Deeper mechanisms for force and the fundamental interactions from a NLHV perspective

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Abstract

Problem: The mechanisms whereby force operates are poorly understood at the fundamental level. This is reflected in the difficulty of finding a single coherent theory for explaining all the interactions. **Purpose:** This work constructs a theoretical framework for the interactions from a non-local hidden-variable (NLHV) perspective, specifically the Cordus NLHV theory. **Findings:** The interactions arise from different attributes of discrete force emissions from the particle: electrostatic from the direct linear effect of the discrete forces; magnetic from bending of the flux tube; gravitation from handed energisation sequence; strong from the synchronisation of emissions; and weak from rearrangement of discrete force emissions hence remanufacturing of particle identity. **Originality:** A single underlying mechanism, that of the discrete force and its multiple attributes, is sufficient to explain all the interactions. No new particles or bosons are required. Also novel is provision of a mechanism whereby a particle detects and moves in the force gradient.

Keywords: electric; field; electrostatic; magnetism; electromagnetism; strong; nuclear force; weak; decay; fundamental; new physics

1 Introduction

The concept of force is well established in mechanics and the resulting principles of statics and dynamics extensively applied in science and engineering with great success. However, despite the precision and familiarity with force at the macroscopic level, the fundamental physics of force are incompletely understood. Furthermore there is no single coherent theory for all the fundamental interactions. This paper builds on earlier non-local hidden-variable (NLHV) contributions of [1] and [2], by proposing mechanisms for how the interactions generate force, and for the deeper common causality between interactions.

2 Existing approaches

The first problem is explaining how force arises. The effects of electrostatic, magnetic, and gravitational (EMG) forces are well represented by Newtonian and classical continuum mechanics. However these mechanics do not describe the underlying mechanisms of how force arises or operates. The same limitation applies for general relativity (GR). In quantum mechanics (QM) force is conceptualised as occurring by the exchange of smaller particles, the gauge bosons. However there are many unexplained processes, such as how intrinsic properties are transferred between particles. Furthermore the bosons can only be detected as forces not individual particles.

The second problem is the lack of a single coherent theory for explaining all the fundamental force interactions. The interactions - excluding hypothetical dark energy mechanisms – are the electrostatic, magnetic, gravitational, weak, and strong. The standard model of QM proposes that electromagnetism is carried by virtual photons, the strong interaction between quarks by the gluon, and the weak interaction (e.g. quark flavour-changing between left-handed fermions) by W and Z bosons. The strong nuclear force has a partial explanation in quantum chromodynamics (QCD), but the theory is limited to quarks. It also has no explanation of nuclear structures at the level of nucleons and atomic nuclei. A coherent explanation of gravitation is especially problematic from a particle perspective. In GR, gravity arises from the warping of space time, i.e. the effect is a geometric one [3]. Holographic theory provides an explanation for gravitation as an entropic force [4], but not for the deeper mechanisms nor the other forces. It seems that any theory that explains gravitation does not explain all the other interactions. QM has attempted to explain gravitation by loop quantum gravity, but a solution is elusive. Alternatively, gravitons may be the boson for gravity, though this is speculative. Thus there is no accepted explanation within QM for gravitation.

Existing efforts at unification have primarily attempted to extend quantum mechanics, on the expectation that a continuum physics like general relativity is unsuited to representing particle interactions. A second premise that has historically shaped the research is the belief that there ought to exist an undiscovered single progenitor force that, at sufficiently high energy density, forms the basis for all the other interactions. Unification is indeed available for the electrostatic and magnetic forces into the electromagnetic with the photon as the boson, and decay interactions (weak nuclear force) via electroweak unification. Models exist providing grand unified theories whereby the electromagnetic, weak, and strong forces might unite into an electronuclear force. However the predicted new particles have not been observed. Furthermore QCD is not integrated with electroweak theory, and gravitation has been especially problematic.

The elusiveness of solutions may indicate that the necessary physics is not accessible with the premises that underpin quantum mechanics. QM is premised on particles –and bosons- being zero-dimensional (0-D) points with stochastic and intrinsic properties. If the interactions were to actually have a spatial component, then 0-D points might be inherently unable to represent the mechanisms. Hence alternative theories of physics are also candidates, with their greater number of dimensions for their particles. These other theories may be broadly categorised into string theories, and hidden variable theories. Neither has been especially effective.

String theory has been attempted as a route to a theory of all the interactions. However its lack of specificity has frustrated progress. Hidden variable theories takes the premise of physical realism, that manifest attributes are carried by physical substructures to the particle, but they too have been mostly unsuccessful. Of the NLHV theories, historically the de Broglie-Bohm has been the best known [5, 6], but has made no contribution to a holistic explanation of force interactions. Hence a unified theory of all interactions remains elusive, despite considerable effort.

3 Method

Objective

The first purpose of this paper was to identify how force arises at the next deeper level of fundamental physics, under the Cordus variant of NLHV theory. A second aim was to seek explanations for each of the interactions.

Approach

The Cordus theory [7] was used to infer candidate explanations for force interactions. The earlier conceptual contributions of [1] and [2] were the initial basis. The work was theory-building in nature. A design method was used, whereby the forces and interactions were considered relative to how these might originate within the particle sub-structures. Three principles were applied in the method.

Parsimoniousness - New particle sub-structures should not be created for each new phenomenon (function) being included. This is conceptually similar to the need to avoid over-parameterisation and model degeneracy in quantitative modelling.

System integration - Any newly proposed particle substructures or concepts must be integrated into the rest of the theory. This is necessary for conceptual coherence. Where appropriate this is expected to result in reconsideration of parts of the theory that show conceptual discoherence.

Sufficiency - The solution needs to be a sufficient match to the empirical phenomena. This corresponds to the function needs in the language of design, see also [28].

This approach was applied iteratively. The results present the final theory that emerged, not the intermediate work. The theory is constructed of lemmas, which are conceptual propositions that are valid within the wider Cordus theory, even if unable to be immediately verified. We first present general principles for interactions, and then elaborate on the different sub-types of interaction.

4 Results

4.1 Context

Like any NLHV theory, the Cordus theory proposes that particles are not zero dimensional points but instead have internal structures that provide the observed functionality (charge, mass, spin, etc.). It makes specific predictions about the identity of these structures at the sub-particle level, see Figure 1.

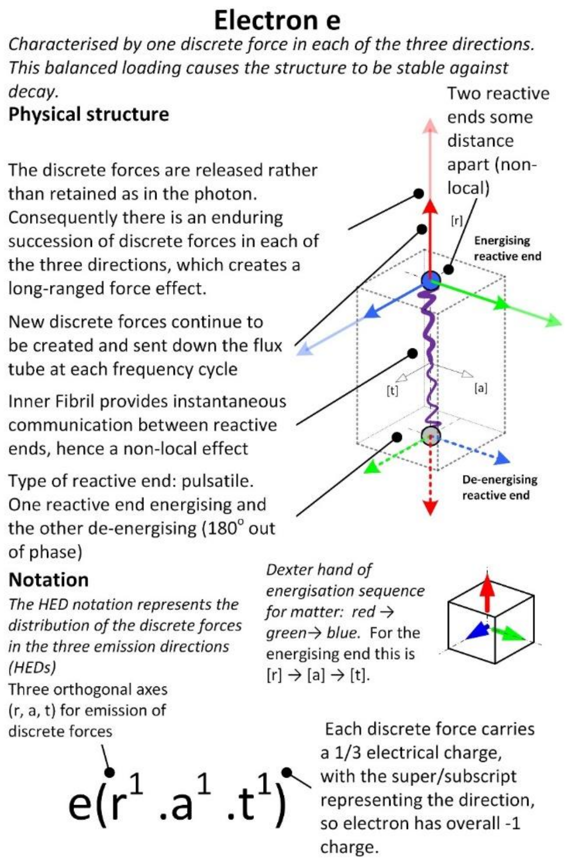

Figure 1: The representation of the electron's internal and external structures. It is proposed that the particle has three orthogonal discrete forces, energised in turn at each reactive end. Adapted from [29].

The particle is proposed to comprise two reactive ends some short distance apart, connected by a fibril. The fibril does not interact with other particles, instead the interaction occurs at the reactive ends. The reactive ends are energised at the de Broglie frequency, at which time they emit discrete forces into space in each of three spatial directions (r, a, and t, see Figure 1) [11, 24]. For massy particles the discrete forces are encapsulated into extended fibril structures that propagate into space – these are called flux tubes. The aggregation of these in space makes up a fabric of discrete forces [12].

4.2 A proposed general mechanism for force

Now consider test particle B, say an electron, in a field (e.g. electrostatic) set up by particle A. Each particle has two reactive ends, and for B these are denoted B_1 and B_2. See Figure 2. The location of interest is reactive end B_1 which receives forces from A, and emits its own discrete forces.

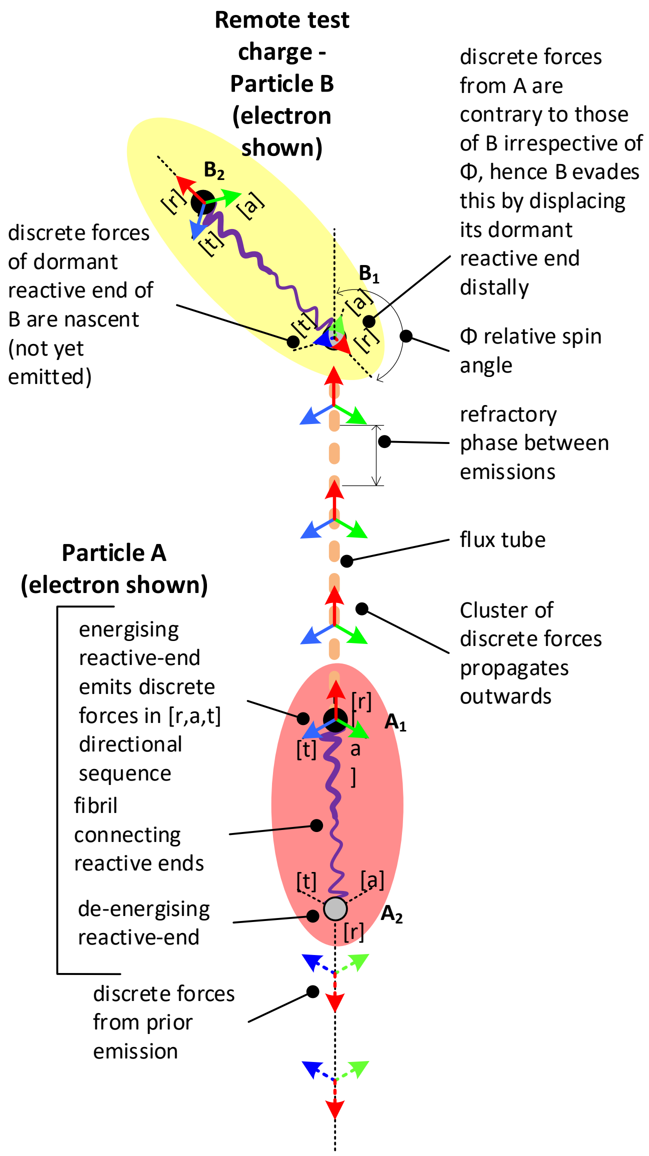

Figure 2: Discrete forces emitted by basal particle A, and intercepted by remote test particle B. Each particle has two reactive ends.

Lemma 1: That Emission of discrete forces occurs at the energisation frequency of the particle

It is proposed that discrete forces are emitted from massy particles, and at each cycle of energisation a fresh discrete force is created and emitted. It follows that higher frequency particles, i.e. those that are in more energetic states, emit discrete forces more frequently. The corollary is that the magnitude of the force effect is proposed to be determined by the number of discrete forces received.

Lemma 2: That similar-charged particles interact via the transphasic synchronous interaction, while opposite-charged particles interact via the cisphasic interaction.
The Cordus theory predicts that bonds between *proximal* particles arise from synchronisation of their discrete force emissions. This is called the synchronous interaction [11] and has been applied to predict the structure of the atomic nucleus for multiple nuclides [10, 17], and also explains Pauli pair structures [27]. Favourable emission states have already been defined for this theory, see [11], and include assembly of opposite charge discrete forces and complete sets of discrete forces. There are two subtypes to the synchronous interaction, which are transphasic and cisphasic. These are when reactive ends from different particles energise out- and in- phase respectively.

This lemma extends the synchronous principle to *ranged* particles: we propose that the same mechanism applies even if the particles are some distance apart, e.g. in the electrostatic force and ranged forces generally.

If the emission of discrete forces of one particle favours the emissions of the other, then the particles move closer together. The direction of motion is along the gradient in a direction that favours increased compatibility or evades incompatibility (as the case may be).

Lemma 3: That Force is caused by coercive displacement of reactive ends
Under the Cordus assumptions, force at the deeper level is a process of discrete displacements of reactive ends, under the coercive effect of incoming discrete forces.

More specifically, force on test particle B is caused by incoming discrete forces interacting with the emission sequence of B's discrete forces. This coerces the reactive end to re-energise in a different location. Those incoming discrete forces may be from other particle A or the fabric (many other particles) generally.

The nature of the interference for B is the phase difference between its intended emissions vs. the incoming emissions. This prescription causes the reactive end of B to move its location in space, such that it more nearly synchronises its emissions in or out of phase (cis- or transphasic respectively) with the external discrete forces. The process is one of the reactive end of B being drawn to, or evading, the discrete forces produced by distant particles.

Such a motion is a finite displacement and occurs during the energisation cycle of the particle, hence we refer to it as a coerced discrete displacement. It is the particle's response to the external discrete force. This has the effect that the reactive end energises at a *different location* to its natural preference, hence causing the position of the particle as a whole to change, and this effect is perceived as force.

The response depends on the bound state of B. For free particle B the free reactive end may move in response to the external discrete forces. For a partially bonded particle B, one reactive end is co-located with the reactive end of other particles, and hence B is constrained in span and frequency and this limits the available locations into which it can move. For particle B bonded at both reactive ends, there is no ability to move. If there is sufficient reaction force applied to the test particle, then it can be prevented from making this discrete displacement. Instead the body as a whole responds to the external discrete forces. Hence a larger body is subject to the same effect of prescribed displacement, but in an aggregate manner. Thus the effect of prescribed displacement scales from the small to the macroscopic discoherent state. If the external discrete forces are sufficiently compelling, even full bonded particle A may be broken free from its assembly. This is consistent with the effect of ionising radiation.

The displacement is not uniform or fixed, being instead determined by the relative strengths of the native vs. incoming discrete force emissions (hence also type and mass of test particle), and the degree of freedom or constraint on the test particle. The test particle makes a small displacement each time it de-energises, and hence the underlying response to the field is a series of discrete motions. As particles have high frequencies (de Broglie frequency), this process is apparently continuous at the macroscopic scale. Hence the explanation does not undermine classical continuous mechanics, but rather offers a deeper explanation. Likewise the force bosons of quantum mechanics are re-explained as discrete forces. QM requires different bosons for each interaction, whereas the Cordus theory proposes that different attributes of the discrete forces result in the different interactions.

Lemma 4: That a field comprises sequential discrete forces

In this way force at the fundamental level is proposed to be a series of discrete displacements of the reactive end, as opposed to a continuous effect per classical mechanics. The perturbing external discrete force is of finite duration, hence the displacement per energisation cycle is also finite. For a particle B in a steady field, the next discrete force it encounters causes a displacement consistent with the previous one. Hence the particle in this situation shows a consistent direction of discrete displacements, hence a motion of increasing velocity, i.e. acceleration in response to the force field. Thus the effect of the force appears smooth and continuous at the macroscopic level of examination, even though it is fundamentally discrete. A field is interpreted to comprise discrete forces, the action of which causes a particle to move in a rapid series of finite displacements in space.

Lemma 5: That Discrete forces are connected in flux tubes
The discrete forces are emitted at each cycle of energisation and propagate out into the universe, being released from the emitting particle. The sequence of discrete forces emitted by any one particle is proposed to be connected in a *flux tube,* this being a curvilinear assembly of discrete forces. The discrete force in the flux tube is a persistent structure even when not energised. This concept was used to derive the Lorentz transformation from a Cordus particle basis [26]. The mixing of these flux tubes in the space between matter creates a fabric [9], the density of which is proposed to affect the speed at which the discrete forces propagate [22].

As a particle moves, so the next discrete force is emitted from a different position of the reactive end. Hence the direction of action of the following discrete force will be slightly different to that before it. Hence the flux tube is required, by this theory, to have bends in it corresponding to the energisation cycles of the reactive end. This is particularly relevant in what follows for the explanation of the magnetic interaction. Furthermore the flux tube is proposed to convey the handedness and structure of the discrete force emission, and this is relevant to gravitation.

Lemma 6: That the discrete force interactions are fundamentally unidirectional
It is proposed that the displacement effect of a received discrete force, and hence the force interaction, is fundamentally unidirectional: when test particle B *receives* a discrete force, it reacts to it via the displacement effect. The *emitting* particle A is unaffected, unless it also receives a discrete force from B. This means that the process whereby A emits a discrete force does not commit A to a future interaction dependent on whether or not that discrete force is intercepted by B.

This is an unorthodox premise since force is generally held to be reciprocal in action. Indeed in the type of *situation* in which the Earth is positioned, similar particles affect each other equally, and hence force the bi-directional nature of force is recovered. Nonetheless in general the theory predicts unidirectional effects: discrete forces from A unidirectionally affect B, and those from B affect A, but there is no fixed reciprocity nor an exchange per se. In the Cordus theory *situation* refers to the reference frame of general relativity, with the addition of the fabric density [26]. The fabric density is variable with matter distribution and epoch of the universe [22].

Lemma 7: That discrete forces are not consumed in the interactions
It is proposed that, in general, discrete forces are not consumed by interactions but continue to propagate outward to affect yet other particles. In specific cases the discrete force may be consumed, such as annihilation of matter-antimatter particles [14], and pair-production [21].

Lemma 8: That the capability to make discrete displacement of a reactive end is affected by its energisation state
The discrete displacement of a reactive end is affected by its energisation state. A reactive end that is fully energised in one of its emission directions (r,a,t) is momentarily stationary in that direction, or would prefer to be so. At times of incomplete energisation the reactive end is mobile and most susceptible to being displaced by an incoming discrete force.

Lemma 9: That the reactive end samples the discrete forces around it
A reactive end experiences all the discrete forces passing through that region of space which it occupies in its migrations. The reactive end is transparent in that the external discrete forces intrude into the reactive end temporarily as they propagate. Furthermore the reactive end moves in a cyclic locus as it emits, which increases the volume of space it samples. For an explanation, see Lemma 16.

A particle is not solely affected by the fields (or in this case the discrete forces) passing through its centre (or in this case its two reactive ends). Instead it is affected by discrete forces in the nearby locality of the reactive end. The incoming discrete forces occupy a volume of space during their transit. Consequently the reactive end has the ability to sense what is happening in the volume of space immediately around it, with an interaction between the external environment, discrete forces, and reactive end. This is non-local behaviour.

Lemma 10: That sampling of the environment provides the mechanism for the reactive end to determine the field gradient
At intermediate stages of energisation the reactive end moves a small distance in reaction as it undertakes its own emissions. This result in a small-scale repetitive displacement motion of the reactive end at the de Broglie frequency. This motion is in all three directions of space, which allows the reactive end to sweep through -and sample- a small volume of space. This is proposed as the mechanism whereby it senses the gradient of the external field.

The mechanism whereby the reaction end moves under the influence of an external field arises because the RE spends longer time in those regions of space where the density (or strength) of external discrete forces is more favourable (higher or lower depending on relative attributes of particles A and B). It preferentially energises there. Since energisation also means the RE is stationary, it dwells there longer, hence the mean position of the RE is changed.

Lemma 11: That Geometric properties of flux tubes correspond to interactions
The flux tube is expected to have three geometric properties of linear strength (radial emissions), curvature (bending), and twist (torsion). It is proposed that these geometric properties provide the mechanisms for the electrostatic, magnetic, and gravitational (EMG) force interactions respectively, as elaborated below. A fourth attribute of the discrete forces (not so much of the flux tube) is the synchronisation of emission between two particles, and this is proposed as the mechanism for the strong interaction (see below). The weak (decay) interaction is proposed to have an altogether different cause (see below).

The above are the general principles for how force operates within the Cordus theory. Next these principles are applied to offer explanations for the different interactions. The most detailed explanation is provided for the electrostatic, as the mechanism is the basis for the other field forces.

4.3 Electrostatic interaction

Further to lemma 11 the theory implies the following.

Lemma 12: That the electrostatic interaction arises from the linear (radial) component of discrete forces

Under these premises the electrostatic interaction is interpreted as the direct linear action of the incoming discrete force on a remote particle. It applies in a direction along the line of the flux tube, and the effect is to move the remote particle B closer or further from the emitting particle A depending on the relative charge. See Figure 3.

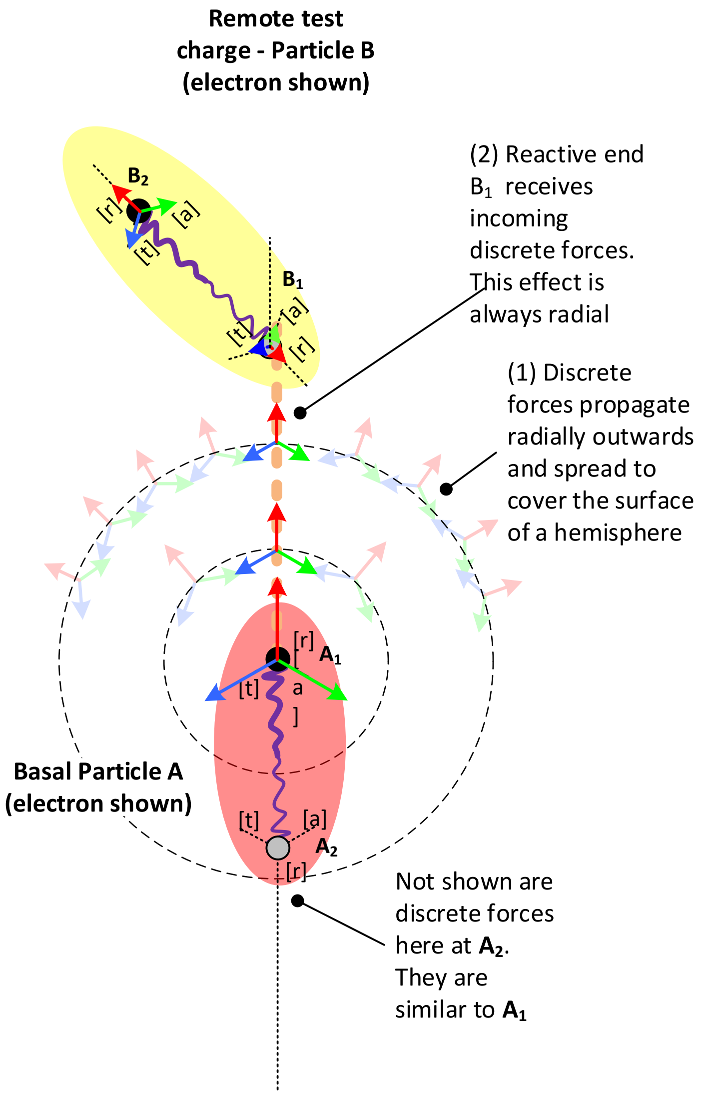

Figure 3: The electrostatic interaction arises from the direct linear action of discrete forces emitted by basal particle A.

The underling mechanism is proposed to be that the recipient reactive end attempts to emit its own discrete forces, but is affected by the incoming discrete force. It may be enhanced or inhibited depending on the compatibility between the native and external discrete forces. As a consequence this changes the position of the reactive end, with the displacement being along the axis of the fibril. A similar mechanism for the spatial readjustment of the reactive end has been proposed for photon absorption and emission [8]. Note that the theory provides that the direction of the discrete force is the basis for the sign of the electric charge. This is presumed to be the direction of action of the discrete forces within an outward travelling flux tube. Negative charge is assumed outwards – this is merely a sign convention.

Explanation for like-charge interaction

Consider the interaction between two electrons, being a typical like-charge case. Electron A is the basal one and is nominally assumed to be fixed, while B is the remote test charge that reacts to A. Each electron has two reactive ends (1 and 2) per this theory. The reactive end A_1 of electron A emits discrete forces packages in a flux tube, which propagate out into space at the local speed of light and impinge on reactive end B_1 of remote test electron B.

Consider now the energisation of dormant reactive end B_1. As B_1 begins to energise it encounters incoming discrete forces from A_1, that are incompatible with its own emissions. Per lemma 1, this ranged interaction is transphasic, since the particles have like charge, and the synchronous interaction therefore operates to put the emissions $\pi/2$ out of phase. However B_1 cannot delay its energisation indefinitely. This because energisation state and frequency are determinants of particle identity and energy respectively [15, 19]. Consequently B_1 has to adjust its location to move with those imposed forces

If the remote charged body has physical depth, i.e. comprises many particles, then the incoming discrete forces apply displacements to the fore-most parts of the body, then pass through and apply displacements to the deeper layers. Hence a charged macroscopic object feels the electrostatic effect and moves holistically. The discrete forces propagate at the local speed of light in this theory, hence also the dynamic effect of the electrostatic interaction.

Electric field

At the macroscopic scale of a negatively charged sphere, each of many electrons generates its own discrete forces and flux tubes. Macroscopic bodies tend to be discoherent in not exhibiting quantum behaviours. The Cordus theory interprets such bodies as discoherent assemblies of matter, wherein the particle spans are not aligned. Furthermore the theory identifies spin as corresponding to the angular position of the fibril. Hence a discoherent sea of electrons can be expected to generate flux tubes pointing in random directions. This is consistent with the observation of an electrostatic field that is smooth, continuous, and uniform in all directions. The theory predicts that the field will however be granular at the frequency of the charge emitters.

The electrical force $\vec{F}_{eB}$ between two particles of charge q_A and q_B is:

$$\vec{F}_{eB} = -K\frac{q_A q_B}{r^2}\hat{r} \qquad (1)$$

Where r is the radial separation, $\hat{r}$ is the radial direction and K is a constant. A qualitative explanation for the form of this relationship follows. The reason for the product of charge ($q_A q_B$) is that charge determines the number of discrete forces involved: the amount of displacement coercion (hence force) experienced by particle B is determined by the strength q_A of the incoming discrete forces, and the strength of its own response q_B, hence a multiplicative relationship. The inverse square relationship $1/r^2$ arises from the expansion of the discrete forces on a spherical front. This expansion occurs because the discrete forces are emitted in three orthogonal directions in surface shells at each energisation cycle.

Irrespective of the relative orientation (spin) of A and B, there is always a component of B's emissions that is radial to A, i.e. in the direction $\hat{r}$. The electrostatic interaction may be simplified to only this component.

Dissimilar charges attract even across the matter-antimatter species. So this implies that the energisation sequence –which differentiates the species – is immaterial for the electrostatic interaction.

Electrostatic Shielding

An electric field is known to be shieldable by a Faraday cage, whereas gravitation is not able to be shielded. The Cordus theory predicts that discrete forces penetrate all matter, but in a Faraday cage the electric field only appears to be shielded, because electrons in the conductive cage material have sufficient mobility to move in response to the external field and set up a countering field.

In contrast the photon can be shielded: it can be absorbed, by mechanisms identified in [8]. Applying this to interaction of electromagnetic radiation *photons* from an antenna or reflector, the Cordus theory explains that the frequency and span of the photons is inversely related [7], which is consistent with the observation that the conducting elements of the antenna need to be closer spaced for higher frequency radiation. As the photon frequency rises still further, the required conductive loops are of the order of atomic spacing, i.e. the shield must be of a continuous material. For even greater frequencies the electrons cannot encounter all the discrete forces in which case the photons pass straight through.

4.4 Magnetic interaction

A test charge q moving with velocity V in a magnetic field Bm experiences a sideways force F_m that is perpendicular to both its direction of travel and the *external* magnetic field, i.e. excludes the magnetic field of the test charge itself):

$$F_m = qV \times Bm \quad (2)$$

This is explained as follows.

Lemma 13: That movement of the basal charge bends the flux tube
A flux tube is a directional propagation of discrete forces. It is proposed that this may be bent by movement of the basal emitting reactive end. Per Lemma 8, motion of a reactive end occurs during its de-energised state. Motion is therefore in discrete displacements. This results in emissions expanding from each progressive location of energisation. Consequently the flux tube, which is continuous, has kinks. The new curvature moves outward with the discrete forces at the local speed of light. If the speed of light was infinite, i.e. disturbances propagated instantly, then there would be no magnetic effect.

Lemma 14: That the magnetic interaction arises from curvature of the flux tube
Under these premises the magnetic interaction arises interpreted as the action of the incoming discrete forces in a recurved flux tube, causing a yaw adjustment in the velocity of a remote moving charged particle. This idea is from [1].

A remote test particle B moving with velocity V_B receives at reactive end B_1 the discrete forces and the re-curved flux tube emitted by A. This causes a coerced displacement of B_1, which provides a yaw moment that changes the direction of motion of B to be more parallel or antiparallel (depending on the charge) to the velocity of A. See Figure 4.

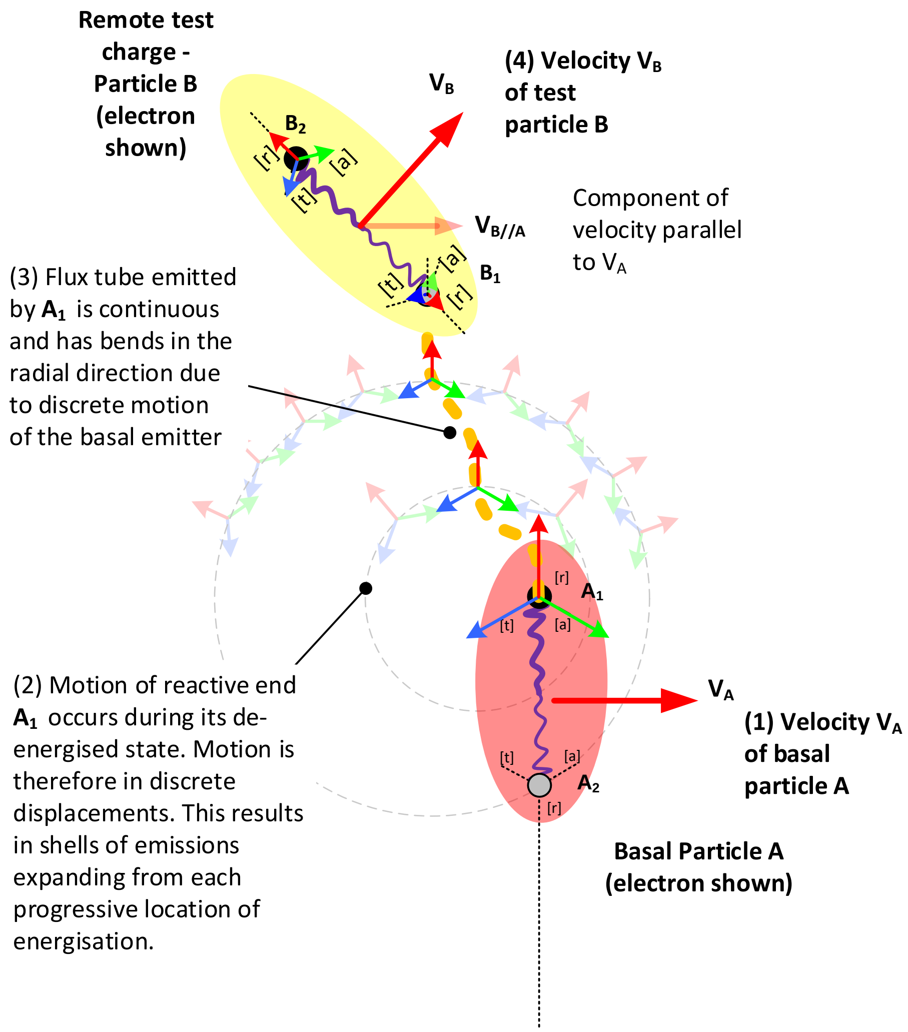

Figure 4: The magnetic interaction arises from the rotational action of the incoming discrete forces in a recurved flux tube

Coerced displacement of a remote moving charge

How does a curved flux tube create the magnetic force on the moving remote test charge? If the remote test charge is stationary, then any curvature of the incoming discrete forces in their flux tube only re-orients the *direction* of the electrostatic force. Since the flux tube is recurved, this imposes a transient change in orientation that integrates to zero. However, if the test charge is also moving, and encounters a curved flux tube, then the magnetic interaction attempts to realign the *locus* of the moving test charge to the same handed direction of motion as the basal charge.

When the discrete forces in their flux tube reaches the remote moving test charge B, it upsets the geometric location for the reactive end B_1 of the moving test charge. Whether it delays or advances that reactive end depends on the sign of the magnetic field, i.e. the relative direction of the velocity of B, and the relative charges. The discrete force pulse prevents B_1 from advancing forward as far as it usually might during a frequency cycle, or it pushes it forward.

The incoming discrete forces are not consumed but passes on outward to the other reactive end of the remote particle. The effect on B as a whole is additive rather than being negated, since the direction of the flux tube is reversed when it reaches that other reactive end. This sets up a yaw moment across the fibril of the remote particle, thereby adjusting the direction in which the remote charge is moving.

Magnetic fields

Magnetic fields represent the motion of the charge (basal generator) that is emitting the discrete forces. A remote moving charge changes direction to be more closely parallel (or antiparallel depending on charge sign) to the locus of the basal charge [30].

The magnetic force $\vec{F}_{mB}$ in the radial direction $\hat{r}$, experienced by particle B of charge q_B and velocity $\vec{v}_B$ in a magnetic field created by particle A with q_A and $\vec{v}_A$ is:

$$\vec{F}_{mB} = \frac{\mu_0}{4\pi}\frac{q_A q_B}{r^2}\vec{v}_A \times \vec{v}_B \tag{3}$$

where r is the radial separation, and $\mu_0$is a constant. A qualitative explanation for the form of this relationship follows. The reasons for the product of charge ($q_A q_B$) and the inverse square relationship $1/r^2$ are as before. Having more charges q moving in the same direction does not increase the curvature but simply means that there are more discrete forces reaching the remote test charge, i.e. the effect simply scales for increase in either of the charges.

The direction of the magnetic field is perpendicular to the plane in which the curvature of flux tube occurs. The velocity dependency arises because the faster the basal charge moves $\vec{v}_A$ the greater the curvature of the flux tube. The greater the velocity $\vec{v}_B$ the greater the rate at which the kinks are encountered, hence a multiplicative relationship. The magnetism effect depends not simply on the speed of the charges, but also their relative directions. The effect depends on the component of curvature that is apparent to B in its direction of motion, hence the cross product. Thus magnetism only works in remote particles that already have some degree of alignment of their locus with the velocity of the basal charge.

It is proposed that the reason for the effect being right-handed is due to the way that reactive ends emit discrete forces in an energisation sequence (see Figure 1), and the dominance of the matter species. Each package of discrete forces has three orthogonal sub-forces and these are energised in a sequence. This sequence has been proposed as the distinguishing structural feature of the matter-antimatter species [13], the anti-electron structure [31], and the basis for annihilation [14].

A common illustration of magnetism depicts a moving charge being forced into a circular trajectory in the presence of a uniform magnetic field. Our explanation is that when the magnetic field is large and uniform, then the transecting moving test charge is forced into a circular path which is the same motion as the large basal current required to make that magnetic field. In this case the magnetic field dominates the interaction, and the moving test charge tends to move into a circular or helical trajectory (its own back-reaction is miniscule). However the case of the uniform field obscures the important fact that creation of that uniform field requires charges to be moving in a circular path too. Uniform magnetic fields are therefore a special case. It is the interaction of two moving charged particles where the more interesting mechanics occurs. The geometrically simplest form of magnetism, two particles affecting each other, is surprisingly complex. The moving test charge is not simply a passive participant, but also radiates its own discrete forces in their flux tube. If the basal charge is of similar size, it will be affected in turn by the magnetism of the test charge. For this and relativistic considerations see [32] and earlier work by [30]. We propose it can be qualitatively interpreted as one moving charge attempting to force another to conform to the same direction of motion: it is a type of alignment effect.

If the test charge is not moving, then the effect of incoming magnetism is to align the remote test charge, which means interfering with its orientation (spin). This is consistent with behaviour of permanent magnets and magnetic resonance imaging. In both these cases the spins of all the electrons in the macroscopic body tend towards alignment. Again this shows that magnetism is primarily an alignment effect.

Permanent magnets

A permanent ferro-magnet has a magnetic field, but no apparent electric field. The usual explanation is that that the electron and nucleon spins are aligned across a domain (region of atoms). The Cordus theory explains this based on the orientation of the particle. Being a hidden variable theory, it provides a natural explanation for spin [27]. We propose that the alignment of the span of electrons and nucleons, i.e. spin, results in the discrete forces in their flux tubes pointing in the same direction along the axis of the magnetic poles, but randomly orientated in the transverse directions. Hence the effect is summated along the axis, and neutralised laterally. The magnet does not appear to be charged or to emit an electric field because of the equal contribution of positive and negative charges. Nonetheless it emits discrete forces in their flux tube. From this perspective, the magnetic domains are formed in the first instance because electron discrete forces extend to neighbouring atoms and encourage alignment of other electrons. We suggest that within the magnetic material the electrons themselves move, either through their unfilled orbitals, or as current flow within the sub-lattices of the material, and this generates curvature of the discrete forces in their flux tubes and thus magnetic fields.

4.5 Gravitation

Gravitational force has been proposed in this theory to be transmitted via a torsional attribute of the flux tube [1] and [2]. A further development of that idea follows.

Lemma 15: That the discrete force emissions take the form $\sin^2(\theta/2)$
Previous diagrams have shown the reactive ends as either energised or not, but this is simplistic. The strength of energisation, hence also of the emitted discrete forces, evolves over time. The question is what the shape of this energisation function might be. We are required, for reasons of logical consistency with the Lorentz work [26], to see the reactive ends as producing a continuous flux tube, without breaks, so abrupt step-like functions are excluded. It is logical to assume it takes a sinusoidal function, and ranges between 1 and 0 over a cycle (discrete forces of massy particles do not change sign, though photons do). We also need to consider the second reactive end B_2 and that the energy oscillates between the two – this is an established principle of the theory. This requires that the total energy is conserved at any one moment. A relationship that fits these criteria is $\sin^2(\theta/2)$ where θ is the phase angle of energisation, and this is marked as lemma.

Thus the potential energy of a discrete force in a particular direction (say r) at reactive ends B_1 and B_2 is:

$$U_{B_1} = sin^2 \frac{\theta_B}{2} \qquad (4a)$$

$$U_{B_2} = cos^2\frac{\theta_B}{2} \tag{4b}$$

Given also that there are three orthogonal discrete force emissions (r, a, t) and that the energisation sequence of these determines the matter-antimatter species, then the potential energy is partitioned into three components offset at thirds of the phase cycle:

$$U_{B_1}(r) = sin^2\frac{\theta_B}{2} \tag{5a}$$

$$U_{B_1}(a) = sin^2(\frac{\theta_B}{2} - 120^o) \tag{5b}$$

$$U_{B_1}(t) = sin^2(\frac{\theta_B}{2} - 240^o) \tag{5c}$$

See Figure 5 for a representation of these three phases. The discrete force emissions do not subtract energy from the particle.

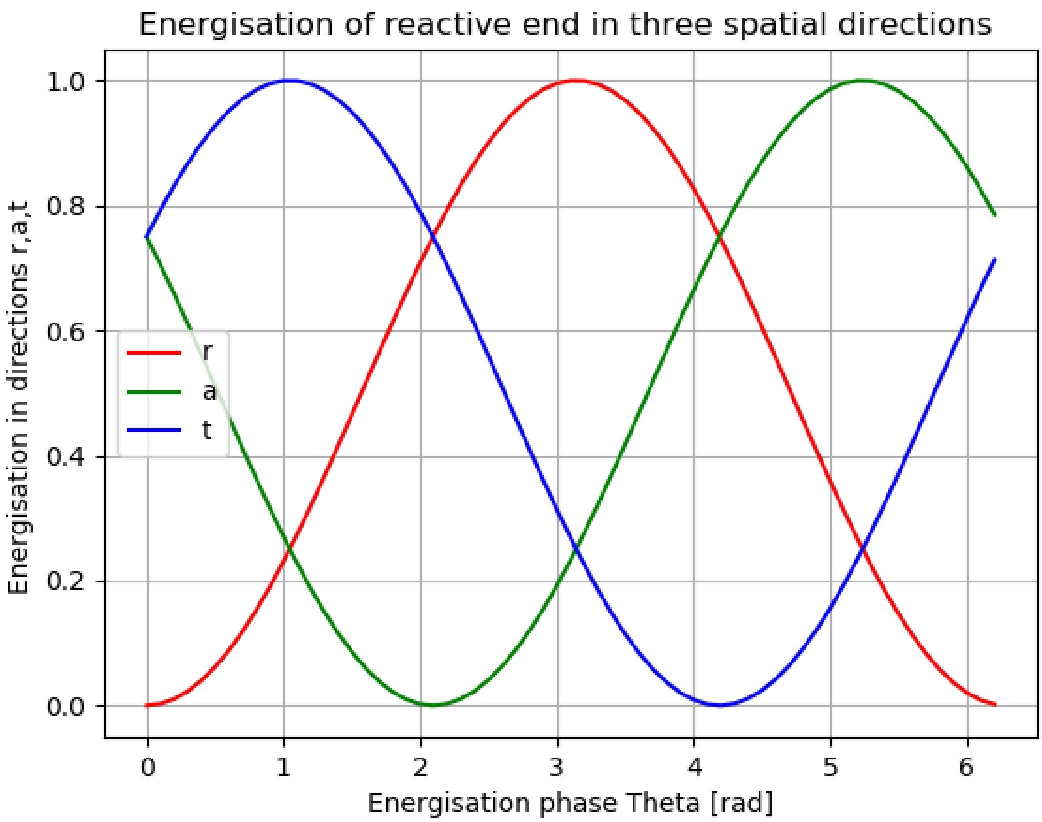

Figure 5: Energisation phases in the three orthogonal emission directions (r,a,t) follow a $sin^2(\theta/2)$ relation.

Thus the reactive end is never fully de-energised (except momentarily in one axis), and this is consistent with the expectations from the Lorentz derivation for a stretchable flux tube.

This also means that the energy at the basal generator, i.e. the reactive end B_1 has a circular function, see Figure 6.

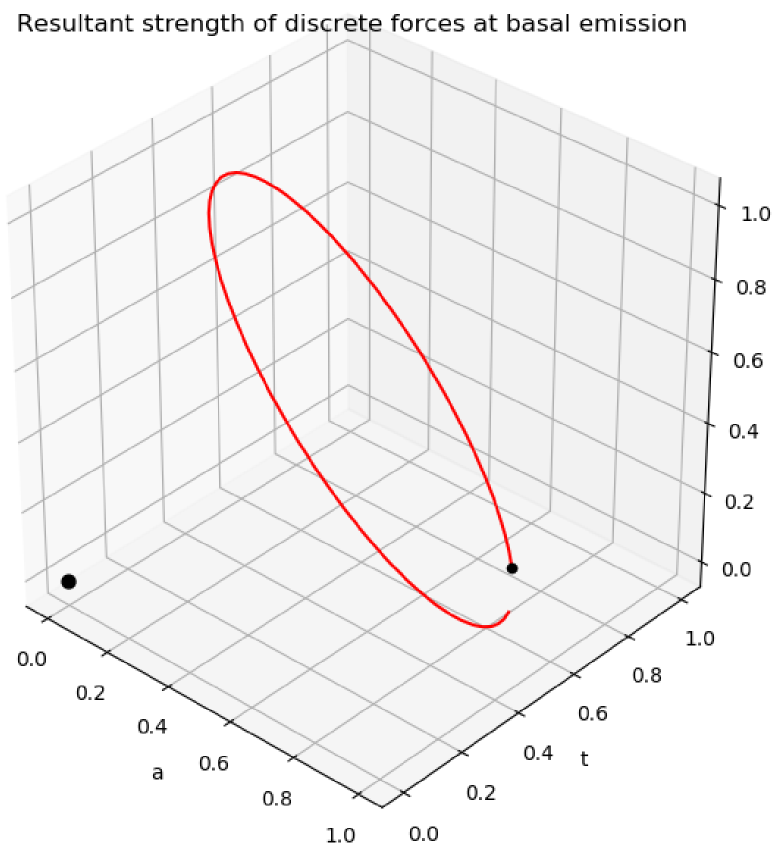

Figure 6: Resultant energy at the basal generator B_1 due to a matter negative charge. The axes are (r,a,t). The larger black marker indicates the nominal origin (0,0,0), and the smaller black marker indicates the location for $\theta = 0$. The chart is deliberately shown incomplete to indicate the direction of rotation.

Thus the phased emission of discrete forces corresponds to a torsional energisation that is carried out into space by the discrete forces. This provides a more substantive explanation for the original assertion that gravitation is conveyed by the torsion in the flux tube. The remote particle B receives this torsional package of discrete forces, and assuming both A and B are matter particles, finds this conducive to its own emissions and moves closer along the field gradient.

Why should the gravitational interaction between matter and matter be attractive when the electrostatic interaction repels like charges? The answer is that a neutral particle A has both positive and negative charge emissions (not nothing), with a handed energisation sequence. The receiving particle B is attracted to the transphasic interaction whereby it energises within the null points in the incoming (r,a,t) emission. It moves up the field gradient to improve this coordination opportunity. This it can only do if the energisation sequence is the same.

Matter-antimatter gravitation would be repulsive

For the case of an anti-electron the energisation sequence is (a,r,t) and the charge is inverted. The corresponding energy locus is shown in Figure 7. This shows that the rotation is opposite in direction for antimatter. It logically follows for this theory that the gravitational interaction between two antimatter particles would be attractive, and repulsive between matter and antimatter.

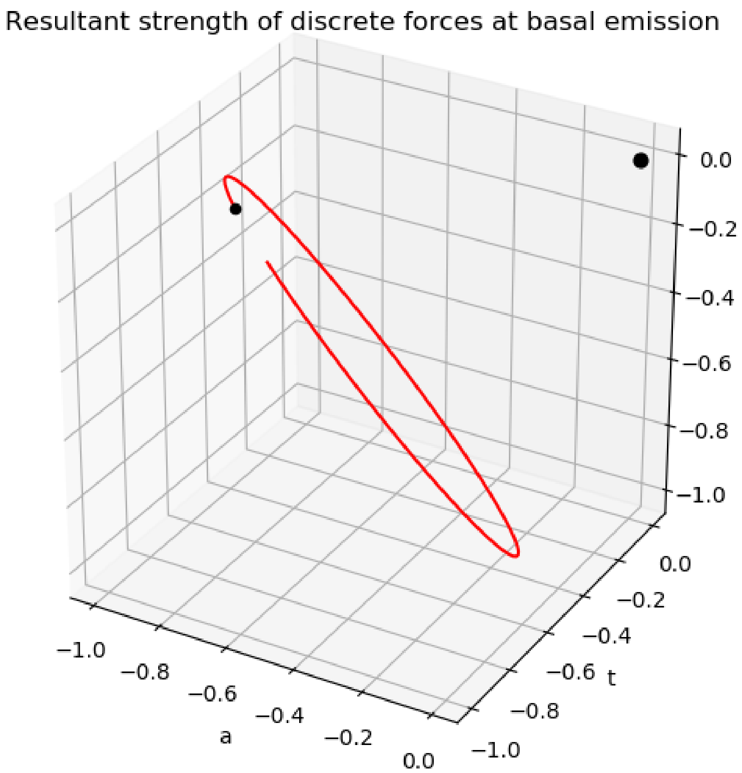

Figure 7: Resultant energy at the basal generator B_1 due to an antimatter positive charge. The axes are (r,a,t), but the energisation sequence is (a,r,t). The larger black marker indicates the nominal origin (0,0,0), and the smaller black marker indicates the location for $\theta = 0$. The chart is deliberately shown incomplete to indicate the direction of rotation.

Gravitational force

The gravitational force $\vec{F}_{gB}$ in the radial direction $\hat{r}$, experienced by particle B of mass m_B in a gravitational field created by particle A with m_A is conventionally:

$$\vec{F}_{gB} = G\frac{m_A m_b}{r^2} \qquad (6)$$

The reason for the product of charge $(m_A m_b)$ is that that the effect is enhanced by more incoming discrete forces (m_A) per lemma 1, and a greater frequency of response (m_b) per lemma 8. The inverse square relationship $1/r^2$ is because of the dilution of discrete forces across an expanding spherical shell, as before.

4.6 Mechanism for force & discrete movement in an imposed field

Above it was stated that force is caused by coercive displacement of reactive ends (lemma 3), that the reactive end samples the discrete forces around it (lemma 9), and that this provides the mechanism for the reactive end to determine the field gradient (lemma 10). However these were conceptual propositions, whereas now with the help of additional assumptions in Lemma 16 it is possible to substantiate this with a more specific mechanism.

Lemma 16: That the process of emitting discrete forces causes the reactive end to move cyclically in the (r,a,t) directions

It is proposed that the sinusoidal potential energy function of the discrete forces corresponds to a movement of the reactive end itself. The nature of the motion is inferred as follows. The discrete forces themselves are a type of potential displacement. Hence the displacement that underpins them is the square root of their potential energy function, hence a $\sin(\theta/2)$ dependency. However the motion must be cyclical, i.e. the reactive end must return to its original position, and this requires positive and negative components to its motion, hence a $\sin(\theta)$ function. Finally, the motion of the reactive end is inversely related to its energisation, being motionless when fully energised, hence a $\cos(\theta)$ relationship. This is shown for a single axis in Figure 8, and for all three axes in Figure 9. Thus the displacement of the reactive end may be inferred to be a circular locus around the nominal location of the reactive end.

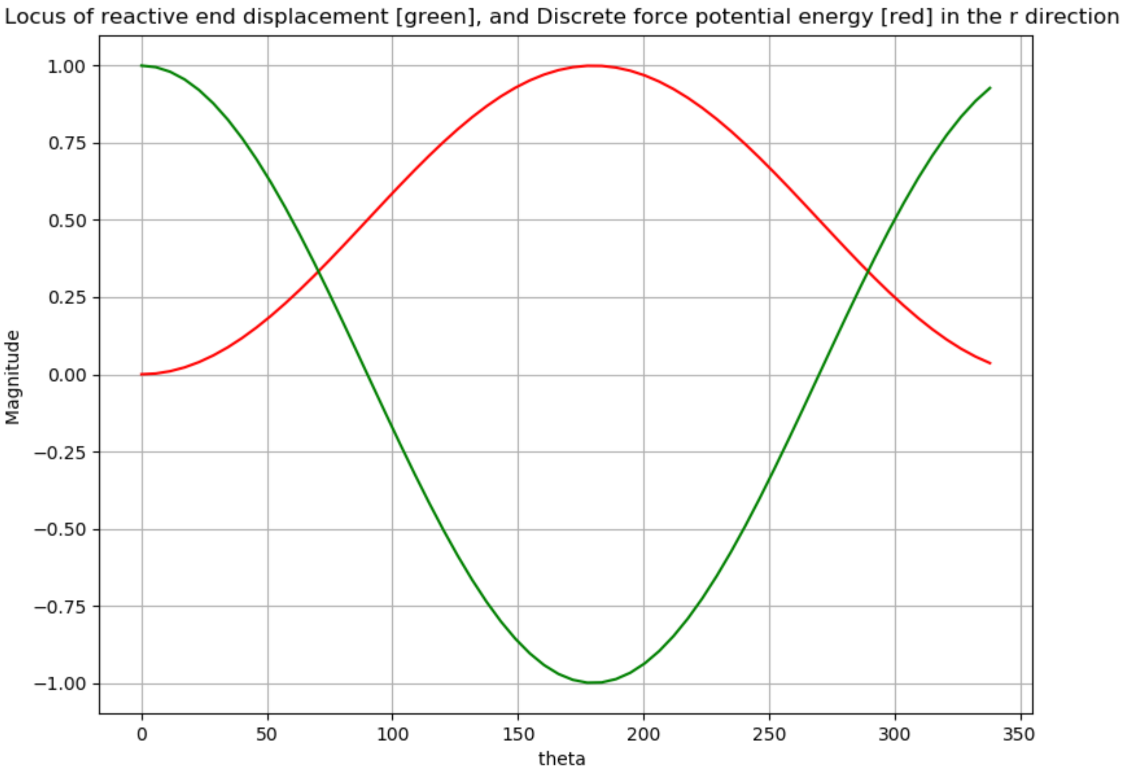

Figure 8: The locus of motion of the reactive end follows a $cos(\theta)$ dependency for each axis, whereas the potential energy follows $sin^2(\theta/2)$.

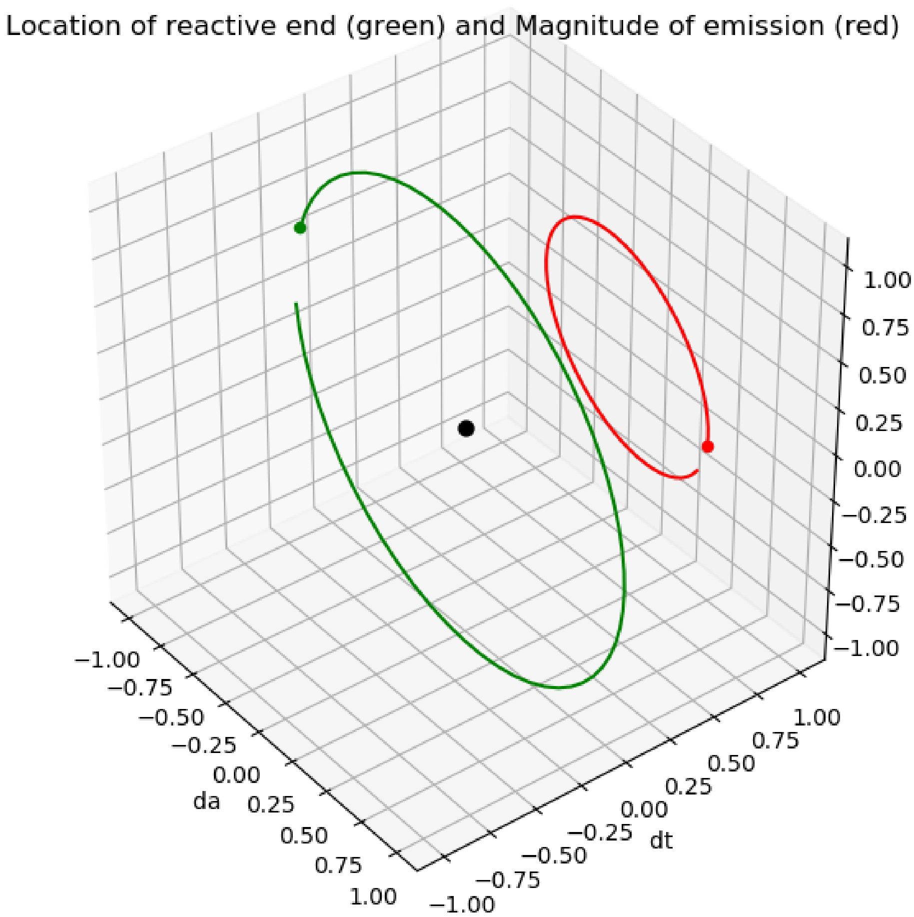

Figure 9: Circular locus of positon of the reactive end over a complete cycle of emission from both reactive ends, for an electron. Green shows the location locus, and red the energy. The vertical axis is the r direction.

While the positional locus is circular in the absence of an imposed field, the reactive end expands its excursion when in a field. Assuming a field gradient applies and consider only the r direction. The amount of displacement from the locus is presumed to be determined by two factors. The first is the strength of the field, which for simplicity is assumed to be linear (which is approximately true far from the centre) with gradient P_{grad} and strength P_{centre} at the nominal centre point of the reactive end. Thus one side of the positional locus experiences the field as slightly stronger than the other. The second factor is the mobility of the reactive end, which is inversely related to its energisation, hence to $\cos^2 \theta/2$. The result is a non-linear distortion of the positional locus of the form:

$$r_{moved}(\theta) = r(\theta) + \left(P_{grad} r(\theta) + P_{centre}\right) \cos^2 \frac{\theta}{2} \tag{7}$$

An example of a distorted positional locus is shown in Figure 10a. Even with a linear field the new locus is a non-linear distortion of the original circular track, i.e. the reactive end is sensitive to the spatial change in field strength.
The progressive accumulation of displacement results in a distorted spiral locus with dwell regions of low progression, see Figure 10b.

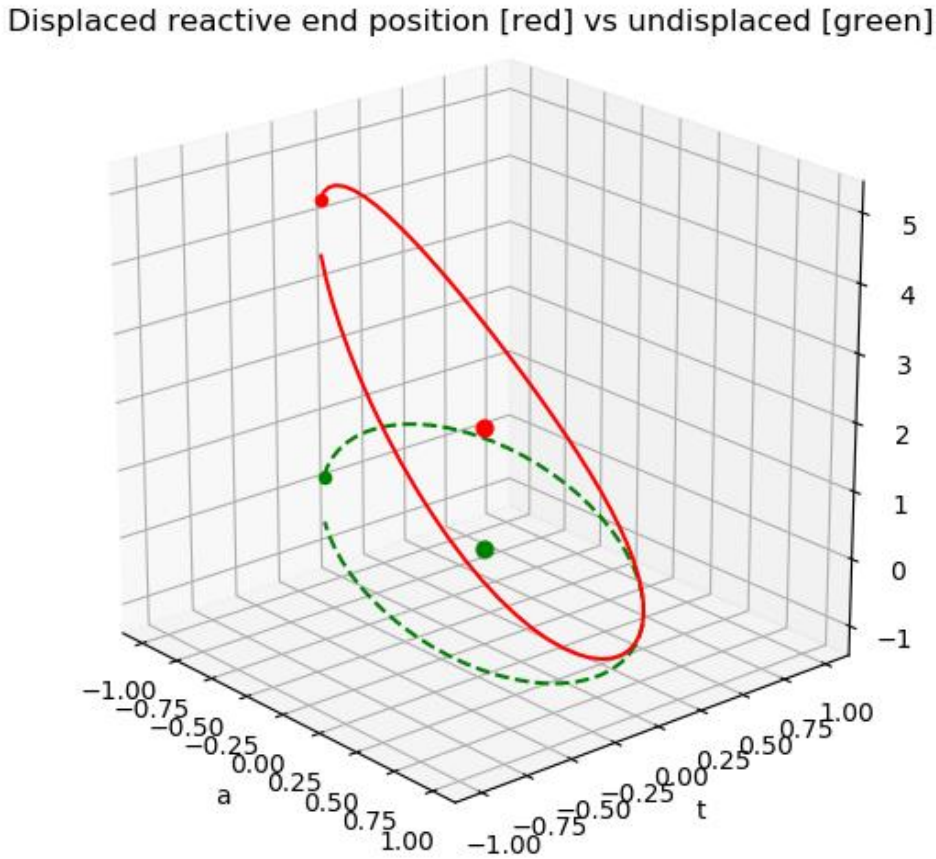

Figure 10a: Distorted positional locus for a reactive end under the effect of a linear field in the r direction. The larger round symbols show the centre point of the locus, i.e. the nominal position of the reactive end. Values in the r direction are nominal.

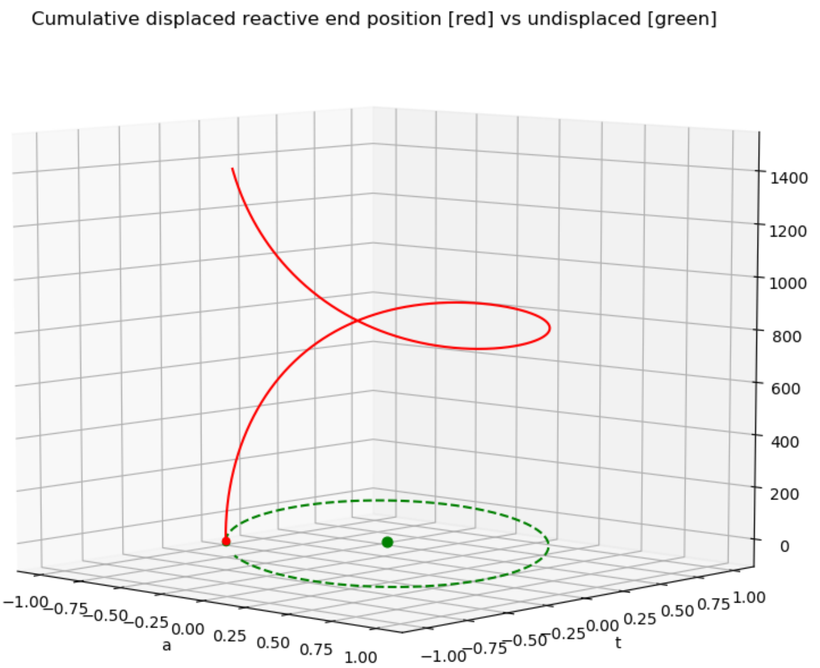

Figure 10b. Cumulative locus of the reactive end. Values are nominal.

The significance is that the mean location of the reactive end changes under the effect of the field. This adjustment occurs in discrete intervals at each frequency cycle while the reactive end is exposed to the field.

This proves the principle that a field can –under these assumptions – cause a displacement of the reactive end. It also substantiates the idea that the reactive end is able to sample the field gradient around it, and move accordingly. While the above example is based on an electrostatic interaction, the principles appear to generalise to any field.

This completes the first objective of this work, which was to show how force might operate at the more fundamental level in the Cordus theory. A second aim was to explore the union of the interactions more broadly.

4.7 Synchronous interaction (strong nuclear force)

The equivalent of the strong nuclear force in the Cordus theory is the synchronous interaction [11]. This interaction is between reactive ends from different particles, that are co-located. If their discrete force emissions are compatible, then this locks the reactive ends together. As identified in Lemma 2, the synchronous interaction has two subtypes, which are transphasic and cisphasic. The terms refer to the phase difference at synchronisation.

The strongest form of compatibility is where the assembly provides a balanced and complete set of discrete force emissions in all three directions [17]. In this case the reactive ends energise simultaneously, and this is the cis-phasic subtype of the synchronous force. An example of the cis-phasic interaction is proposed in the bond between the proton and neutron in the atomic nucleus, see Figure 11.

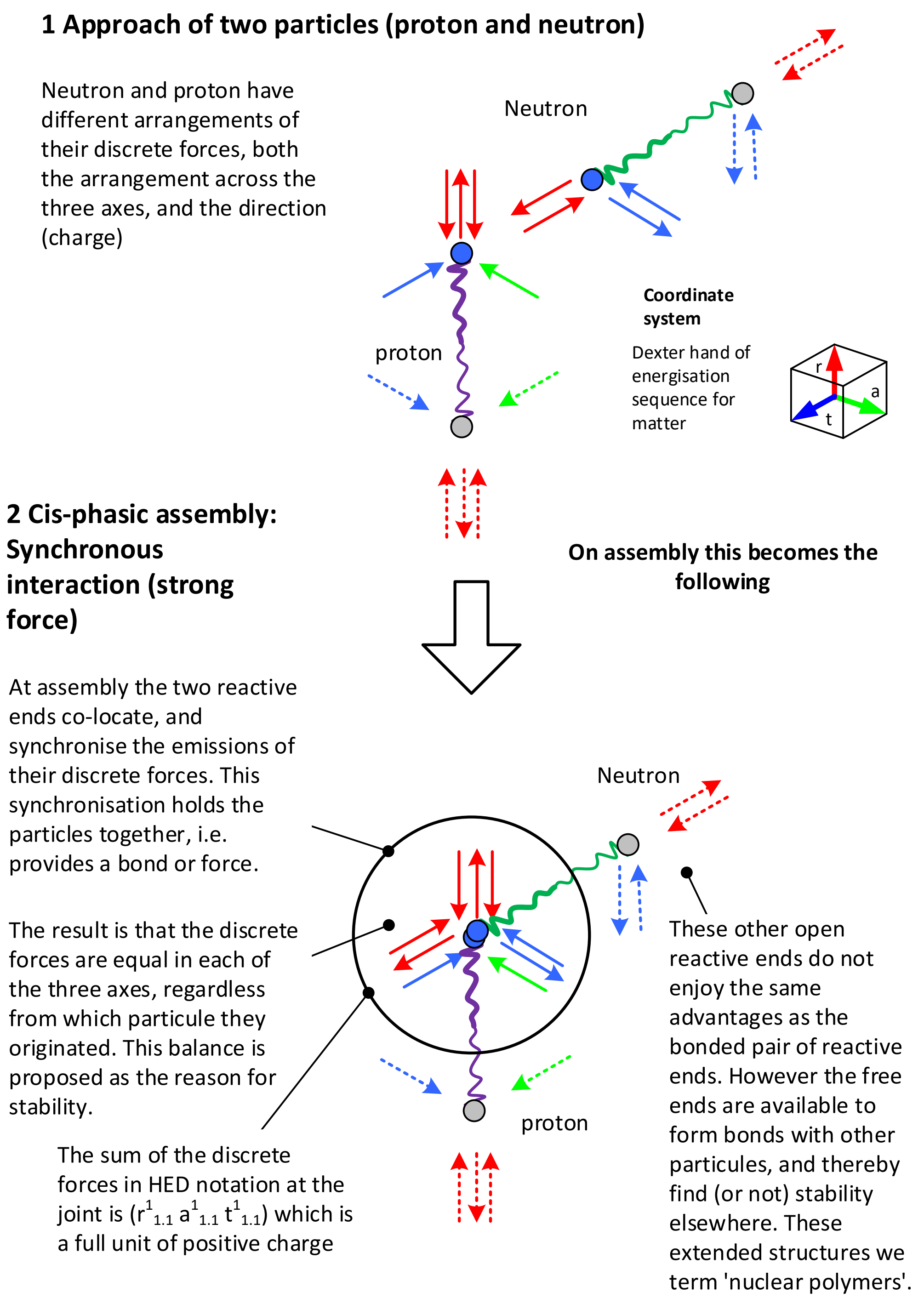

Figure 11: Key features of cis-phasic synchronous interaction as illustrated in the proton-neutron bond. Adapted from [11].

The other subtype of synchronous interaction is trans-phasic, where the reactive ends from two separate particles energise out of phase. The type example of this is the Pauli electron pair [27], see Figure 12.

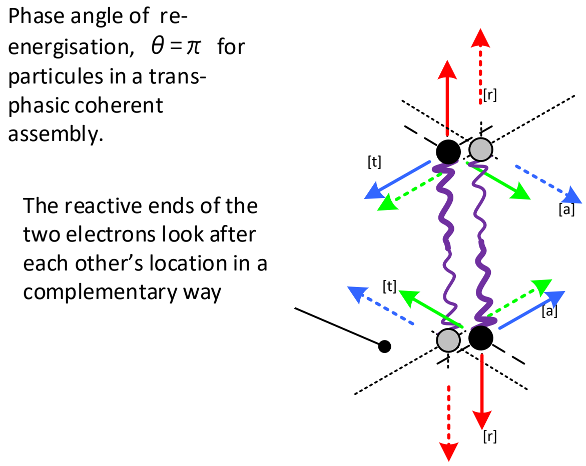

Figure 12: The Pauli pair of electrons uses the trans-phasic interaction to provide a degree of bonding. Adapted from [27].

Application of the synchronous principle is able to explain the structure of the atomic nucleus as a polymer of neutrons and protons. Rules for these bonds have been deduced, and these are sufficient to economically explain why any nuclide is stable, unstable, or non-existent. This has been demonstrated for H to Ne [10, 17] and the trends appear to hold up to at least Ar.

Thus the nuclear force may be explained as a synchronisation of emissions between different reactive ends. The theory proposes that the strong force at the deeper quark level is likewise a synchronous interaction, though the internal structure of the proton and neutron have yet to be fully elucidated within this theory.

4.8 Remanufacturing (weak) interaction

Per QM the weak interaction mediates the nucleon beta decay and electron capture processes via exchange of W and Z bosons. From the Cordus theory the interpretation is somewhat different, as the analysis [15] suggests the weak interactions are part of a more general family of processes that change particle identity. From this perspective the weak bosons are merely transitional assemblies, rather than particles that cause change in quarks. Hence they do not deserve to be called bosons or their process singled out as a fundamental interaction. Instead we propose a set of principles of discrete force manipulation for the remanufacturing processes generally.

Particle identity, in the Cordus theory, arises from the characteristic pattern of discrete force emissions. Change these, and the particle identity is also changed. This process is called ‘remanufacturing’ because the discrete forces are conserved. The conventional term ‘decay’ implies a degenerative, disorderly, or destructive process, which from the Cordus theory is quite the wrong way to think about these transformations. Consideration of the discrete forces and the rules for their transformation [15] shows that it is necessary for many processes to change the *order* of energisation sequence. The theory shows that the neutrino species achieve this by removing unwanted handedness from the assembly [19]. Note that in this theory the handedness is also proposed as the matter-antimatter species differentiator [14, 19]. This is a further reason to use ‘remanufacture’ (*manus*=hand). All the remanufacturing process use the synchronous interaction.

The Cordus theory provides a unified equation for nucleon remanufacture:

$$\boldsymbol{p} + 2\boldsymbol{y} + \boldsymbol{iz} = \boldsymbol{n} + \underline{\boldsymbol{e}} + \boldsymbol{v} \qquad (8)$$

with particle identities and discrete force structures as follows:

n	neutron	$n(r_1^1 .a_1^1 .t)$	Shown for overt part. There is also a large covert component
p	proton	$p(r^1{}_{1.1} .a_1 .t_1)$	ibid
e	electron	$e(r^1.a^1.t^1)$	
$\underline{e}$	antielectron	$\underline{e}(r_{\underline{1}} .a_{\underline{1}} .t_{\underline{1}})$	positron
v	neutrino	$v(r^1{}_1.a.t^1{}_1)$	
$\underline{v}$	antineutrino	$\underline{v}(r_{\underline{1}}^{\underline{1}}.a.t_{\underline{1}}^{\underline{1}})$	
y	photon	$y(r^{\updownarrow}.a .t)$	$\updownarrow$ denotes oscillating discrete force, extended and withdrawn
z	discrete force complex	$x_{\underline{1.}1}^{1.\underline{1}}$	x is one of the emission directions [r.a.t]
2y	a pair of photons	$[r_{\underline{1}}^1 . a_{\underline{1}}^1 . t_{\underline{1}}^1]$	With sufficient energy can also correspond to an electron-antielectron pair

i quantity, e.g. of photons

Note that antimatter is shown with underscore in this notation.

The equation works in both directions. Transfers of a particle across the equality result in inversion of the matter-antimatter species (hand). Rearrangement of the equation gives β-, β+, and EC in the conventional forward directions, and predicts induced decays too [18].

From this perspective the emission/absorption of a photon is also a remanufacturing process [8], as is pair production [21], and annihilation [14]. Furthermore the asymmetrical baryogenesis and leptogensis problems have solutions with the Cordus theory [16], with the genesis remanufacturing process involving electron-antielectron pair production, with the antielectron remanufactured (with the additional of further photon discrete force structures) into the proton:

$$\mathbf{8}\boldsymbol{y} + \boldsymbol{z} => \boldsymbol{e} + \boldsymbol{p} + \mathbf{2}\underline{\boldsymbol{v}} \qquad (9)$$

with particle identities as above. This manufacturing process was derived from consideration of the discrete force structures. It simultaneously addresses baryo- and leptogenesis. Diagrammatically it is represented in Figure 13.

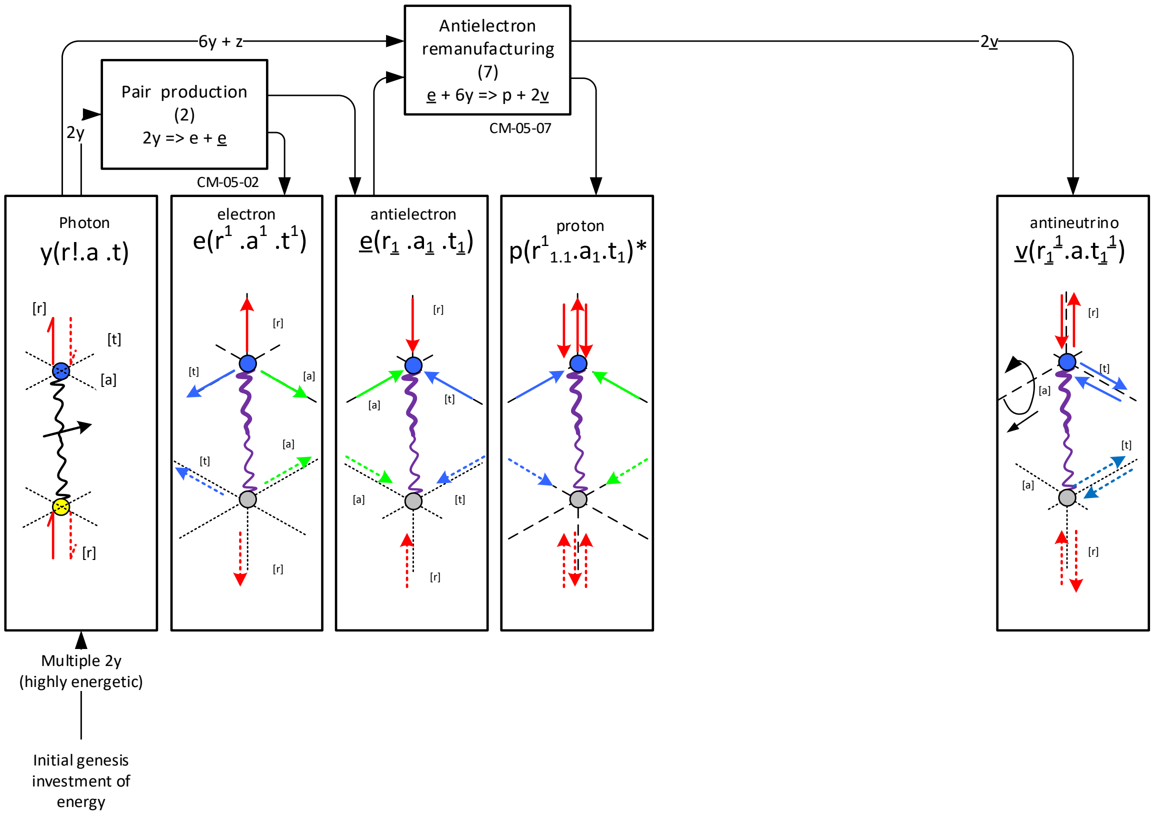

Figure 13: Asymmetrical genesis production stream. The discrete force rules predict a process whereby the antielectron from pair production is remanufactured into a proton, with two antineutrinos ejected in the waste stream. From [16].

In summary, the weak force is reconceptualised as a remanufacturing process. The W and Z bosons are denied causal identity as vectors of change, but instead proposed to be merely transitional assembly structures. This is consistent with their short lives and ranges. Consequently we propose that the weak is not a force interaction. Nonetheless it is a powerful mechanism because it gives rise to all observed matter. Furthermore, like all the other interactions, it is based on attributes of the discrete forces, though the aggregate thereof rather than individual attributes.

5 Discussion

Findings

The results offer new perspectives on old problems. The continuous vs. discrete duality of forces, as evidenced in the general relativity vs. quantum perspectives, now has an explanation. Both are correct: the emitted field is continuous but the effect is discrete. This because emitted discrete forces have a sinusoidal strength function. At the receiving particle, the mobility of the reactive end is inversely related to its energisation, so the interaction has dwell periods.

It also answers another duality question: how can a flux tube be continuous if the forces it contains are discrete [26]? The answer is that the reactive end binary states of energised vs. de-energised are an approximation of a sinusoidal strength relationship for energisation. Furthermore with emissions in three orthogonal directions, there is no point in time when the flux tube is completely de-energised, hence its continuity is preserved.

The theory provides a different way of categorising the interactions. Thus the synchronous interaction becomes the mechanism for bonding coherent assemblies of matter, whereas the electro-magneto-gravitational interactions operate on discoherent matter. These interactions are not continuous but in discrete force increments. The remanufacturing interaction is somewhat different to the others, being less a force and more a large family of processes that change the internal assembly of multiple discrete forces and thereby change particle identity, though it too is synchronous in nature.

We find against the conventional idea that unification might be found at higher energy levels. Instead energy is only a proxy variable according to this theory. The energy in an interaction between particles depends on the number of discrete force involved (hence also mass), and the type of synchronisation of emissions (discoherent or synchronous). Thus there is an approximate increase of energy involved with the progression from the electro-magneto-gravitational forces, to the synchronous, and to the remanufacturing processes with the many discrete forces involved. However we propose it is not energy per se that provides the explanation for unification.

Furthermore the theory offers an information interpretation. The emitted discrete forces communicate to other particles in the universe at large, by broadcasting the identity and attributes of the emitting particle. These attributes include position, orientation, velocity, cis/trans-phasic partnership opportunities, etc. They are a type of information broadcast that consumes no energy, yet allows other remote particles to change their behaviour.

Contrasts
QM attributes the electrostatic interaction to the virtual photon gauge boson. The Cordus theory instead proposes that the interaction occurs via discrete forces. In the Cordus theory there is an important difference between the single pair of discrete forces emitted by a photon, and the three orthogonal ones emitted by a massy particle [8]. The former continue to propagate outwards whereas the latter are extended and then withdrawn. Hence we disfavour identifying the interaction with a virtual photon like structure.

QM proposes that the strong force between quarks arises from the exchange of gluons, and the nuclear force arises from the residual force thereof. The QM concept of three colour charges has parallels with the three orthogonal charge emission directions of the Cordus theory, and the gluons with the discrete forces. However a key difference is that QM has different bosons for each interaction, whereas the Cordus theory attributes the interactions to different functional attributes of the same discrete forces throughout.

The Cordus perspective of gravitation emerges as being similar to but also different from General relativity (GR). In GR, gravitation arises from the curvature of spacetime, and is not so much a force as a geometric interaction of the moving body with that curvature. GR does not explain what makes up spacetime. By comparison the Cordus theory proposes the vacuum is filled with a tangle of discrete forces in their flux tube, which is called the *fabric* [9, 22]. Both perspectives agree that gravitation is an effect that a mass does to the whole universe, not to targeted other bodies. The relativistic Doppler and time dilation have also been derived from first principles using the Cordus theory [26], so there are areas of substantive alignment between the theories.

Both QM and the Cordus theory agree that gravitation is quantised. The Cordus theory offers a specific mechanism, via the discrete forces and their effect on the position of the reactive end. QM is unable to explain gravitation, and its closest approach is loop quantum gravity that proposes that the fabric consists of spin networks. A region of Cordus fabric contains multiple discrete forces in their flux tube, and conceptually these momentarily define small dynamic domains: perhaps these correspond to spin networks? However from the Cordus perspective the underlying mechanism is force lines and force pulses. Loops in the fabric are not precluded, but are interpreted as secondary phenomena rather than the mechanism itself.

Implications
Of the main theoretical approaches to developing a new physics to unite the interactions, quantum mechanics has been the dominant area of endeavour. While string theory is still an active area of research, it has seen less attention and been less successful in this area. The third branch, the NLHV sector, has been conceptually unproductive and become obscure. Specific solutions for the hidden structure have seemed intractable or ridiculous. Nonetheless the NLHV approach has many positive attributes, as shown here, if the question of substructure can be resolved. Demonstrating conceptually that the interactions may be unified in a NLHV theory opens up new lines of thinking.

6 Conclusions

The work makes several contributions that move the field forward. The first is providing an explanation for all the interactions based on non-local hidden-variable theory.

Under the assumptions of this theory, the interactions arise from different aspects of a single underlying mechanism, that of the discrete force emissions.

1. The electrostatic interaction results from the direct *linear* operation of the discrete forces.
2. The magnetic interaction results from the *bending* of the flux tube containing the discrete forces.
3. Gravitation results from the *handed sequence* of the discrete force emission, a type of torsional effect.
4. The strong interaction (and nuclear force) arise from the *synchronisation* of timing of discrete force emissions between reactive ends on different particles.
5. The weak (decay) interactions arise from the *rearrangement* of discrete force emissions, which results in *remanufacturing* of particle identity.

Apart from the concept of the discrete force, and its multiple attributes, no new particles or bosons are required.

Another contribution is providing a novel mechanism for how a particle detects and moves in the force gradient. This is proposed to occur via the reactive end sweeping through a volume of space during its energisation cycle. This locus is warped by the discrete forces of the incoming field, hence displacing the reactive end. The underlying mechanism for force is therefore conceptualised as coerced displacement of the reactive end.

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Conflict of interest statement

The authors declare that there are no financial conflicts of interest regarding this work.

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