.

Do neutrinos decay?

Neutrinos do not decay in the standard model, but they are predicted to do so in the extended model: the hypothetical right-handed neutrinos decay to electrons. This provides an asymmetric leptogenesis model, and then another hypothetical particle called the ‘sphaleron’ converts the leptons to bayons, and hence the asymmetry predominance of matter over antimatter. However these mechanisms are highly speculative. Nonetheless the interest in neutrinos is high because of the potential to answer the bigger questions about the asymmetry of baryogenesis.

We do not support the concept of neutrino decay in the current cordus working model, though we acknowledge that it is not precluded either. In particular, the present cordus model explains the speed of the neutrino as a consequence of its incomplete stability: it is a compromise for an incomplete deck of HEDs. By implication, an arrested neutrino would no longer have that compromise mechanism available, and would decay. However 'decay' is perhaps not the right word, because the process of fully arresting the neutrino (as opposed to merely slowing it down in a strong field) would require that it be captured by another particule. In which case the neutrino would inject its hyff into that new assembly, and new daughter products would form. Hence the detection methods. However we doubt that the free neutrino would ever decay (unlike the neutron).

Neutrino oscillation

Our current working model for neutrino oscillation is that it is a phase-change in the way the discrete field structures are energised, and the frequency (hence mass) required to sustain the HEDs. If so, the structures of the generations are:

$$v_e(r_1{}^{1}\ .a\ .t_1{}^{1});\ v_\mu(r_{1.1}{}^{1.1}\ .a\ .t);\ v_\tau(r^{1.1}\ .a\ .t_{1.1})$$

Similarly for antineutrino. Note that the [a] axis is reserved for propagation, so it is only the [r] and [t] axes that have hyffons. Across these two axes there are indeed only three possible arrangements. The oscillation could conceivable be due to dynamic transient effects at formation of particule, or subsequent interaction with energetic fabric medium.

Implications for fundamental physics

It has long been thought, even in the orthodox paradigm of physics, that better understanding of the neutrino might test the theoretical validity of the standard model of particle physics, and perhaps even lead to a different physics. Indeed, if the cordus conjecture is correct, the implications are that neutrinos do indeed point to a deeper physics, but it appears not to be an extension of quantum mechanics or of the standard model, but rather a turn in an unexpected direction.

With this cordus model we can now suggest answers to some of the neutrino riddles raised at the beginning of this paper.

Why do neutrinos exist?
They remove excess field structures from assemblies of particules so that they can convert into other types of particules, e.g. the beta decays convert between neutrons and protons.

Do neutrinos have mass?
They do not have the necessary structures to create a gravitational field, and hence do not have mass either. However they may have a small dynamic mass (noise-mass).

Why are neutrino trajectories bent by gravity?
The bending occurs due to the gradient in the density of the fabric, not the mass of the particule. Controversially, this explanation requires that the speed of light in the vacuum is not constant, but determined by the fabric-density.

Why are neutrinos so difficult to measure?
Their frequency is so low, and their speed so high, that they seldom have opportunities to meet other matter particules. (Macroscopic objects are not continuously solid). Interaction requires that the HED field structures of the two particules be in the same space and time, and of compatible frequencies. The neutrino is more likely to use any HEDs it encounters for its propulsion rather than stop and interact.

Why do neutrinos travel at the speed of light?
They have incomplete field structures and have to compensate by moving on the fabric of spacetime, the relativistic speed of which is c.

Why are neutrinos left handed?
They have to both move and spin, and this leaves only one direction in which they can spin. This spin direction is fixed by the matter-antimatter chirality called ma-hand.

Could right-handed neutrinos exist?
Probably not. It is not obvious how these could exist in the cordus model.

Is the neutrino its own antiparticle?
No, this is verboten in the cordus model.

What is behind CP violation?
It is a consequence of every particule having a span, and its two reactive ends being energised in turn. Therefore what happens at one reactive end is not a mirror image of the other. However this only becomes apparent at small scales: at the coarser scale of quantum mechanics the particules do look like points.

Future work

The cordus concept of hyff emission directions (HEDs) also provides a discrete field theory,[6] which is coherent across small-scale effects like annihilation and wider effects including gravitation. By comparison, quantum field theory and quantum chromodynamics are more advanced in their mathematical formalisms, but lacking in physically realistic interpretations, and more narrowly focussed. The quantum theory undoubtedly works, whereas the cordus solution is simply conjectural. If cordus really does point to a deeper mechanics and a new physics, then it would be expected to subsume much of the quantitative machinery of quantum mechanics, and checking this could be a line of future work.

Further work that we have already undertaken is to identify the internal structures of the W and Z bosons, and hence better understand the weak interaction [work in progress].

There is further work to be done in exploring the mechanisms at the next deeper level of physics, e.g. spin, and the reactive ends. Furthermore we have not fully explained the difference between the neutron and neutrino, but only given a general suggestion that the neutron has cloaked field structures that we are not seeing. Clearly this requires more work.

6 HED lemmas

We made several assumptions for how the hyffons behave in the HEDs, and these are summarised below as a set of lemmas.

Ma.6 HED (hyff emission direction) dynamics

Ma.6.1 A particule's HED structure determines its functionality. For example the electron is uniquely different to the antiproton in HED notation.

Ma.6.1.1 The HED structure refers to the (a) hand of the hyff emission directions, (b) the number of active hyffon pulses in each HED, and (c) the direction (charge) of those hyffons.

Ma.6.1.2 The cordus particule concept applies to what are conventionally considered 'fundamental particles' as well as assemblies thereof, providing the latter are in coherence i.e. have synchronised frequencies. The proton is considered such an assembly.

Ma.6.1.3 Particules may have oppositely charged hyff that neutralise each other internally, and therefore are not expressed externally as charge. These are nonetheless expected to contribute to mass. See also Ma.6.7.

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[6] We use the term 'discrete', and avoid 'quantum', because the hyffons are not required to be in quantum increments.

Ma.6.1.4 The quantum chromodynamic (QCD) concept of ‘colour’ corresponds to the selective energisation of the [r], [a], and [t] HEDs, where the HEDs are not all full.

Ma.6.2 Any HED may have multiple hyffons, at least temporarily.
Ma.6.2.1 These multiple hyffons may be opposite charge.
Ma.6.2.2 These multiple hyffons may even have opposite ma-hand.
Ma.6.2.3 A hyffon and an antihyffon (opposite hand and opposite charge) in the same HED, e.g. $r_1^{\underline{1}}$, do not generally reduce to zero.
Ma.6.2.4 An exception is that $O(r_{\underline{1}}^1 .\ a_{\underline{1}}^1 .\ t_{\underline{1}}^1)$ reduces to two photons, or an electron and antielectron, see also Ma.4.2.) See also Ma.6.7.3 for another exception.

Ma.6.3 Hyffons may move: Colour migration
Ma.6.3.1 A hyffon (active field structure) can migrate to another vacant HED, e.g. $o(r_1 .a_1 .t) \Rightarrow o(r_1 .a .t_1)$.
Ma.6.3.2 It can do this dynamically.
Ma.6.3.3 This corresponds to colour change.
Ma.6.3.4 Pairs of hyffons may likewise move.

Ma.6.4 Principle of HED negotiation: reactive ends, whether single or when bonded between particules, negotiate hyff emission directions dynamically.
Ma.6.4.1 ‘Negotiation’ means that change to a HED at one reactive end or particule requires a complementary change in the other HEDs in that space.
Ma.6.4.2 We suggest the mechanisms is first-come-first-served, i.e. the HED that energises first tends to get the choice, and in turn that choice is influenced by the spaces left by the HEDs that are de-energising.
Ma.6.4.3 The QCD equivalent idea is the gluons, being the mediators of colour change among quarks. However we do not accept the point-particle interpretation that QCD gives to gluons.

Ma.6.5 Bonding as a shared HED effect
Ma.6.5.1 The HEDs and hyffons of one particule can feed into those of another particule, and this is bonding.
Ma.6.5.2 The shared interlocking of HEDs is what creates the force that holds the assembly together. This force is strong.
Ma.6.5.3 However this force is also short-ranged, since there are many other hyffons that will be attracted into the union if the original participating particules are pulled apart.

Ma.6.5.4 This force is better described as a constraint on the positional re-energisation of the reactive ends. They are forced to re-energise, i.e. emit HEDs, in a location that is consistent with the generally negotiated HED environment.

Ma.6.5.5 This mechanism underpins the strong interaction (force), Pauli exclusion principle, and bonding generally.

Ma.6.5.6 The particules may negotiate common frequencies (the same frequency or a harmonic), to create coherence. Alternatively they may dynamically form fluid bonds with a changing dance of other particules.

Ma.6.6 Principle of conservation of hyff in assembly and disassembly.

Ma.6.6.1 Two particules may assemble into one, by merging their HED structures. Disassembly occurs as the reverse process. Assembly and disassembly are therefore primarily HED processes.

Ma.6.6.2 The total number of active hyff, i.e. hyffons, owned by input particules is conserved across the output particules, unless annihilation occurs. See also Ma.3.8 [10].

Ma.6.6.3 Charge is preserved in assembly and disassembly. In HED notation, this means that the hyffon sums above and below the line must also be preserved. (Conservation of charge is a common assumption in physics).

Ma.6.7 Charge-neutral and hand-neutral twin-pairs of hyffons may be added to, or removed from HED assemblies.

Ma.6.7.1 A hyffon-antihyffon twin-pair, $x\uparrow\downarrow = x_{\underline{1}}^{1} + x_{1}^{\underline{1}} = x_{\underline{1}.1}^{1.\underline{1}}$ may be created in any single HED position, [r], [a], or [t], or split across multiple.

Ma.6.7.2 These pairs are charge neutral, and do not change the net number of hyffons (hence not violating the conservation principle), though do change the gross number and thus permit access to other output states. They are a type of fibrillating pump like the photon [8], but offset across the span of the cordus. They are also hand-neutral.

Ma.6.7.3 The twin-pair $x_{\underline{1}.1}^{1.\underline{1}}$ may be removed from an assembly.

Ma.6.7.4 The twin-pairs are created or destroyed at the same time. However for convenience we sometimes show them as being applied at slightly different times during an assembly process.

Ma.6.7.5 The difference in orientation ($x\uparrow = x_{\underline{1}}^{1}$ or $x\downarrow = x_{1}^{\underline{1}}$) is interpreted as corresponding to one form of spin: SPIN-H, the orientation of hyffon pairs within a particular HED. The neutral-hand requirement thus infers that SPIN-H must be zero for the added hyffons, i.e. ↑ must numerically balance ↓.

Ma.6.7.6 A notable exception is that a whole increment of three pairs all in the same direction, i.e. r↑ a↑ t↑ corresponds to two photons, or an electron and antielectron. Thus these HED structures may be created or destroyed.

Ma.6.7.7 These ↑ or ↓ pairs are spontaneously formed during the HED negotiation processes. The addition of hyffon-antihyffon pairs is presumed to be initiated either by the difference in energy between the assembled and dissembled states (i.e. the native tendency to decay), or the fabric pressure (this latter effect may have some similarity with vacuum fluctuations). [7]

Ma.6.8 Assemblies, which we denote as O particules, may be created by the merging of particules, the breakdown or subdivision of parent particules, or the addition of hyffon-antihyffon twin-pairs.

Ma.6.8.1 These assemblies may be transitional intermediate structures as part of a process of assembly/disassembly, or stable structures.

Ma.6.8.2 An Intermediate (O) structure may be overloaded with hyffons.

Ma.6.8.3 Also, it can accept hyffons of both hands, though this tends to make it unstable.

Ma.6.8.4 These transitional assemblies may subsequently separate to different hyffon arrangements, hence different particules.

Ma.6.8.5 These transitional assemblies have the ability to create further hyffon-antihyffon twin-pairs and partition off another structures.

Ma.6.9 Cloaking and disclosure of hyffons.

Ma.6.9.1 Assemblies of particules may include hidden *internal* hyff that we do not see overtly externalised in the HED notation. These nonetheless contribute to the propagation of external EMG hyffons, and therefore to higher frequency and mass. Examples are the quarks, proton, neutron, and all higher assemblies thereof.

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[7] This is consistent with conventional physics. For example: *'After a high energy collision, a quark or gluon starts to move away from the rest of the formerly color-neutral object that contained it. A region of color force-field is produced between the two parts. The energy density in this color force fields is sufficient to produce additional quarks and antiquarks. The forces between the color-charged particles quickly cause the collection of quarks and antiquarks to be rearranged into color-neutral combinations. What emerges, far enough from the collision point to be detected, is always a collection or jet of color-neutral hadrons, never the initial high-energy quark or gluon alone.'* http://www2.slac.stanford.edu/vvc/theory/colorchrg.html#Confinement

Ma.6.9.2 A fundamental particule is one that overtly displays all its hyffons. Examples are the photon, electron, and neutrino, for the matter (forma) hand.

Ma.6.9.3 Assembly particules can cloak their balanced hyffons and thus appear to have greater frequency and mass than their external HED structure suggests.

Ma.6.9.4 All discrete field structures of a particle, whether a fundamental particule or an assembly, and whether those are externalised or internally cloaked hyffons, contribute to the fabric. These hyffons all need servicing and hence a frequency requirement arises, hence mass.

Ma.6.10 Neutrino HED structure

Ma.6.10.1 Neutrino $v(r_1{}^{1} .a .t_1{}^{1})$

Ma.6.10.2 Antineutrino $\underline{v}(r_{\underline{1}}^{\underline{1}} .a .t_{\underline{1}}^{\underline{1}})$

Ma.6.10.3 The [a] axis is reserved for propagation, so it is only the [r] and [t] axes that have hyffons.

Ma.6.10.4 The neutrino has zero nominal mass, but a small dynamic localised noise-mass through its engagement with the fabric.

Ma.6.10.5 Generational change (neutrino oscillation) is a phase-change in the way the discrete field structures are energised. Some layouts require a higher frequency (hence mass) to sustain the more complex HEDs. If so, the structures of the generations are:

Ma.6.10.6 The generations of the neutrino are assumed to be: $v_e(r_1{}^{1} .a .t_1{}^{1})$; $v_\mu(r_{1.1}{}^{1.1} .a .t)$; $v_\tau(r^{1.1} .a .t_{1.1})$, and similarly for the antineutrino. Note that the [a] axis is reserved for propagation, so it is only the [r] and [t] axes that have hyffons. Across these two axes there are indeed only three possible arrangements.

7 Conclusions

The cordus mechanics, particularly the HED notation, have been used to infer the discrete field structures of the neutrino and antineutrino. The structure of the neutrino in HED notation is found to be $v(r_1{}^{1} .a .t_1{}^{1})$ or variants thereof, and the antineutrino to be $\underline{v}(r_{\underline{1}}^{\underline{1}} .a .t_{\underline{1}}^{\underline{1}})$ etc. The results are consistent whether using beta - decay, beta +, or electron capture. A tentative explanation is given for the three generations of neutrinos. The neutrino structure is nominally identical to that of the neutron. A partial explanation is given for where the deeper differences may lie.

The results suggest that the neutrino is not its own antiparticle, and has zero nominal mass, though a dynamic noise-mass is possible. The reasons why the neutrino moves at the speed of light are explained in terms of how its field structures, which are incomplete, engage with the fabric (spacetime). The gravitational bending of its trajectory is explained, even for a massless neutrino, by abandoning both locality and the invariance of the vacuum speed of light. The model also explains why neutrinos are always found with left-spin-hand, and antineutrinos with right, and suggests that the opposite structures are fundamentally unavailable.

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