Conceptual framework for a novel non-local hidden-variable theory of physics: Overview of the Cordus theory

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Abstract

PROBLEM- There are many integration problems of fundamental physics that still lack ontologically coherent solutions. **NEED-** There is a need to find a new theory of physics with wide-ranging logical consistency. The idea that particles could have internal structure has long been a consideration in the development of theories of physics, as evidenced in the EPR criticism (Einstein, Podolsky, & Rosen, 1935). **DIFFICULTY-** However Local hidden-variable solutions are excluded by the Bell-type inequalities and by the empirical evidence of entanglement. The non-local hidden-variable (NLHV) sector is not entirely excluded on theoretical grounds. However, if any solution existed it would have to be counterintuitive as all the obvious candidates have been excluded [4]. Unfortunately the hidden-variable sector has proved incapable of offering suitable solutions. **APPROACH-** Conceptual design methods were borrowed from engineering design and applied to create an initial conjectural solution for the double-slit device. This was then validated against multiple other phenomena. **RESULTS-** This paper offers a candidate solution, in the form of a new theory of physics wherein particles have internal structures. This Cordus theory proposes a specific structure for particles, for both the structure internal to the particle and the nature of the external discrete field emissions. **FINDINGS-** It also has good external construct validity, as it: explains path dilemmas in interferometers; recovers basic laws of optics from first principles (reflection, refraction, Brewster's angle); identifies the causes of contextual measurement; explains the transition from coherence to discoherence; explains pair-production and annihilation; offers a solution to the asymmetrical baryogenesis and leptogenesis problems; explains time dilation; conceptually unifies the electro-magneto-gravitational forces with the strong interaction; explains the selective spin attributes of the neutrino species; predicts the internal structure of the atomic nucleus and explains the stability, instability and non-existence of the table of nuclides from Hydrogen to Neon. **ORGINALITY-** The Cordus theory is a novel conceptual framework for fundamental physics. It shows that a specific structure of particles has excellent explanatory power for many phenomena. The strengths of the theory are: Explanatory (ontological) power; Coherent solution across multiple

phenomena; Offers candidate solutions to otherwise intractable problems. **IMPLICATIONS-** The Bell-type inequalities are falsified. Physical realism is re-asserted. The stochastic nature of the wave-function is subsumed in a deeper explanation. The theory is not inimical to quantum mechanics, which it reinterprets as a stochastic approximation of a deeper determinism. The new theory has philosophical implications because it shows that it is possible to conceive of a solution for fundamental physics that is grounded in physical realism. The theory therefore rebuts the idea that the deeper level of physics is purely mathematical, and it rejects the many-worlds interpretation.

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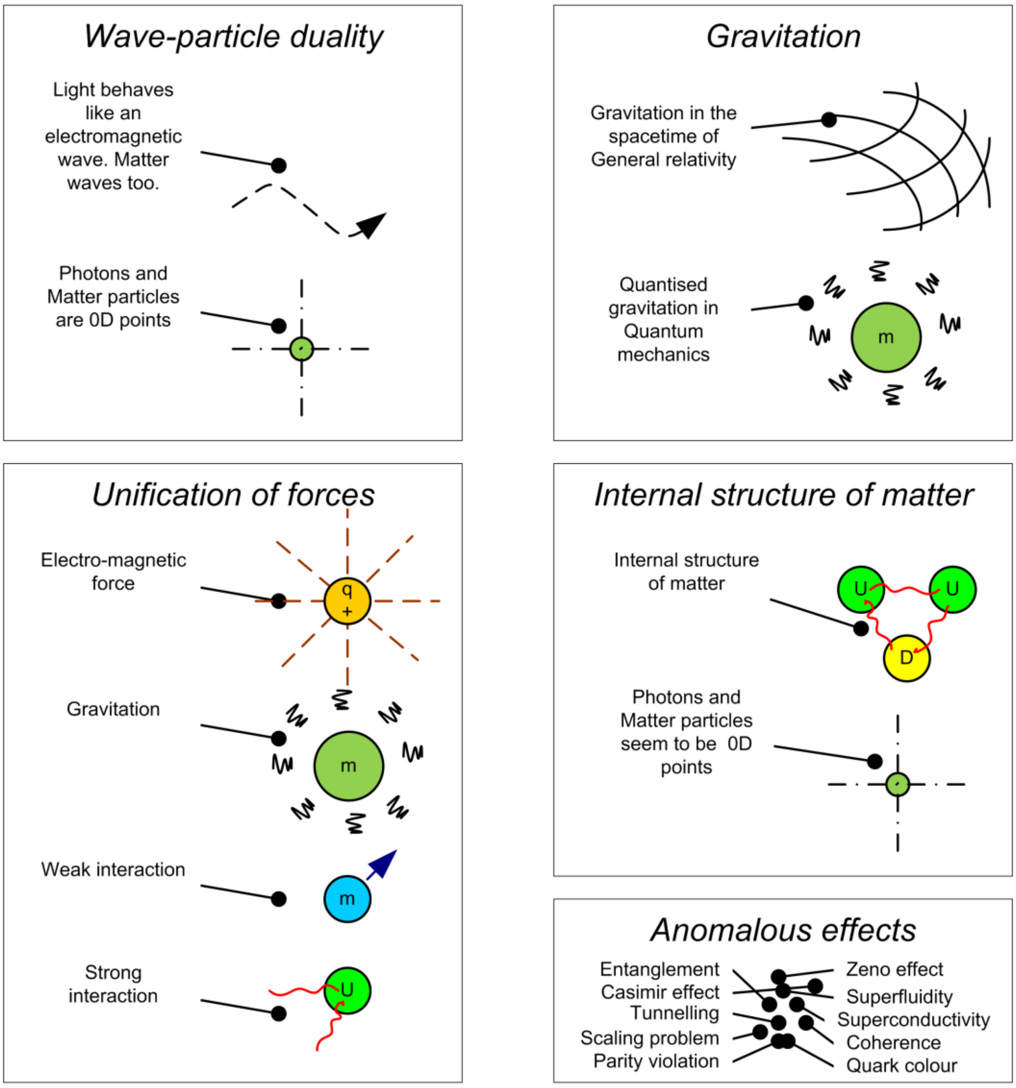
1 Introduction

There are many *integration problems* of fundamental physics that still lack coherent solutions.



UNSOLVED: Some of the integration problems in fundamental physics

This paper offers a candidate solution, in the form of a new theory of physics wherein particles have internal structures. The theory proposes a specific structure for particles, for both the structure internal to the particle and the nature of the external discrete field emissions. This new physics is called the 'Cordus' theory for the shape that it predicts for particles. A condensed overview of the theory is provided here.

The dominant existing frameworks for fundamental theoretical physics are quantum mechanics (QM) for particles, electromagnetic wave theory for light, electrostatics and magnetism, and general relativity for gravitation. While those are generally accepted as valid in their particular areas, they do not integrate well. Of these integration problems the most intractable have been: the incongruence of wave-particle compared to physical realism; unification of interactions (forces); reconciliation of quantum mechanics (QM) with general relativity (GR), and the structure of matter. For example the latter problem is how to explain the properties of the atomic nucleus from the basic principles of the strong force. Other phenomena that are ontologically challenging are superposition, wave-particle duality, entanglement, quantum tunnelling, and contextual measurement.

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2 Background literature

The nature of the proposed solution makes it a type of hidden-variable theory. Hence the following review of the literature.

2.1 A brief history of the field of hidden-variable theories

EPR criticism: That quantum mechanics cannot be complete, on logical grounds.

But then…

Bell-type inequalities exclude local hidden variable solutions as incompatible with entanglement.

And also…

Many sub-classes of *non-local* hidden variable solutions (NLHV) are also excluded.

But not all…

It is still possible that a NLHV solution exists, but it would have to be highly counterintuitive.

And anyway…

It has been hard to conceive of NLHV designs, so there is a dearth of candidates

Hence a stalemate.

The idea that particles could have internal structure has long been a consideration in the development of theories of physics, as evidenced in the EPR criticism [1]. However the concept of internal variables has been historically unproductive. Local hidden-variable solutions are excluded by the Bell-type inequalities [2, 3] and by the empirical evidence of entanglement.

Bell did not manage to extinguish all classes of hidden variable theories, but he did establish the *inequality* approach that other mathematicians would subsequently use. Subsequent contributions, e.g. [3, 4], showed that *local* hidden-variable solutions were non-viable.

The non-local hidden-variable (NLHV) sector is not entirely excluded on theoretical grounds. However, if any solution existed it would have to be counterintuitive as all the obvious candidates have been excluded [4]. Unfortunately the hidden-variable sector has proved incapable of offering suitable solutions. This is evident in the dearth of candidate solutions, other than the de Broglie-Bohm proposal [5, 6] which has not progressed. Consequently this line of work became stalemated, since none of the inequalities totally precluded all *non-local* hidden-variable solutions, but neither were there specific candidate NLHV solutions to evaluate, and it was not obvious how such a theory could be constructed in the small residual space permitted by the inequalities. Regarding internal structures, the String/M theories have attempted to solve this problem, and have shown mathematically that in principle a solution should be achievable providing particles are permitted to have multiple hidden dimensions. The number of dimensions varies with the theories. However these theories are mathematical abstractions that have not yet been fruitful. They have been unable to identify a specific solution from the infinity of possibilities. Nor is it clear what those other dimensions correspond to. There are other more exotic conjectural theories for the structure of matter. These include vortices and whirlpool structures in space-time, torsion fields, field structures, helical or ring geometric structures, coupled pairs of 0-D particles, pure energy and standing waves, corpuscles (assemblies of hypothesised smaller 0-D particles) [7]. In application these range from narrow solutions for specific problems, to expansive but vague theories of everything. It is difficult to identify the merit in these ideas because they are invariably tentative, and infrequently published in journal papers. Consequently none of the alternatives to QM have provided any better solution.

2.2 Gaps in the field

Methodological issues

The inequality approach is mathematically elegant but has weaknesses. Many of the inequalities have delivered trivial outcomes. They concluded that hidden variable theories cannot have local parts, e.g. [2-4, 8]. However this is not a useful conclusion, since it is self-evident that any theory based on *locality* is not going to be able to explain entanglement, since the latter is inherently non-local. To use a mathematical formalism to come to this point is to over-work the problem.

The inequality approach has a problem of bias, because it takes the starting position that quantum theory is correct, and then seeks confirmation thereof. Almost all applications of the method have this problem including recent applications [9]. They have a null hypothesis that QM is correct, which weakens their construct validity. Exceptions exist [10, 11].

Third, and related to the other objections, the inequality approach only tests between plain-QM and QM-with-hidden-variables. The inequalities only show that 0-D point particles are incapable of having internal structure. However this is an obvious conclusion as a zero-dimensional point cannot, by definition, have internal structures. Consequently those inequalities are circular in their reasoning. They have no way of testing against the possibility that a non-QM formulation of a hidden-variable theory might exist. Consequently when the method finds against hidden-variables, that only applies to a 0-D point QM formulation of hidden variables.

In the specific case of the C&R argument [9], the proof was based on three key assumptions, each of which place severe and unreasonable limitations on the outcomes. Those assumptions were: (1) that particles are zero-dimensional (0-D) points, this being an intrinsic premise of quantum theory, (2) that locality prevails ('the outcome, *X*, of a measurement is usually observed at a certain point in spacetime'), and (3) that quantum mechanics is correct ('We additionally assume that the present quantum theory is correct'). We argue each of these is wrong, or is at least not a proven universal truth.

Throughout quantum theory, particles are held to be zero-dimensional points, without internal structure of any kind. Yet paradoxically, quantum mechanics also assigns attributes of spin, charge, mass, etc. to these same points. These zero-dimensional properties, or *intrinsic variables*, must then somehow aggregate and scale up to the macroscopic world, via mechanisms that are imperfectly understood, to give the illusion of physical realism at that level. However quantum theory is quite unable to describe how the causal mechanisms operate from the fundamental to the macroscopic level.

2.3 Does it really matter?

That it has been possible to achieve so much with QM generally, without directly solving the wave-particle duality, might seem evidence that the duality is irrelevant. If the qualitative descriptions of QM are poor, or seem weird, does that really matter?

However it is also possible that the inability of current physics to provide physically realistic explanations points to a conceptual deficit in QM.

Many scientists are inclined to accept QM and disbelieve physical realism. For example, it has been claimed that it is ‘impossible’ that there could exist a hidden-variable theory that explains the indeterminism whereby ‘measurements generate random outcomes’ [9]. From that perspective the next deeper layer of fundamental physics is non-physical.It has been claimed that no extension of quantum theory can exist with better predictive power than quantum mechanics itself [9]. Those authors interpreted their results as a vindication for the supremacy of quantum mechanics, and the non-viability of hidden-variable solutions. However the proof merely showed that no extension of quantum theory is possible, which can also be interpreted to mean that QM is irredeemably unsuitable as a theory.

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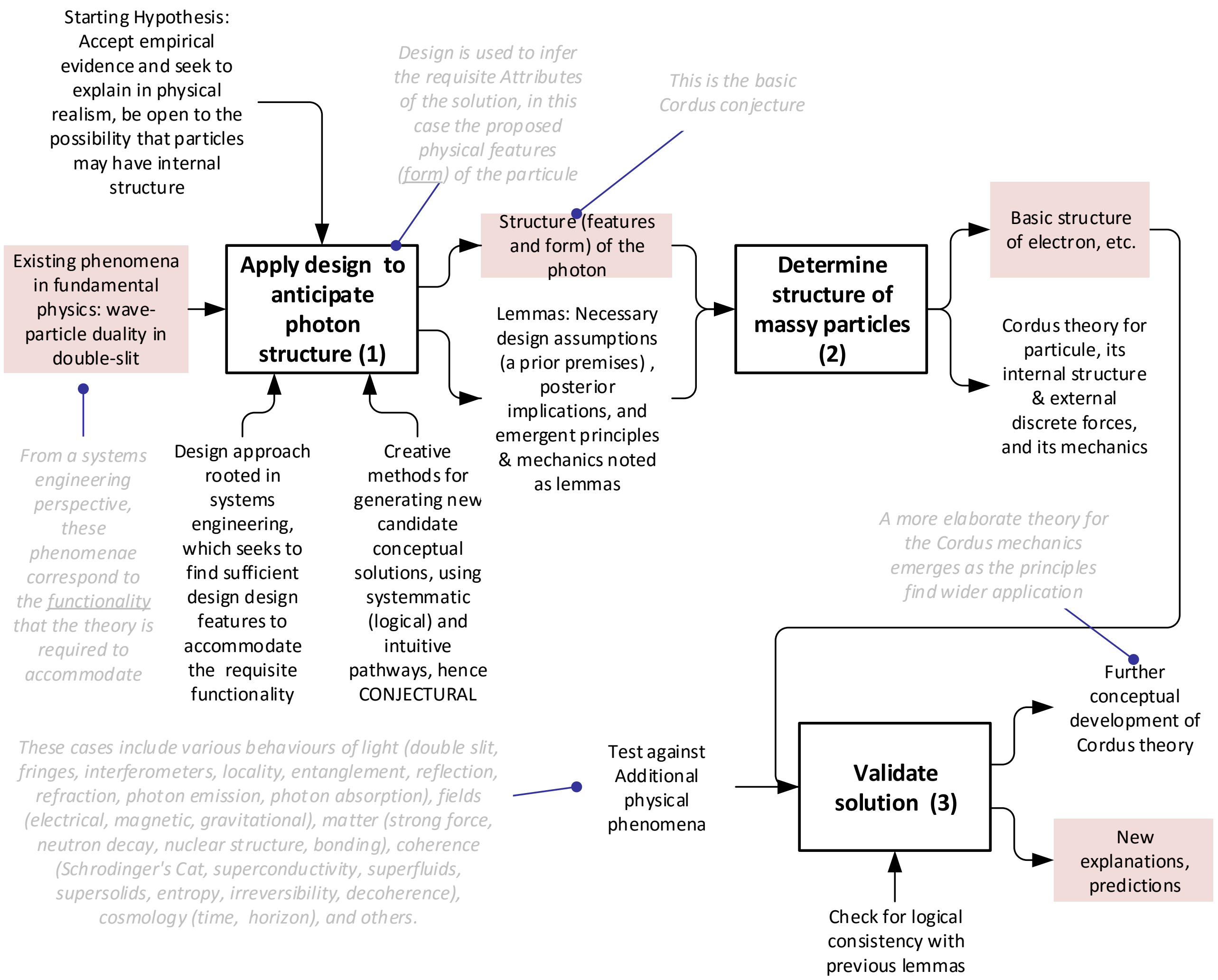
3 Method

3.1 Purpose

The purpose of this work was to attempt to reconceptualise an alternative theory of fundamental physics based on physical reality.

3.2 Approach



APPROACH: A three phased approach was applied, using conceptual design methods borrowed from engineering design.

A staged approach was taken. The first part of this was to find a photon structure that was sufficient to explain wave-particle duality in terms of physical reality. For this a systems engineering design method was used. This involved (a) accepting the empirical evidence for wave-particle duality, (b) extracting the minimal *functional requirements* of a photon in such a system, (c) designing a particle structure to meet those requirements. This is termed the Cordus *conjecture.*

The second stage was to infer the structure of massy particles. For this logical inference was used to determine what the conjecture implied for the structures of the electron, neutron, etc. Any new assumptions were explicitly noted as lemmas. These lemmas were required to be consistent with earlier parts of the theory, or alternatively to trigger a reevaluation of earlier work. In this way a systematic qualitative description of the theory is available in the lemmas. Also, the consistency across the lemmas gives the theory coherence.

The third stage was to apply the theory to a variety of other empirical observations for which it had not specifically been designed a-priori. This was done to test the theory against spurious causality. Falsifiable predictions were identified. This process *validated* the theory by showing that it had the strength to provide explanations for other phenomena. Hence it has good external validity. However these actions cannot verify or *prove* that the theory is correct, so it is instead considered a *candidate* theory for a new physics.

3.3 Resulting papers

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Pons, D. J., Pons, A. D., & Pons, A. J. (2013). Explanation of the Table of Nuclides: Qualitative nuclear mechanics from a NLHV design. *Applied Physics Research* 5(6), 145-174. DOI: http://dx.doi.org/10.5539/apr.v5n6p145

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http://www.scirp.org/Journal/PaperInformation.aspx?paperID=51921

Pons, D. J., Pons, A. D., & Pons, A. J. (2014). Beta decays and the inner structures of the neutrino in a NLHV design. *Applied Physics Research, 6*(3), 50-63. DOI: http://dx.doi.org/10.5539/apr.v6n3p50

Pons, D. J., Pons, A. D., & Pons, A. J. (2014). Differentiation of Matter and Antimatter by Hand: Internal and External Structures of the Electron and Antielectron. *Physics Essays, 27*, 26-35.

Pons, D. J., Pons, A. D., & Pons, A. J. (2015). Asymmetrical neutrino induced decay of nucleons *Applied Physics Research, 7*(2), 1-13. DOI: http://dx.doi.org/10.5539/apr.v7n2p1 or http://vixra.org/abs/1412.0279

Pons, D. J., Pons, A. D., & Pons, A. J. (2015). Hidden variable theory supports variability in decay rates of nuclides *Applied Physics Research* 7(3), 18-29. DOI: http://dx.doi.org/10.5539/apr.v7n3p18

Pons, D. J., Pons, A. D., & Pons, A. J. (2015). Nuclear polymer explains the stability, instability, and non-existence of nuclides. *Physics Research International 2015*(Article ID 651361), 1-19. DOI: http://dx.doi.org/10.1155/2015/651361

Pons, D. J., Pons, A. D., & Pons, A. J. (2015). Pair Production Explained in a Hidden Variable Theory *Journal of Nuclear and Particle Physics, 5*(3), 58-69. DOI: http://dx.doi.org/10.5923/j.jnpp.20150503.03

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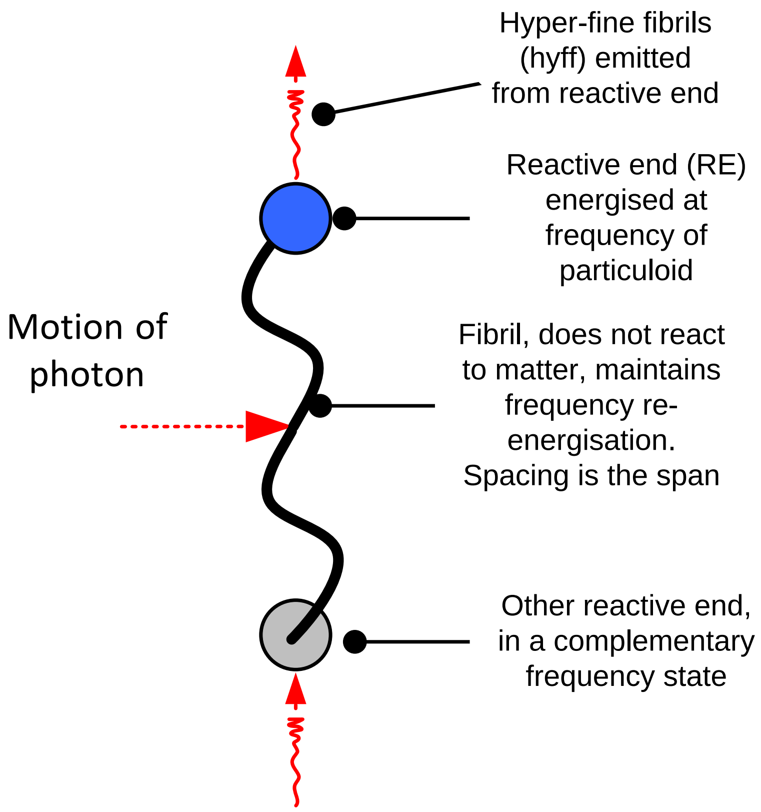
4 Results

4.1 The starting Cordus conjecture for the photon structures

The Cordus theory predicts a specific internal structure for fundamental particles. Specifically, it is proposed that particles are not 0-D points but instead comprise *two reactive ends* that are energised in turn, connected by a fibril, and which emit discrete forces at each cycle of energisation [12].



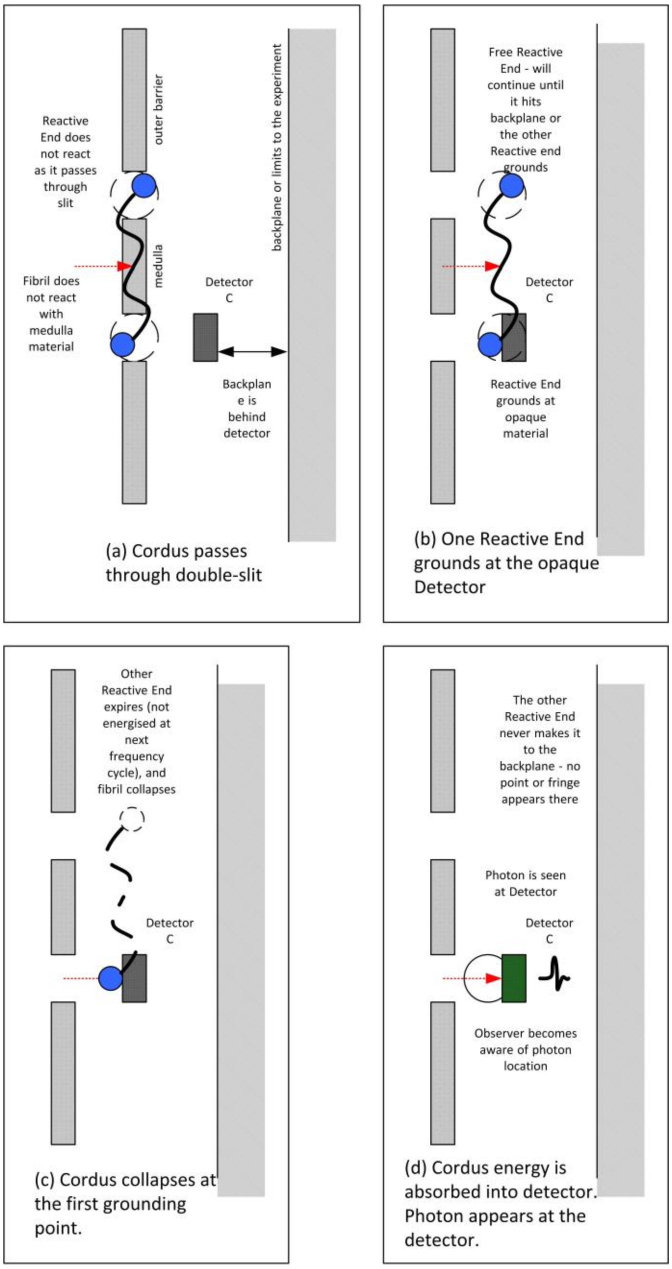
PHOTON: The initial Cordus conjecture for the photon structures.

Pons, D. J., Pons, A. D., Pons, A. M., and Pons, A. J., *Wave-particle duality: A conceptual solution from the cordus conjecture.* Physics Essays, 2012. **25**(1): p. 132-140. DOI: http://physicsessays.org/doi/abs/10.4006/0836-1398-25.1.132
Original publication: Vixra: http://vixra.org/abs/1106.0027

Originality: This design is able to explain all three phenomena in the double slit: the blocked-slit behaviour of an individual photon, the fringes formed by multiple photons taken singly, and the fringes produced by of a beam of light. It also describes photon path dilemmas in interferometers [13].

4.2 Double-slit device

This theory proposes that the single photon, made up of two reactive end, passes through both slits: one reactive end through each slit. The reactive ends therefore take different loci. Once through the slits, the whole photon collapses to, and therefore appears, at the first place where a reactive end is arrested. This explanation suffices for single photons and beams of light.



Photon behaviour in the double-slit experiment with only one detector

GROUNDED: Photon behaviour in the double-slit experiment

This describes the observed phenomenon that blocking one slit, (or placing a detector only at one slit) causes the whole photon to appear there. The span of the photon is plastic and hence the effect is only approximately dependent on the spacing of the slits.

Wave behaviour and fringes

This basic idea can also explain how the fringes arise in single gaps and double-slits. Each of the two reactive ends also interacts, through the discrete fields, with the opaque material bounding the slits. The discrete fields become engaged with the surface plane of the material and exert a quantised force that retards the reactive ends and bends its trajectory by set angular amounts, causing fringes at set intervals.

The double-slit device best shows the fringe behaviour because the short-span photons are barred entry by the medulla. Thus the device imposes an upper and lower filter on the range of spans admitted. Hence narrower slits produce more pronounced fringes.

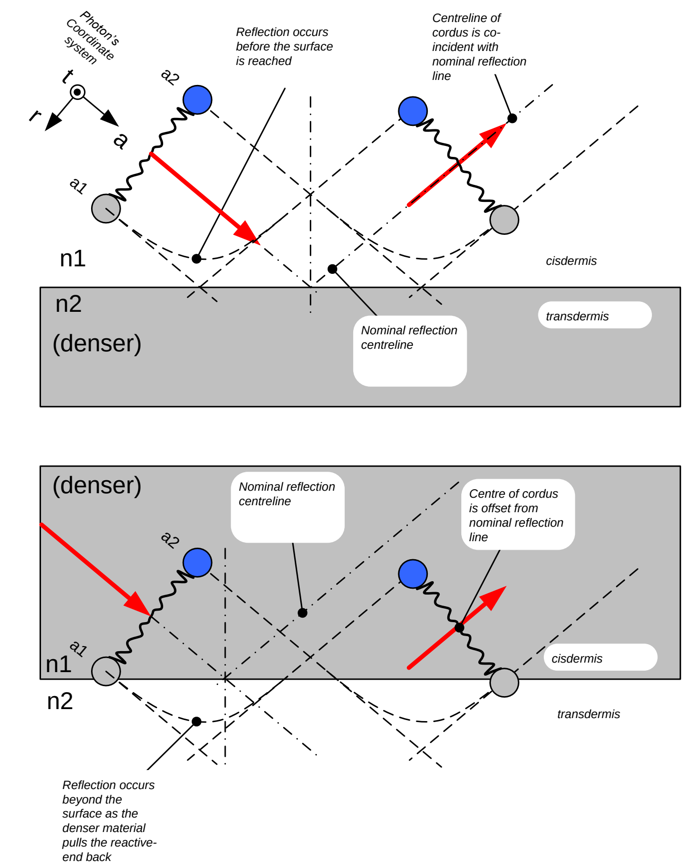
The two locations of the fringe are the modes of the reactive ends, and it is somewhat random as to which will ground first. Note that this explanation accommodates the fringe behaviour of both single photons and beams of coherent light. Thus a solitary photon will be deflected into discrete angular steps, and will appear at one of the fringe locations. A whole beam of coherent light will likewise form fringes because all the photons have the same discrete angular deflection, providing that they are of the same energy. In the Cordus theory massy particules with higher energy (i.e. also higher frequency) have shorter spans. However photon spans are flexible.

This also explains why both photons and electrons form fringes: in both cases the fringes arise because of the interaction of the electric field, which is in discrete pulses, with the frontal surface plane of the matter bounding the slit.

4.3 Reflection

Explaining basic optical effects is not possible with classical particle mechanics, and even with quantum mechanics it is not straight forward. Optical effects such as reflection and refraction are conventionally best described by electromagnetic wave theory, at least when they involve beams of light.

The Cordus explanation is that both reactive-ends of the particule separately reflect off the surface as their discrete fields interact elastically (lossless) with the substrate.



(a) Reflection off a denser material (n2>n1)

(b) Internal reflection off a less dense material (n2<n1)

REFLECTED WITH CHANGES: Reflection occurs as a curved transition some distance off the surface (a), not an abrupt change at the precise surface. In the case of internal reflection (b), the transition may occur in the second medium and result in the centre of the particule being offset from the nominal.

The precise locus taken by a reactive end depends on its frequency state at the time it approaches the surface, and the nature of the surface. Thus the reflection is proposed to be not a sharp instant change in direction occurring at the surface, but rather a curved transition. Depending on the situation, that curve might occur above the surface (cisdermis) or beneath it (transdermis).

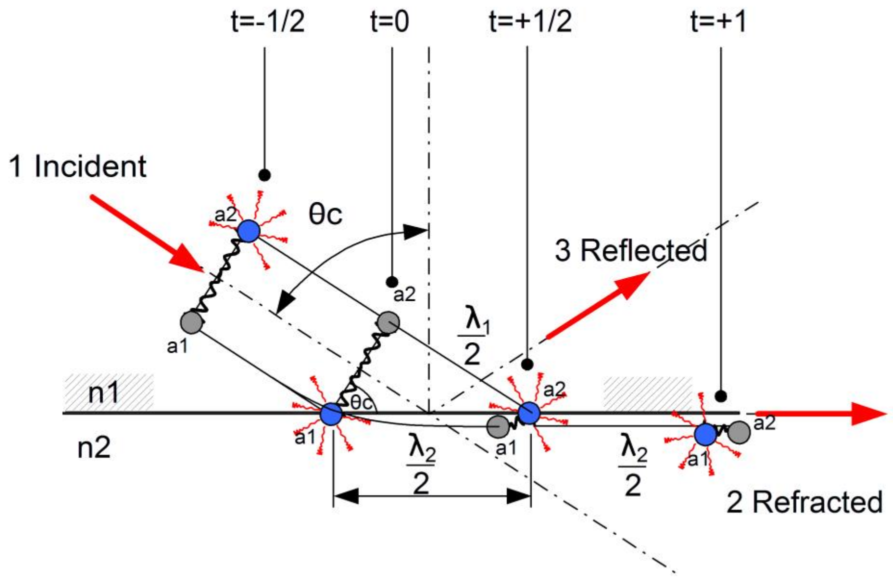
Consequently the centreline of the reflected particule may be laterally offset from the nominal: the photon is displaced sideways from where it should be by simple optics. This effect is known for p-polarised light at total internal reflection as the Goos–Hänchen effect. The Cordus explanation is that the actual reflection occurs in the transdermis in this situation, and Figure provides a graphical explanation of how the offset arises. Phase changes at reflection are also explainable [14]. Optical effects can be described from the Cordus theory. Importantly, this explanation is applicable for single photons and beams of light.

Wave theory takes the perspective that a beam of light is not so much a stream of photons, as a continuously existing electromagnetic wave, comprising an electric field and a magnetic field. From the perspective of wave theory, reflection is caused by the mirror surface absorbing and re-emitting its own EM waves. Depending on the perspective taken, these interfere with each other or with the incident wave to produce the reflected wave. The mathematics of wave theory accurately quantifies the phenomenon, though its qualitative explanations are not intuitive. Nor does that theory explain why single photons should also show such behaviour.

4.4 Critical angle

Critical angle for internal reflection is also explainable [14].

Internal reflection is when light passes from a region of high refractive index n_1 to lower n_2, e.g. glass to air. The critical angle is where total internal reflection occurs, i.e. no transmission, and is known to be: $Sin(\theta_c) = n_2/n_1 = \lambda_1/\lambda_2$ where λ are the wavelengths.

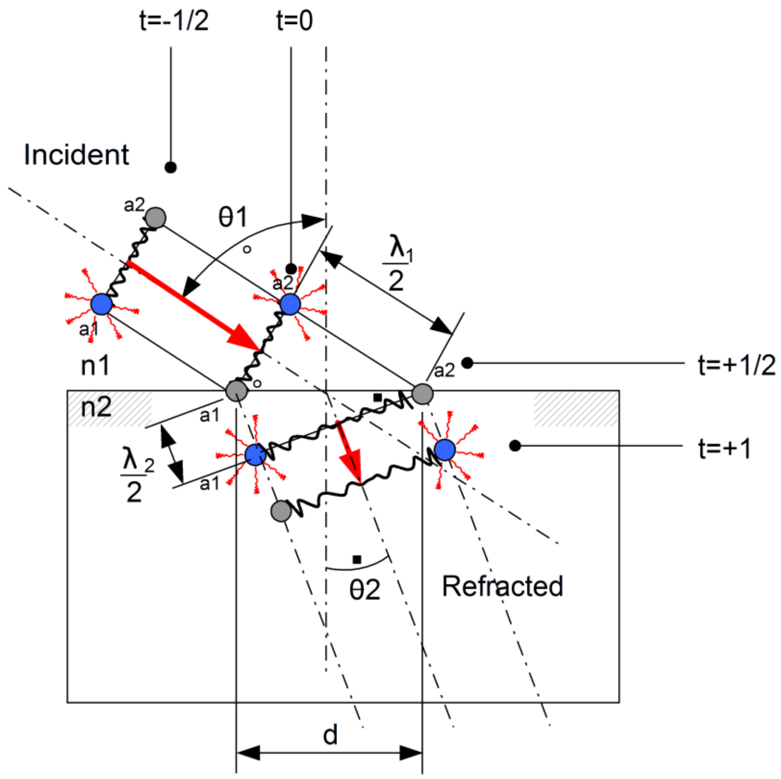


CRITICAL ANGLE: Geometry of the photon at the critical angle θ_c for total internal reflection.

The Cordus explanation is that at the critical angle θ_c the reactive end a1 is inserted into in the faster material n_2 at t=0, and therefore moves forward a distance $\lambda_2/2$. This motion is parallel to the surface because this is the angle of refraction. By comparison at the same time reactive end a2 continues to travel distance λ_1 in the slower medium, before it later also enters the faster medium, at t=1/2 of a frequency cycle. RE a1 is thus accelerated by the sudden freedom of being in the faster medium. The angle θ_c is steep enough to push the RE out of the slower medium, but only steep enough to place it at the boundary. A moment later the second RE is likewise positioned at the boundary. The important points are: Over the period from t=0 to t=1/2 cycles, a1 moves $\lambda_2/2$ whereas a2 moves $\lambda_1/2$, because they are in different media. The angle θ_c is such that there is only a half-cycle of frequency involved. The angle at which the above two conditions is met is apparent from inspection of the geometry in the figure, $Sin(\theta_c) = \lambda_1/\lambda_2$, and this is the same as the critical angle derived from optics. For more details see reference [15].

4.5 Refraction

The bending of light as it enters an inclined boundary is usually explained in optical wave theory as a change in the speed [phase velocity], such that the wavelength changes but not the frequency.



REFRACTION: Refraction involves a dormant reactive-end penetrating into the second medium, and being angularly deflected with reduction in speed.

The Cordus explanation for refraction [16] is that the inclined incoming photon strikes the surface and one reactive-end and then the next penetrates into the second medium n_2. Assuming the case where n_2 is more dense, e.g. from air to glass, then the photon slows down.

Internal reflection is when light passes from a region of high refractive index n_1 to lower n_2, e.g. glass to air. The critical angle is where total internal reflection occurs, i.e. no transmission, and is known to be: $\text{Sin}(\theta_c) = n_2/n_1 = \lambda_1/\lambda_2$ where λ are the wavelengths. The angle of refraction θ_2 in the second medium (2) is given by Snell's law: $\sin\theta_2 = v_2/v_1 .\sin\theta_1 = n_1/n_2.\sin\theta_1 = \lambda_2/\lambda_1.\sin\theta_1$ where the angles are measured from the normal to the surface, and v are the velocities in the two media. Explanations vary for *how* the change in speed occurs. The wave interpretation is that the delay occurs because the electric field interacts with the electrons to radiate a delayed wave, thereby forming the new but slower wave. Hence the Huygens–Fresnel principle that each point on the wave propagates new waves and these interfere.

4.6 Cordus derivation of Snell's Law

The separation of the reactive ends along the interface is given by $d = \lambda_2/(2.\sin\theta_2) = \lambda_1/(2.\sin\theta_1)$, which simplifies to Snell's law. The frequency and other forms arise by noting that v_1=f. λ_1 and v_2=f. λ_2 and n = c/v where c is velocity of light in vacuum.

Birefringence is also explained by the Cordus theory, and Brewster's relationship derived. The Cordus mechanics for optical phenomena are the same for single photons and beams of light, which is an advantage compared to wave theory. The same mechanics are logically consistent with those for the double-slit device. Therefore the theory can describe particle behaviour, fringes, and optical effects, using a single coherent mechanics. The explanation does not need the conventional concept of 'interference'. In fact the Cordus theory refutes interference as a physical mechanism. Instead the theory proposes that interference is only a mathematical model of the en-masse behaviour of the discrete fields from multiple particules.

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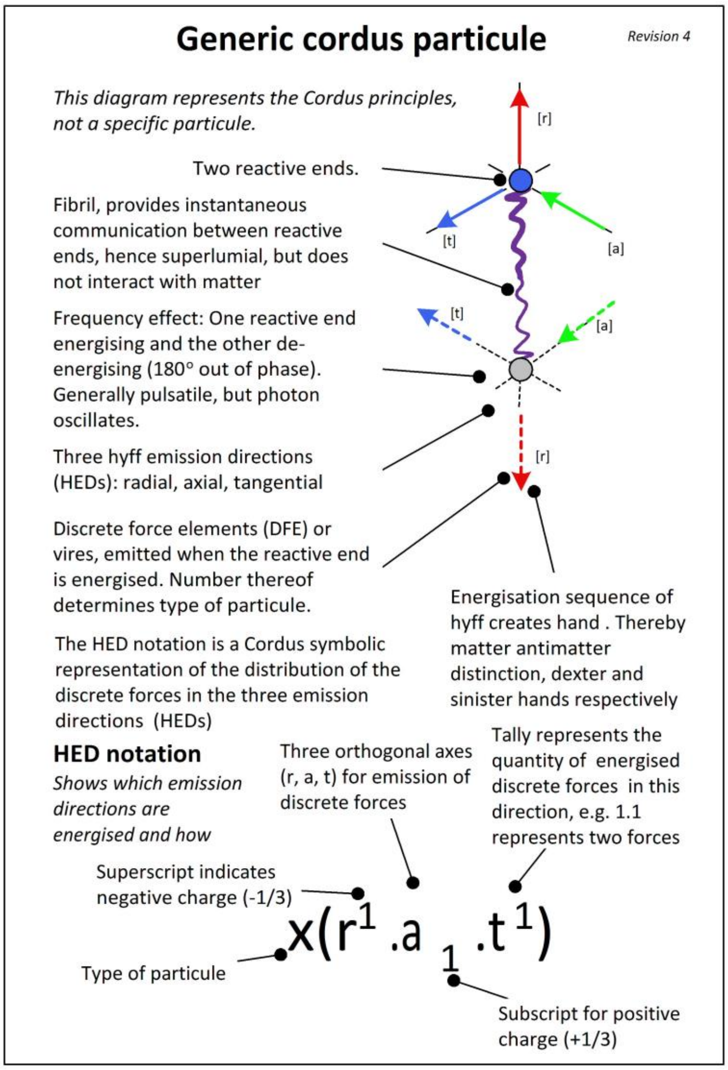
5 Generalisation to the Cordus theory for particules

The basic conjecture has been expanded to cover particles in general, including those with mass. This is called a *particule*, and it has inner and external structures.



GENERALISATION: The Cordus theory proposes that particules have an internal structure and emit a signature of discrete external forces. This diagram shows the generic principles.

5.1 Inner and outer structures

Inner structure of the Cordus particule

The basic idea is that every particule has two reactive ends, which are a small finite distance apart (span) [17]. A fibril joins the reactive ends and is a persistent and dynamic structure but does not interact with matter. It provides instantaneous connectivity and synchronicity between the two reactive ends.

Each reactive end of the particule is energised in turn at the frequency of that particule (which is dependent on its energy). The reactive ends are energised together for the photon, and in turn for matter particules. The frequency corresponds to the de Broglie frequency. The span of massy particules shorten as the frequency increases, i.e. greater internal energy is associated with faster re-energisation sequence, hence also faster emission of discrete forces and thus greater mass.

External structure: Cordus discrete field structures

When the reactive end is energised it emits discrete forces in up to three orthogonal directions. These discrete forces travel down flux lines. The quantity and direction of these are characteristic of the type of particule (photon, electron, proton, etc.), and the differences in these signatures is what differentiates the particules from each other.

Although for convenience we use the term discrete *force* for these pulses, the Cordus theory requires them to have specific attributes that are better described as *latent discrete prescribed displacements*. This is because a second particule that subsequently receives one is prescribed to energise its reactive end in a location that is slightly displaced from where it would otherwise position itself. Thus in the Cordus theory, that which we perceive as force is fundamentally the effect of many discrete prescribed displacements acting on the particules.

These discrete forces are connected in a flux line that is emitted into the external environment. (In the Cordus theory this is called a hyperfine-fibril, or hyff). Each reactive end of the particule emits three such orthogonal flux lines, at least in the near-field. The exception is the photon, which only emits radially. These directions are relative to the orientation of the span, and the velocity of the particule, and termed hyperfine-fibril emission directions (HEDs).

The axes are named [r] radial outwards co-linear with the span, [a] and [t] perpendicular to the span and to each other. These are so-named for consistency with previous nomenclature for the photon [12], but when applied to massy particules do not necessarily imply motion. It is proposed that the quarks and other leptons follow the same pattern, though in the case of the quarks not all the emission directions [r,a,t] are filled (hence their fractional charge).

5.2 Contrast against 0-D points

Locality

The Cordus theory is a non-local solution. The particule is affected by more than the fields at its nominal centre point. Locality fails, because the particule is affected by what happens at *both* reactive ends, and by the externally-originating discrete forces it receives at both locations. However locality only fails at the scale at which the span is apparent, and hence locality is applicable at the macroscopic level for practical purposes.

Locality: that the behaviour of an object is only affected by its immediate surroundings, not by distant objects or events elsewhere.

Local realism: that the properties of an object pre-exist before the object is observed.

Physical realism: that physical observable phenomena do have deeper causal mechanics involving parameters that exist objectively. It is refers a belief about causality.

Wider Locality

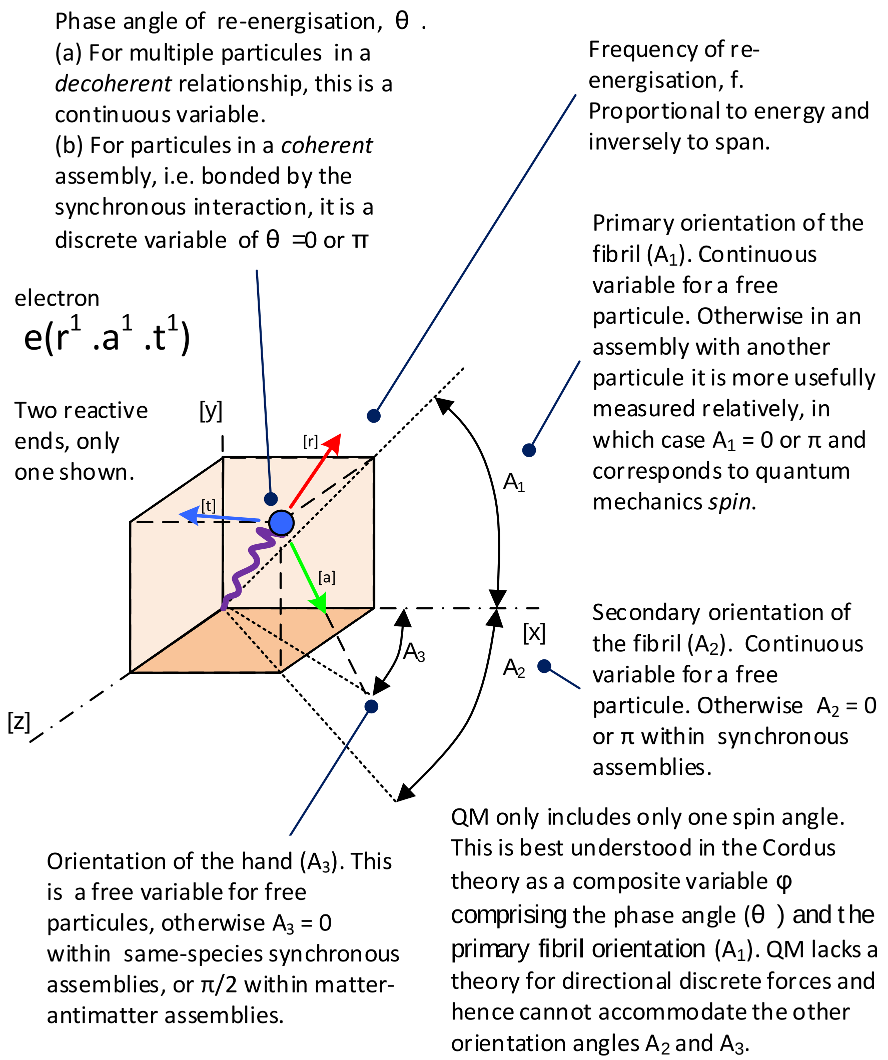
The Cordus theory provides a Principle of Wider locality: a particule is affected by the cumulative effect of the fields in its local surroundings, these being the space to which its discrete fields have access. Further, that the discrete fields have access to spaces that the physical particule with its reactive ends does not.

Spin

The alignment of this structure gives a natural explanation for spin and polarisation.

Cordus orientation variables

Free electron relative to an arbitrary frame of reference [x, y, z]



CM-01-03-02	**Spin definitions for a Cordus particule**

PARAMETERS: Particle properties such as spin, phase, and polarisation have physical representations in the Cordus theory.

Superposition

The non-local behaviour, hence superposition, is evident in the particule existing in two places at once, namely at its reactive ends.

Entanglement

Entanglement is explained as two photons (four reactive ends) being assembled such that the pair of reactive ends of the one is matched with those of the other. This occurs via the synchronous emission of discrete forces at each reactive end. The fibrils of the photons keep all four reactive ends synchronised.

Hence sending one matched pair of reactive ends (from two photons) to a remote location merely extends the fibril.

Subsequent changes to any of the reactive ends are transmitted to all the others. This occurs via the fibrils, which are superluminal in that they coordinate their two reactive ends within half a frequency cycle if not immediately.

The theory provides that the fibrils of photons are able to be stretched to any length, and explains this in terms of the nature of the discrete force emission pattern for photons [18]. However massy particles like electrons cannot be stretched in the same way, for reasons which the theory explains. Their span is required to be inversely proportional to their energy hence to frequency. This is consistent with the empirical evidence that photon entanglement can be accomplished over macroscopic distances, but electron entanglement is difficult to achieve and has only been demonstrated at small scales, e.g. in quantum dots and molecular arrangements [19-22].

Parity violation

The reason parity is not conserved by weak interactions is explained by the Cordus theory as a geometric consequence of the particule having both a span and a hand. The arrangement of the discrete forces is conserved across the span (the hand is the same at both ends), but the span is a finite length of separation. Therefore a mirror image of a Cordus particule is not identical to itself about every mirror plane. If fundamental particles were points, which is the QM position, then they would look identical for any mirror operation.

The Cordus theory not only explains why parity violation occurs, but also explains why it only occurs at small scales. This is because at a coarse enough level of view, the span becomes negligible and the Cordus particule can be considered a zero-dimensional point for practical purposes.

Force

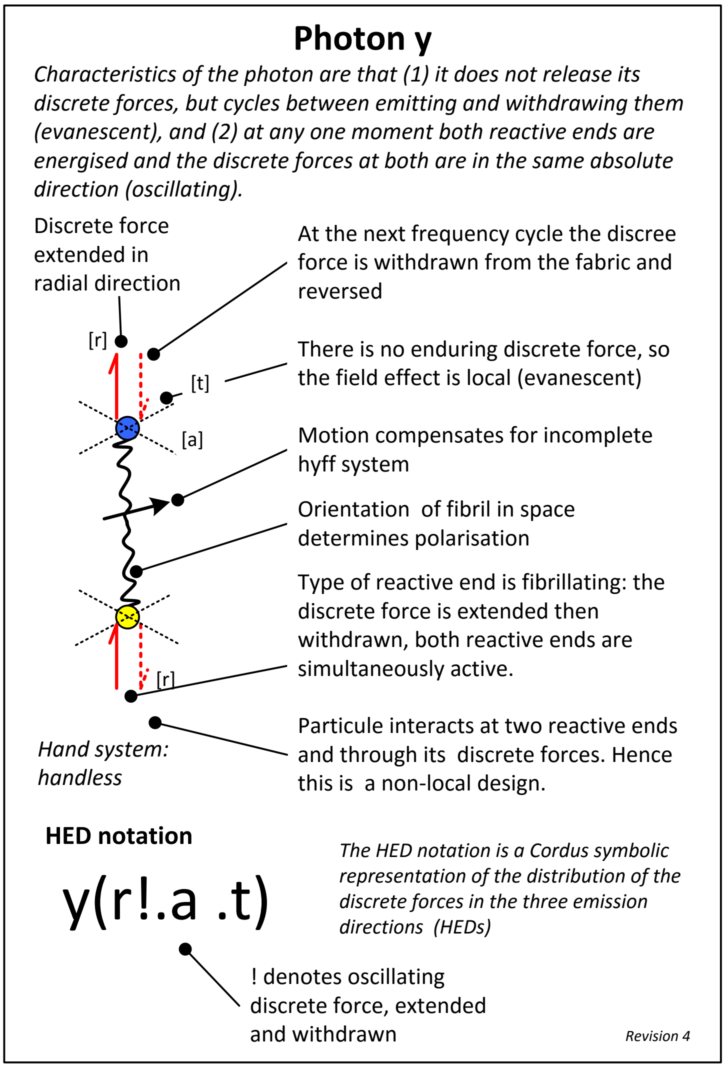
Although for convenience we use the term discrete *force* for these pulses, the Cordus theory requires them to have specific attributes that are better described as *latent discrete prescribed displacements*. This is because a second particule that subsequently receives one is prescribed to energise its reactive end in a location that is slightly displaced from where it would otherwise position itself. Thus in the Cordus theory, that which we perceive as force is fundamentally the effect of many discrete prescribed displacements acting on the particules.

5.3 Cordus particle structures

The quantity and direction of the emitted discrete forces are characteristic of the type of particule (photon, electron, proton, etc.), and the differences in these signatures is what differentiates the particules from each other.

The HED notation is a shorthand symbolic representation of the HED arrangements for this particule, and includes the three axes and the number and direction of discrete forces in each (superscripts are negative charge, subscripts positive charge). For antimatter the axes and field system takes the other hand.

Photon



PHOTON: Cordus theory for the internal structure of the photon, and its discrete field arrangements. The photon has a pump that shuttles energy outwards into the fabric. Then at the next frequency cycle it draws the energy out of that field, instantaneously transmits it across the fibril, and expels it at the opposite reactive end. From [23] with permission.

Recovery of the evanescent and electrostatic fields

Note the specific differences in the behaviour of the discrete forces between the photon and electron, as this is important in what follows. The photon emits and withdraws its discrete force in an oscillating manner. Consequently the field of the photon recruits a volume of space, which is consistent with the observation that the evanescent field scales exponentially as e^{-r}. The electron, in contrast, is proposed here to continue to emit new discrete forces outwards. Therefore its field dilutes over the area of a sphere. This too is consistent with the observation that the electro-magneto-gravitational (EMG) fields scales as r^{-2}. This is to do with the nature of the reactive ends: the photon does not release its discrete forces, hence the y(r!a.t) representation, whereas the electron with its pulsatile reactive ends does. So the Cordus theory recovers both the evanescent field of the photon and the electrostatic field of the electron.

Electron

Electron e

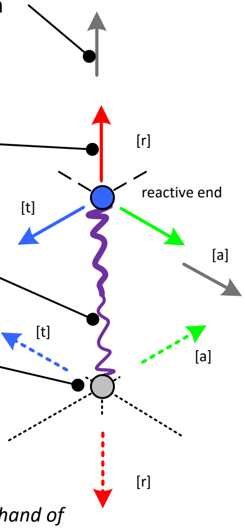
Characterised by one discrete force in each of the three directions. Therefore this a highly stable structure.

The discrete forces are released rather than retained as in the photon. Consequently there is an enduring succession of discrete forces in each of the three directions, which creates a long-ranged force effect.

New discrete forces continue to be created and sent down the flux tube (hyff) at each frequency cycle

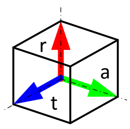
Inner Fibril provides instantaneous communication between reactive ends

Type of reactive end: pulsatile. One reactive end energising and the other de-energising (180^{o} out of phase)



The HED notation represents the distribution of the discrete forces in the three emission directions (HEDs)

Dexter hand of energisation sequence for matter: [r]→[a]→[t]



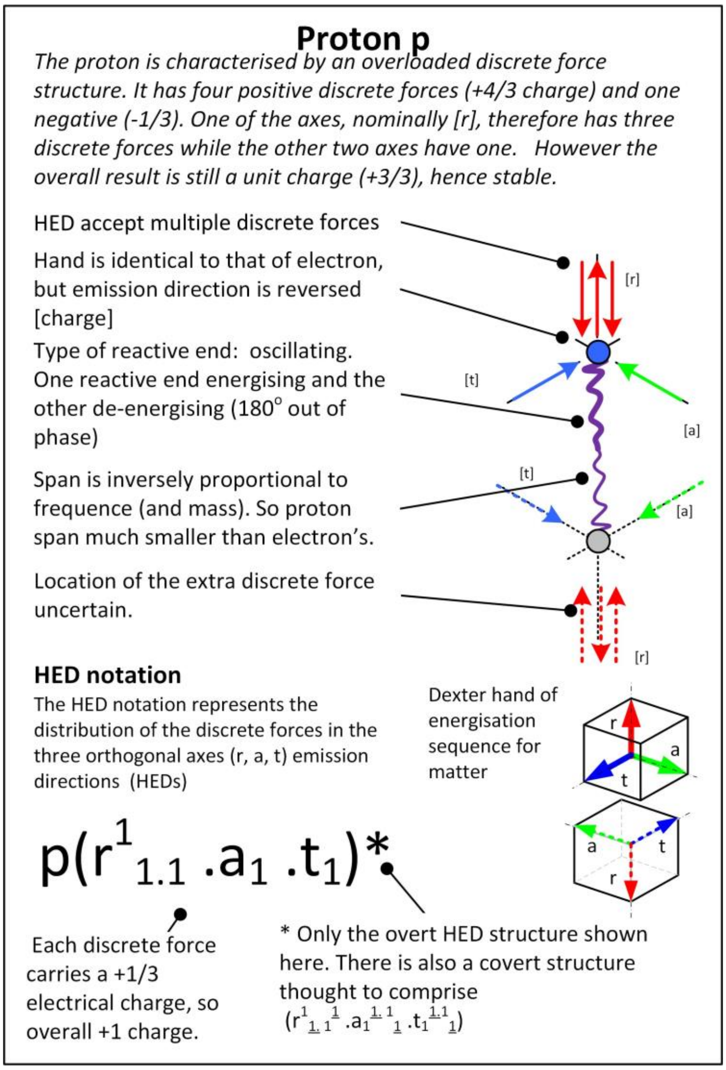
HED notation
Three orthogonal axes (r, a, t) for emission of discrete forces

$$e(r^1 .a^1 .t^1)$$

Each discrete force carries a 1/3 electrical charge, with the super/ subscript representing the direction, so electron has overall -1 charge.

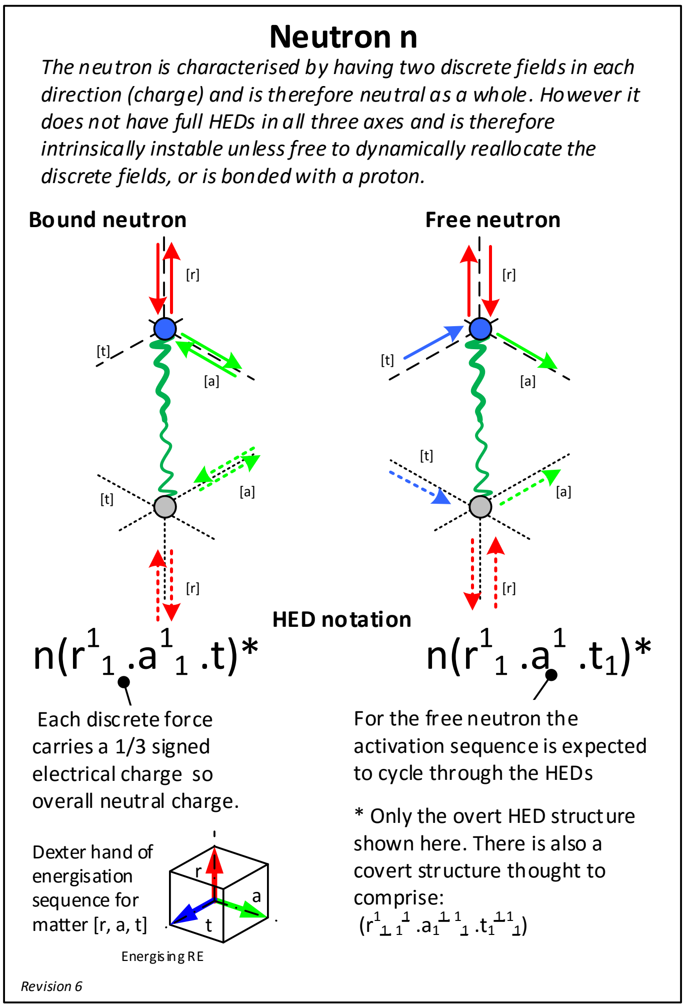
Revision 4

Proton



Cordus model of the proton. The distinguishing feature of this particule is the overloaded discrete forces. The higher mass of the particule, compared to say the electron, is proposed to arise from the higher frequency of re-energisation for this particule, in turn driven by internal fibril dynamics not apparent here. Compared to the antielectron (positron) note the direction of propagation of discrete forces is inwards in both cases (hence both have positive charge), but the hand or activation sequence is different.

Neutron



Proposed internal and external (discrete force) structures of the neutron. From [24].

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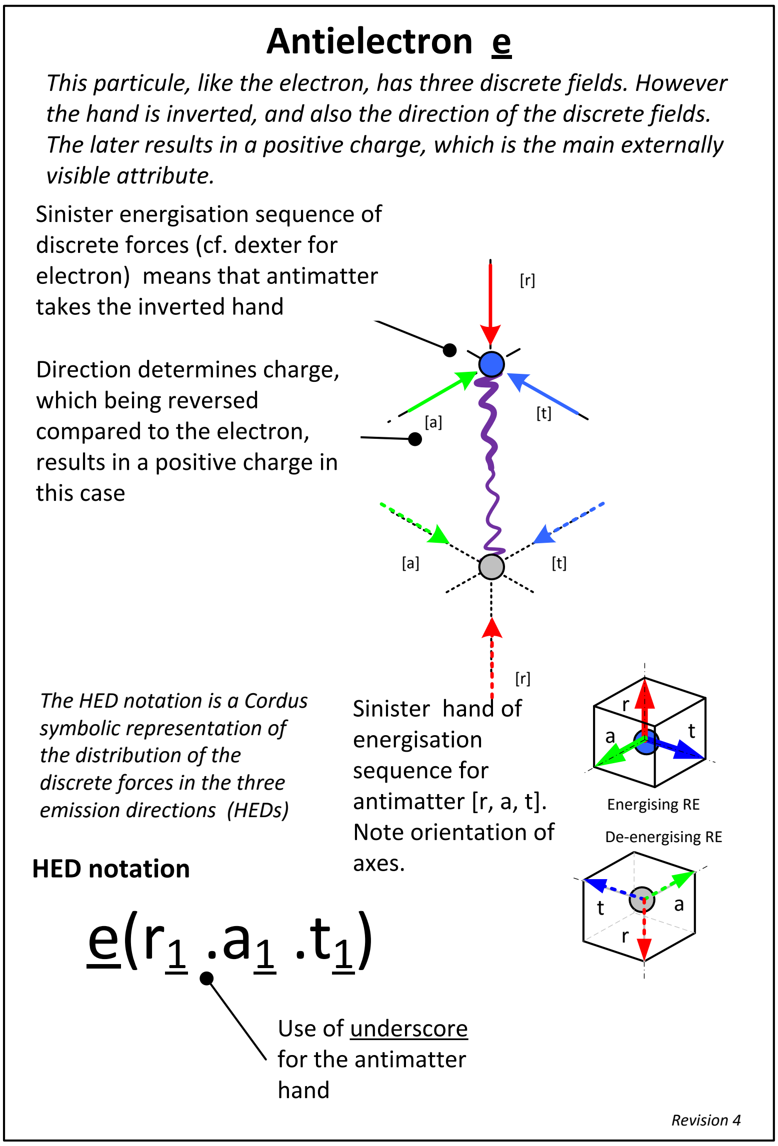
6 Matter-antimatter species differentiation

The Cordus theory provides a coherent model for handedness. Thus we propose that the fundamental difference between matter and antimatter is the hand of their discrete fields. Hand then corresponds to the energisation sequence of three orthogonal discrete field elements. There are only two unique ways this can be done, which we term dexter and sinister for matter and antimatter respectively.

6.1 Antielectron structure



ANTIELECTRON: Cordus theory for the antielectron. The difference, compared to the electron, is the inversion of the hand of the axes, and that of the direction of discrete forces (hence also charge).From [25].

The simplest conventional theory is that matter and antimatter are differentiated solely by charge: e^- and e^+. This view, while ingrained in the general notational system, is known to be inadequate due to the inability to explain the antiparticles of neutral particles (most obviously the neutron). The quantum mechanics (QM) perspective is that antimatter is opposite charge *and* opposite quantum numbers. However there is no universal set of quantum numbers, and the quantity of these variables is situationally specific. Furthermore, the main quantum numbers for fermions are charge and spin, but these are common throughout any one generation, e.g. e, μ, τ. Parity, a spatial inversion (mirroring) of physical properties, is another way to differentiate the species, (hence 'mirror matter', as Robert Forward termed it). However it is impossible for QM, with its premise of particles being zero-dimensional points, to provide a physically meaningful interpretation of parity, or the related concepts of chirality, helicity, and spin. These are only mathematical abstractions, like the other intrinsic variables of QM. Thus there is no clear explanation from conventional physics as to what parity corresponds to in a particle, and how it contributes to annihilation.

This creates a handedness (parity/chirality) for matter, e.g. the right-hand rule of the Lorentz magnetic force. Further, it is proposed that this handedness is set at the point in time when the particule is created and cannot be subsequently changed while that specific assembly remains.

It is important to note that this Cordus concept for handedness is different to the quantum mechanics concepts of 'hand' and 'chirality'. Handedness in QM refers to the direction of spin of the particle relative to its linear motion [26]. When the spin is in the same direction as the momentum, then it is termed right-handed. The particles of QM may have either right or left spin-hand, and this spin-hand inverts for antiparticles. The concept of chirality is known in QM, but in a different theoretical formulation, e.g. chiral perturbation theory in quantum chromodynamics. Here we reconceptualise it, and therefore use different terms to distinguish the Cordus concept.

The Cordus theory therefore conceptualises the inversion of hand in terms of the functional geometry of the particule structure. Thus it provides a physically natural interpretation for antimatter.

6.2 Comparison of electron, antielectron, and proton

Comparison of the electron, proton and antielectron Cordus structures shows that all these particules have different external structures, either in the hand, direction of discrete forces, or number of discrete forces.

The only thing that is common between the antielectron and proton is that they both show positive-charge behaviour. The Cordus theory explains why the electron and proton do not annihilate despite their opposite charges: the hands are the same.

One of the paradoxes of conventional theories of antimatter is that it is not immediately clear what the difference is between the proton and the positron. After all, they both have charge +1. Why then does the electron not annihilate with the proton, but does with the positron? Why do the proton and positron have such difference masses, given that their charge is the same? With the Cordus concept of hand, an explanation is possible.

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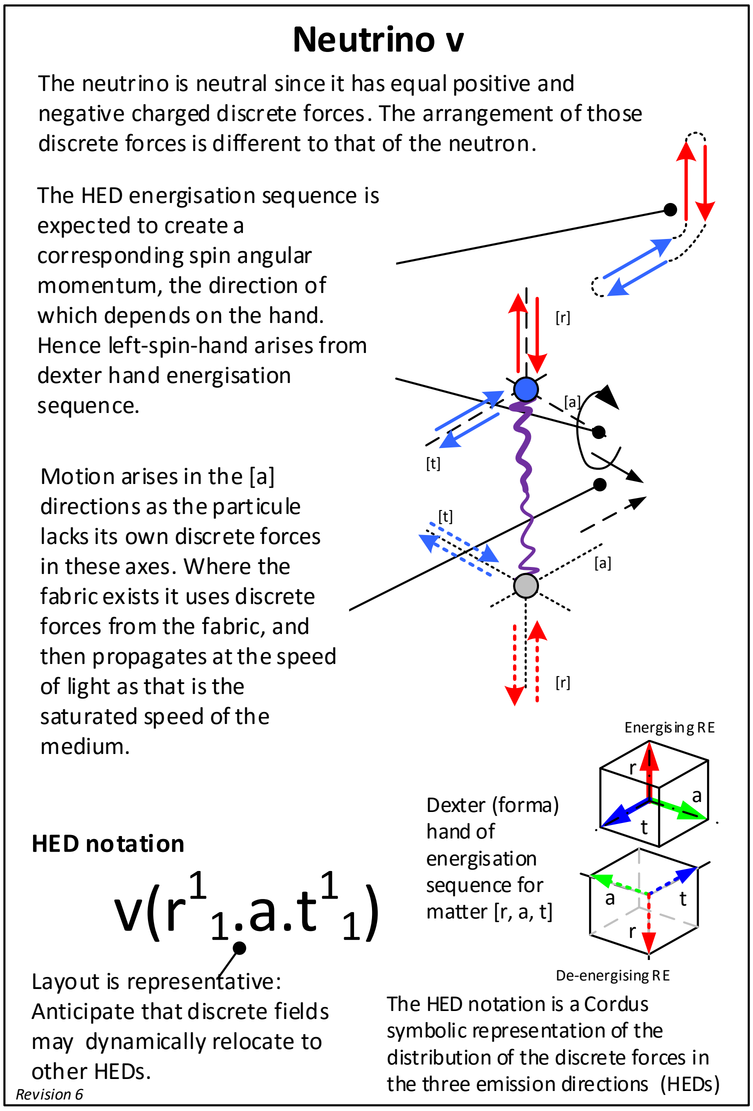
7 Neutrino species and decay

7.1 Neutrino



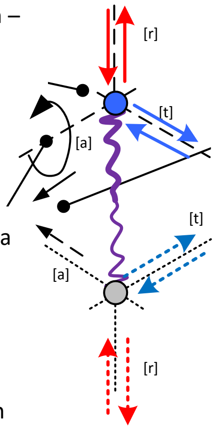
NEUTRINO.

7.2 Antineutrino

Antineutrino $\underline{v}$

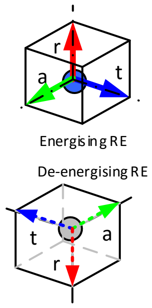
The antineutrino has the same discrete force count as the neutrino, but the opposite hand of energisation sequence. The unique spin directions of the neutrino and antineutrino arise due to the hand differences.

The timing of the HED energisation – which is sinister-hand – creates a spin angular momentum.



Motion arises in the [a] directions as the particule lacks its own discrete forces in these axes. Where the fabric exists it uses discrete forces from the fabric, and then propagates at the speed of light as that is the saturated speed of the medium.

Incomplete HED activation creates a reaction torque against the fabric, hence a spin, the direction of which depends on the hand (energisation sequence), hence $\underline{v}$ always has right-spin hand.



Sinister hand of energisation sequence for antimatter [r, a, t]

HED notation

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

It is anticipated that discrete forces may dynamically relocate to other HEDs, perhaps in a cyclic manner.

Revision 6

ANTINEUTRINO

7.3 Attributes of the species

This design conceptually explains several known attributes of the neutrino-species [24]:

Moves at the speed of light

The mobility of the neutrino species arises from lack of complete coverage of all three emission directions, and the resulting necessity to move relative to the discrete forces of the surrounding fabric [27]. The particle is propelled through the fabric by its imbalanced interaction with the fabric.

Exclusive spin

The same imbalance in discrete field emission creates a spin angular momentum. Hence this explains why the neutrino always spins in one direction, and the antineutrino in the other (because they have opposite hands of emissions).

7.4 Decay

The decay processes are predicted to be asymmetrically sensitive to the neutrino species.

- It is predicted that a species asymmetry exists, whereby β- neutron decay is sensitive to the input loading of neutrinos, but not antineutrinos.

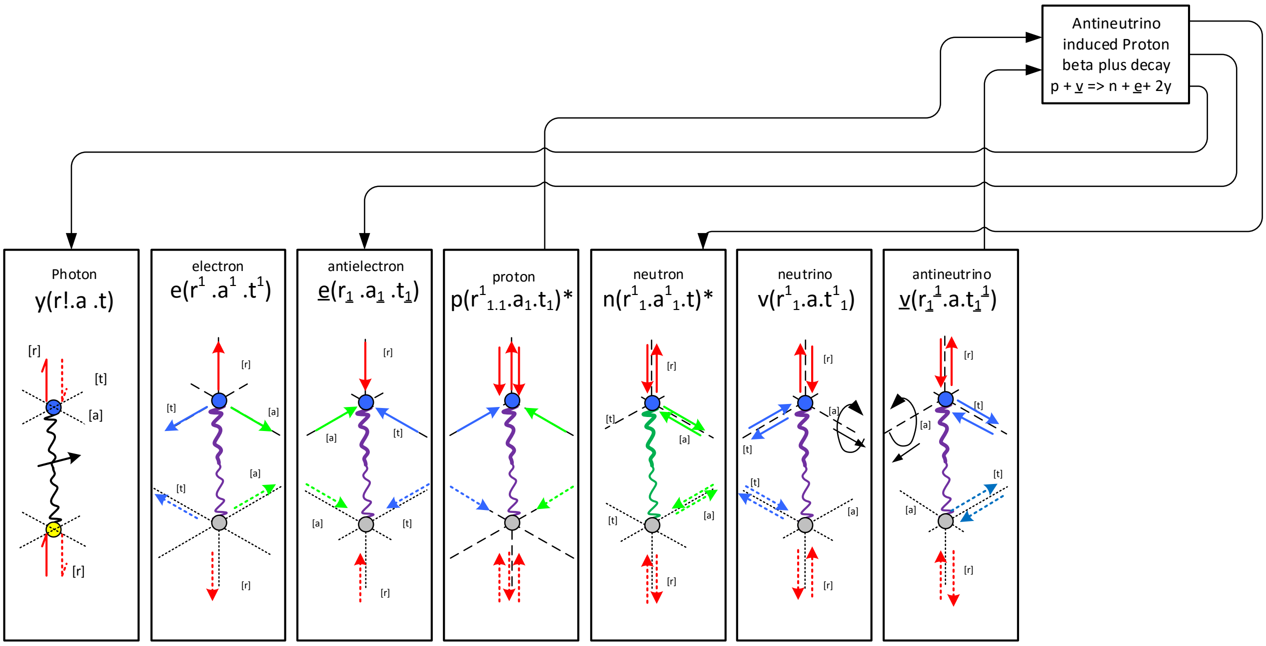
- It is predicted that a species asymmetry exists, whereby β+ proton decay may be induced by input of energetic antineutrinos, but not neutrinos.

- The inverse electron capture is predicted to be induced by pre-supply of either a neutrino or antineutrino, with different energy threshold requirements in each situation. The Neutrino induced channel is predicted to have the greater energy barrier than the antineutrino channels.

Neutrino-less double beta decays

Neutrino-less double beta decays (0νββ) are predicted by some theories and are an area of active experimental search [28] [29], usually in the context of exploring whether the neutrino is its own antiparticle (Majorana particle). The HED mechanics suggests that pre-supply of an antineutrino to the electron capture process (Eqn 11b, 12) is a potential area to explore for neutrino-less outcomes. Nonetheless the Cordus HED mechanics does not support the interpretation of the neutrino itself being a Majorana particle, and instead proposes specific structures for the two species [24].

Decay processes



PROCESS FLOW: Proposed NLHV structures of the inputs and outputs to the antineutrino-induced β+ decay.

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8 Remanufacture of particle identities

Particles are found to be defined by their field emissions, with rearrangement of those fields changing the particle's identity.

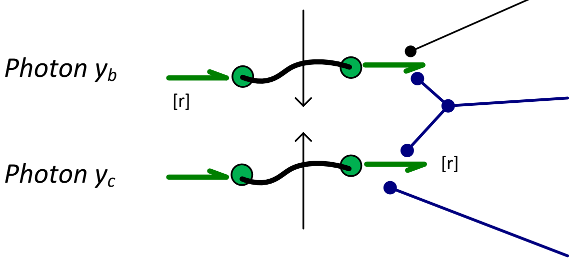
8.1 Pair production

The process mechanics are extracted from the theory, and successfully applied to explain remanufacture of the evanescent discrete fields of the photon into the electric fields of the electron and antielectron. The mechanics also explains recoil dependency on photon polarisation. A Physical representation of the process is possible.

MATTER CREATION: Production processes for converting two photons into an electron and antielectron.

(1) Photons come close

CM-05-02-01



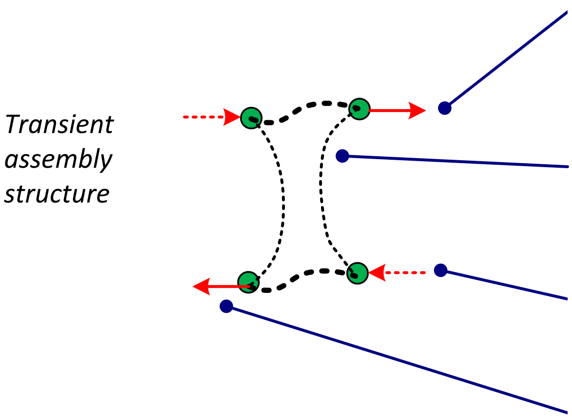
1.1 Photons y(r↕.a .t) incident on each other, same frequency, and in same phase (could be considered opposite phase since they are moving in opposite directions)

1.2 When photons are sufficiently close, distress arises because their HEDs compete for rights to emit into the fabric in the situation.

1.3 Complementary sharing of the HED is not possible, not with an oscillating reactive end where both ends are simultaneously active. Usually particules in this situation would repel each other, but the velocity or proximity prevents it.

(2) Reactive ends respond to constraints

CM-05-02-02



2.1 The constraints are too great. Therefore the renegotiation of HEDs has to go deeper, so the reactive ends are changed to the pulsatile type (one side active then the other).

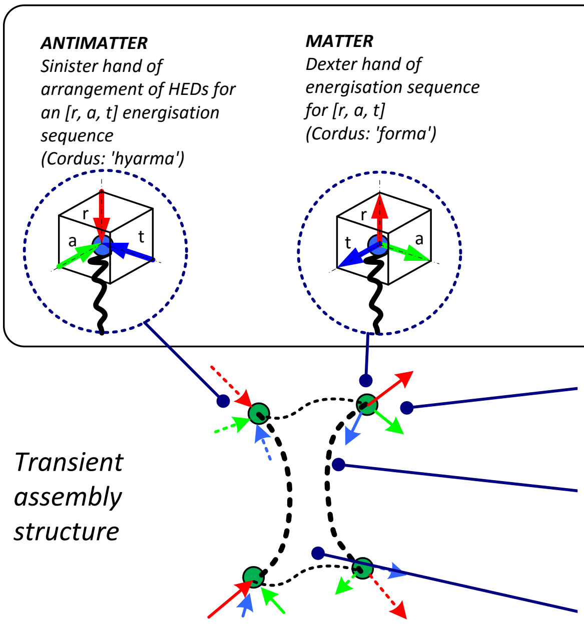
2.2 The results of the negotiation are to coordinate emissions between the four reactive ends. This creates [mechanism uncertain] a short-circuit protofibril between them, which instantly communicates and co-ordinates the discrete forces

2.3 One discrete force has to become dormant, and the other active, to satisfy the constraints.

2.4 Similar structures emerge on the other side, with complementary directions of discrete forces. Complementary regarding both charge (direction of discrete force) and frequency state (active vs. dormant)

(3) Reactive ends develop 3D HED structures

CM-05-02-03



Cordus Matter-Antimatter species differentiation

CM-05-01

The difference is proposed to be in the hand, more specifically in the energisation sequence of the discrete forces across three orthogonal emission directions [r, a, t].

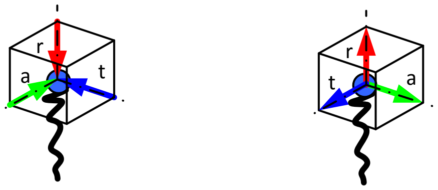
3.1 Change to pulsatile reactive end requires creation of 3D [r,a,t] HED structure (shown emerging)

3.2 Protofibril becomes stronger as the 3D structure emerges

3.3 Original photon fibril becomes correspondingly weaker

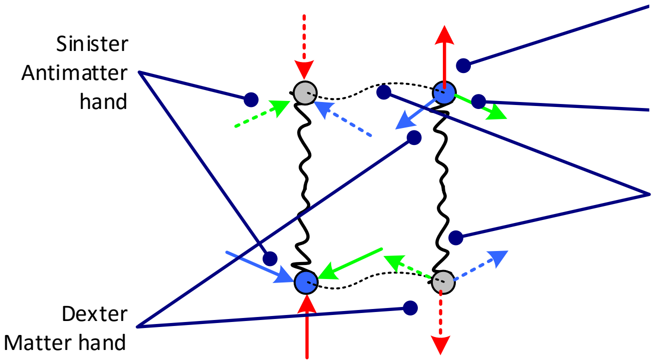
ANTIMATTER
Sinister hand of arrangement of HEDs for an [r, a, t] energisation sequence (Cordus: 'hyarma')

MATTER
Dexter hand of energisation sequence for [r, a, t] (Cordus: 'forma')



(4) New particule identities emerge

CM-05-02-04



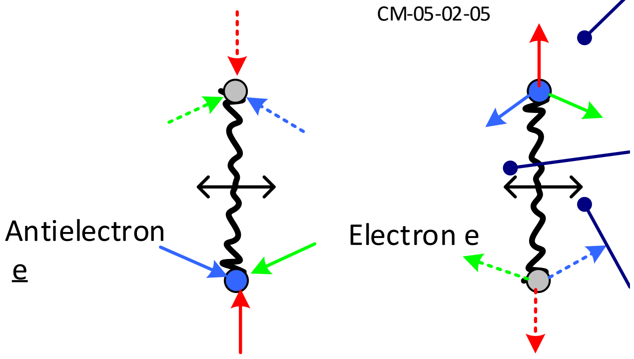
4.1 Hyff emission directions (HEDs) are formed in a hand, i.e. an energisation sequence. There are only two such sequences, hence matter and antimatter species.

4.2 Outward discrete forces take the dexter hand, not sinister, for reasons given in the text.

4.3 New fibrils becomes stronger, old ones weaken and finally disappear

(5) Antielectron and electron emerge

CM-05-02-05



5.1 HED form determines structure, in this case $(r^1a^1t^1)$ is an electron

5.2 A HED structure of $(r_1a_1t_1)$ is an antielectron

5.3 These particules could bond to form parapositronium and then annihilate, unless parted.

5.4 The length of the span may vary dynamically with frequency cycle, even if shown here as a static length. We assume that this or another effect causes an elastic recoil and separation of the two particules.

Simplified representation of pair production

Here we show a simpler and more efficient means of representing the process of pair production, using HED mechanics and its notation [24]. This is a mathematical formalism for the discrete fields in the Cordus theory.

$2y = y_b(r^{\updownarrow} .a .t) + y_c(r^{\updownarrow} .a .t)$

$=> O(r^1_{\underline{1}} .a^1_{\underline{1}} .t^1_{\underline{1}})$

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

$=> e + \underline{e}$

This is because previous work [24] identifies that two photons corresponds to a discrete force structure represented by $(r^1_{\underline{1}} .a^1_{\underline{1}} .t^1_{\underline{1}})$, hence the O transitional assembly above (E1.2). This assembly is driven by the synchronous interaction [30] to partition into more stable HED structures (E1.3). These structures, by inspection, are the electron and antielectron. Thus it is relatively simple to use HED notation to represent the overall remanufacturing process of pair production. The HED mechanics are for this NLHV design what Feynman diagrams are to QM, and the representations are not incompatible, though they have different levels of detail.

Polarisation dependency

The theory proposed here recovers the dependency of opposite polarisation, and can explain why it is more pronounced at higher energies. The higher the energy the shorter the energisation cycles (higher frequency) and the more important it is for the photons to be pre-supplied in a state amenable to pair-production, hence opposite polarisation.

Direction of recoil

The theory explains the direction of recoil. Others have shown that the orientation of recoil depends on the polarisation of the incoming photons, and does *not* depend on the photon energy [31]. Such results are difficult to interpret using QM, for which polarisation is merely an intrinsic variable without physical embodiment. However the Cordus theory readily allows an appreciation of the issues, since the span of the particule is an important orientation variable.

The Cordus theory interprets both photon polarisation and electron spin as orientation of the main fibril of the respective particule. It is therefore natural to expect that the relative orientation of the photon and the target electron will determine the outcomes.

Furthermore, the Cordus theory for photon emission predicts that the photon is emitted in a direction orthogonal to the electron span [32].

Thus, it is understandable that the orientation of the photon, hence polarisation, will affect the recoil of the host electron. The Cordus theory therefore accommodates and conceptually explains why the recoil should be dependent on and transverse to the incoming photons [33]. This is consistent with the observation that 'the azimuthal distribution of the recoil electron is highly sensitive to the polarization of the incoming gamma radiation' [31], and also consistent with the theoretical indications of polarisation-dependency [34]. Similar highly anisotropic recoil behaviour is also empirically evident in collisions occurring within an aligned molecular framework [33]. The dependency is so strong that it may be used in the inverse direction, as a measurement of photon polarisation [35]. Our comment in this regard is that the mathematical models predict the effect, and it is empirically observed. Yet an interpretation is difficult to make from within the 0-D point paradigm, whereas this is much easier from the NLHV solution provided by the Cordus theory. Likewise known other minor effects, like heavier atoms being more prone to pair production, can also be more easily explained when particles are acknowledged to have physical size, as here [36].

Recovery of electron holes

The theory provides an explanation for electron holes. The Not-Real matter is peculiar but not fundamentally problematic. Instead it is interpreted as *holes* in a sea of coherent electrons (for !e) or antielectrons (!e). If one electron is missing in a network of electrons, e.g. in a superconductor or local region of coherent electrons, then the fields inside that hole correspond to the fields of the neighbouring electrons, but reversed in direction. The *hand* of those fields is therefore unchanged.

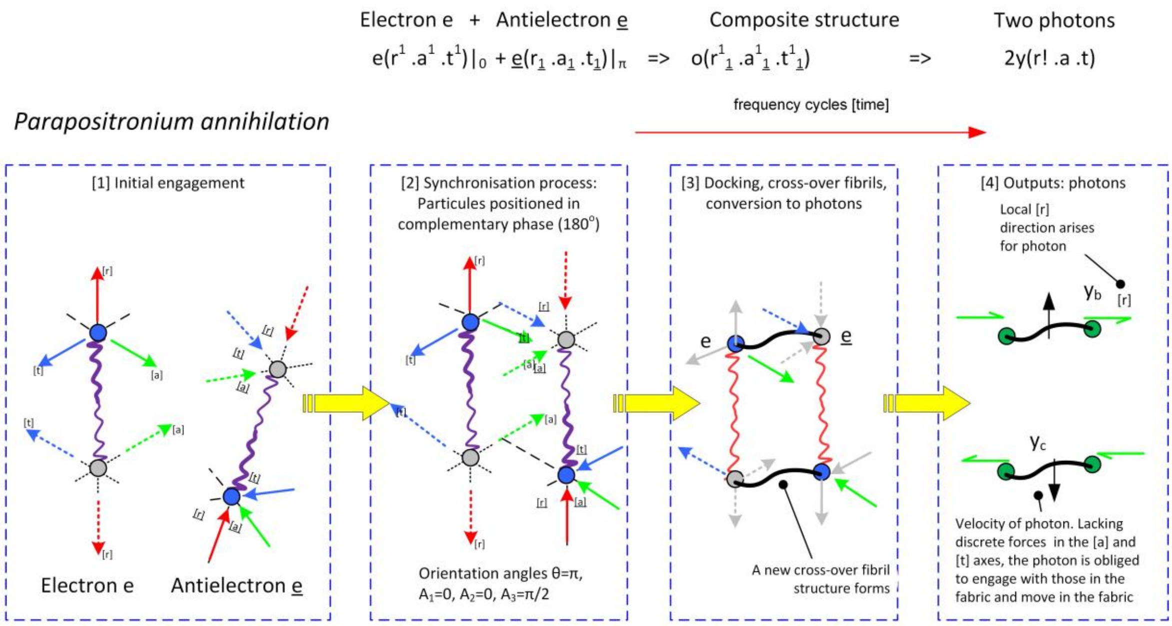
These are the field configurations of (r_1 .a_1 .t_1) and ($r^{\underline{1}}$.$a^{\underline{1}}$.$t^{\underline{1}}$), which we term the positive notElectron !e(r_1 .a_1 .t_1) and negative antiNotElectron !e($r^{\underline{1}}$.$a^{\underline{1}}$.$t^{\underline{1}}$). We term these substances Not-Real matter.

So according to the Cordus theory, this hole is not antimatter but an absence of matter, and behaves like a particule in its ability to move around. In other words these are empty locations where there are no reactive ends, but instead the discrete forces of the surrounding particules protrude into the hole. Consequently the hole *does* have an electric field structure and can interact accordingly, though its life is bound up with the fluid of particules around it. In this way the conduction of current by holes is recovered by the Cordus theory. These holes have been physically observed, so that part is not contentious. The novel contribution is providing physical explanations for these structures.

8.2 Annihilation

Positronium and spin

Positronium is the temporary bound states of electron-antielectron. Two states are known: parapositronium (life of about 125E-12 s), and orthopositronium (life 142E-9 s). Positronium has been relatively well studied [37] and production channels modelled mathematically [38] [39]. Positronium has the known behaviour of producing two photons when the electron and positron have antiparallel spins (parapositronium), and three photons for parallel spins (orthopositronium).



Engagement of discrete forces and flux tubes (hyff) creates electrostatic approximating force and magnetic alignment force

If the energies of e and e are different, then the spans will differ, and the frequencies too. It is likely that the system can adjust for this to some extent, by transferring energy between particules.

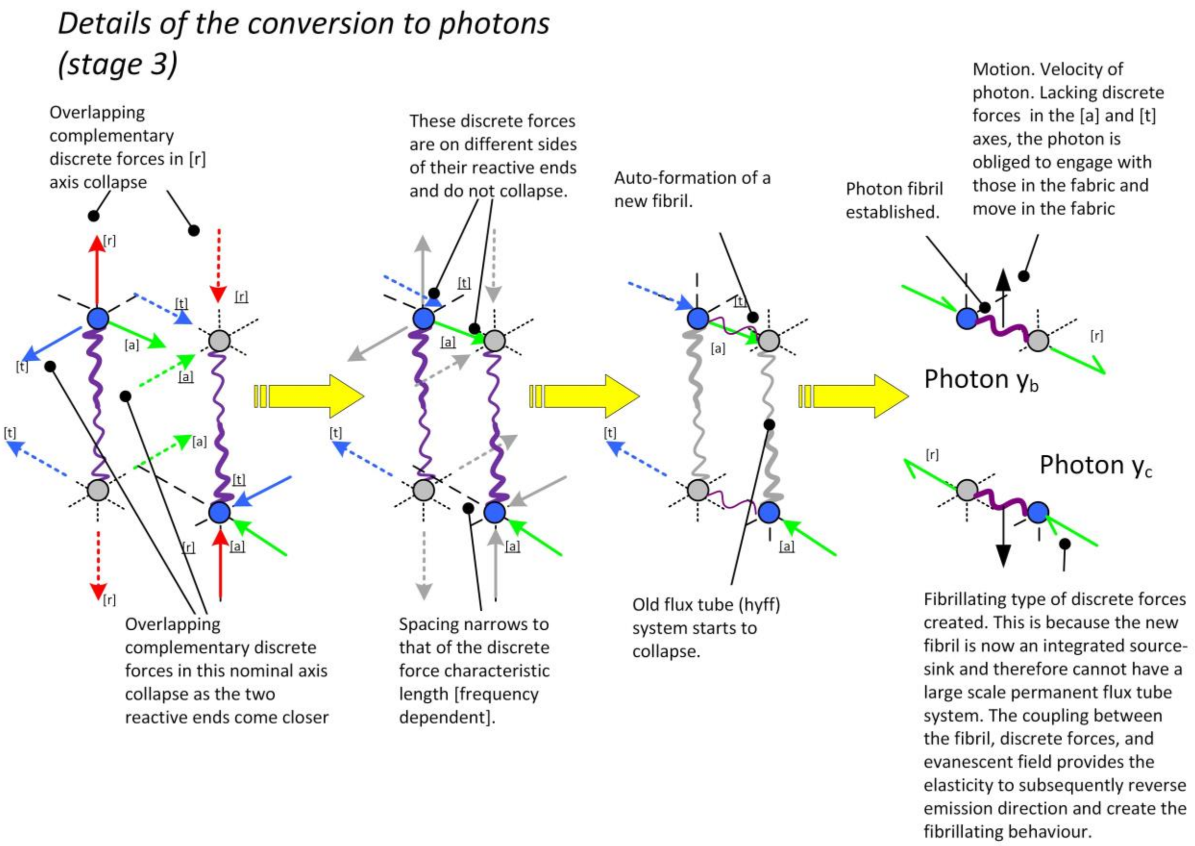
Spans and frequencies have now been adjusted in magnitude to match, and 3-axis alignment now continues, with synchronisation of phase.

Reactive ends e1 and e1 are now in range, comparable frequencies, aligned in 3 axes, and in complementary phases. Reactive ends e1 and e1 move into a hybrid state. The discrete forces in the [r] and nominal [t] axes are superimposed and collapse. The remaining discrete forces are converted to the fibrillating type and form the photon structures. Old fibrils finally balance energy across the junction, then fade. For more complex forms, multiple quark pairs (pions and kaons) may form, as transitional disassembly structures.

Each pair of reactive ends forms a new photon.

This theory predicts that the direction of photon emission is in the same direction as the spin axis, $A_1=0$ and π .

PARAPOSITRONIUM: Annihilation route.



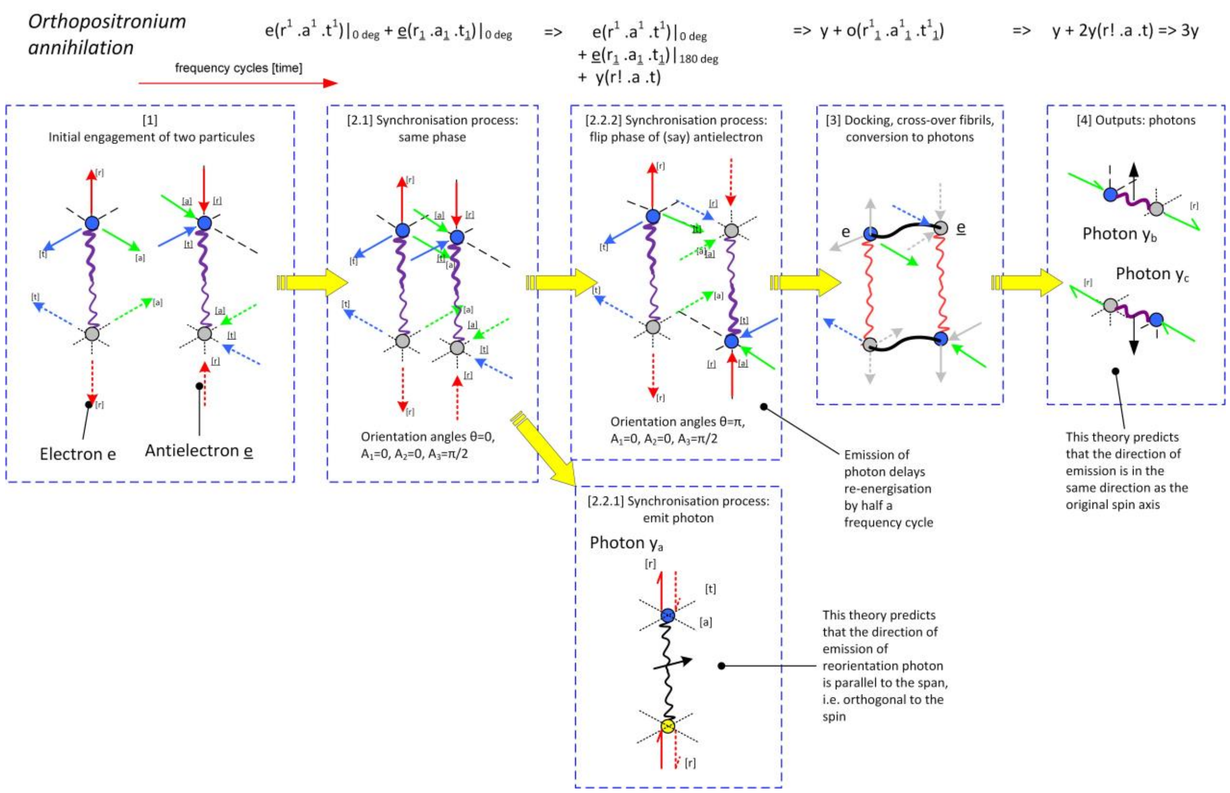
POSITRONIUM: Conversion details for photons.

Orthopositronium

Orthopositronium is the other temporary association of an electron and antielectron, and has the longer life before annihilation, though still short. It is known that the two particles have parallel spins. Annihilation is known to produce three photons, less often five. One of the photons may be of a different energy [28].

Photon-emission phase-offset

For this design to work requires a further and very specific assumption, that emission of a photon causes a particule to delay the re-energisation of its reactive end by half a frequency cycle, i.e. to change its phase θ by π. Thus a particule-pair that is caught in a certain unfavourable phase state may escape that state by emitting a photon. We anticipate that either the electron or antielectron may emit the photon, and that it will probably be whichever is more geometrically constrained or higher energised. With that addition it possible to explain the orthopositronium behaviour. This is consistent with the Sokolov–Ternov effect whereby electrons or antielectrons can invert their spin by synchrotron radiation.



ORTHOPOSITRONIUM: Cordus process diagram for annihilation of orthopositronium.

This diagram is more complex than the previous one. This is because orthopositronium has additional activities required before the main annihilation process can get underway. A testable prediction arises: That the first (of three) photons emerging from orthopositronium annihilation will have the following characteristics: (a) be emitted before the other two, (b) be emitted orthogonal to the spin axis of the orthopositronium assembly, (c) be dissimilar in energy to the other two photons.

The Cordus theory also offers a qualitative explanation of why the lifetime for parapositronium is so much less than orthopositronium: the latter has further processes to undergo, and these take time. Parapositronium is a preassembly that is already in a suitable orientation to proceed to photon production. By comparison orthopositronium first has to emit a photon before it can continue. If this interpretation is correct, then we can make another inference: that the time taken to get the particules into the correct geometric position is much the greater contributor to the decay time than the annihilation process to photons.

Various output photon scenarios

The annihilation of an electron and antielectron is known to produce two photons (or less often 4, 6..) or three (less often 5). It is known to depend on the relative spins: antiparallel or parallel spins respectively. Output of a single photon is possible, but only if there is other matter nearby to absorb some of the energy. The Cordus theory explains these outcomes.

One photon. Single photon, nominally y_b, is emitted. Its companion y_c is emitted and immediately absorbed by nearby matter (e.g. other electrons) before detection. This effect may also remove photons from any of the following cases.

Two photons, y_b and y_c are produced from each pair of reactive ends. This occurs if the original e and $\underline{e}$ were in opposite energisation (180^o phase offset).

Three photons. The first photon, y_a is produced as an initial adjustment to get the e and $\underline{e}$ into in a suitable phase. The y_b and y_c photons are subsequent outcomes.

For others see paper.

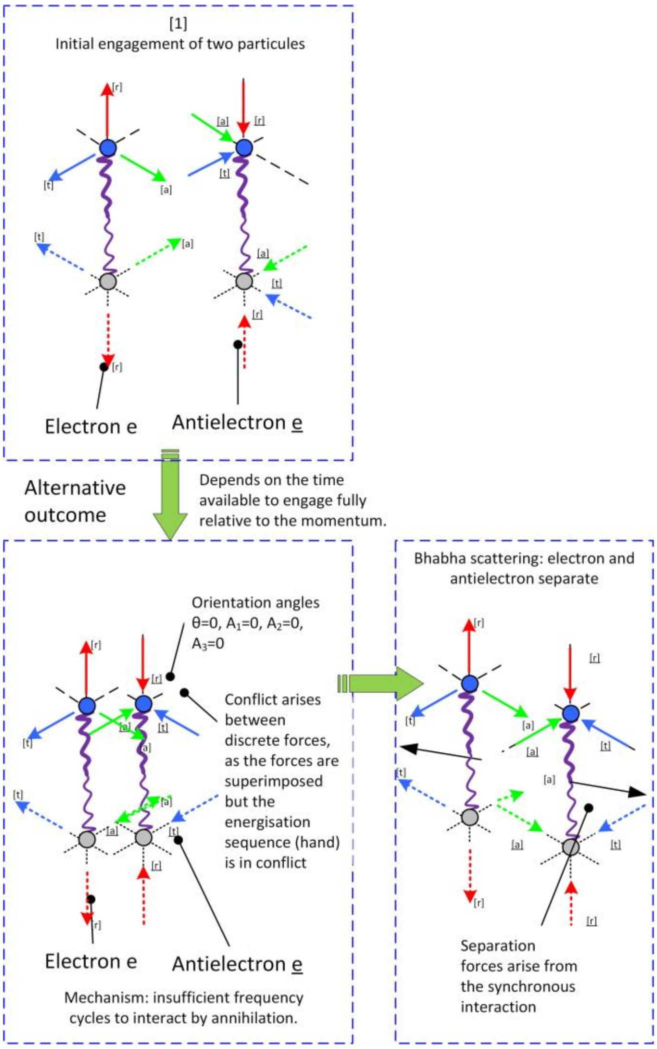
Testable predictions

The theory identifies specific testable hypotheses.

Particules with greater disparity in energy or less degrees of freedom, will take longer to annihilate. Also, for cases where both particles have the same energy, higher-frequency is expected to result in faster reactions.
The two photons emerging from parapositronium annihilation will have the following characteristics: (a) be emitted in opposite directions along the parapositronium spin axis, (b) have opposite (π) polarisation, (c) be identical in energy.
The first (of three) photons emerging from orthopositronium annihilation will have the following characteristics: (a) be emitted before the other two, (b) be emitted orthogonal to the spin axis of the orthopositronium assembly, (c) be dissimilar in energy to the other two photons.

Bhabha scattering

In the specific case of Bhabha scattering, it is proposed that there are two contributory factors: if the phase is mismatched then the synchronous interaction causes repulsion, and if the momentum is too high the particules do not have enough frequency cycles (time) to get into a complementary phase state.

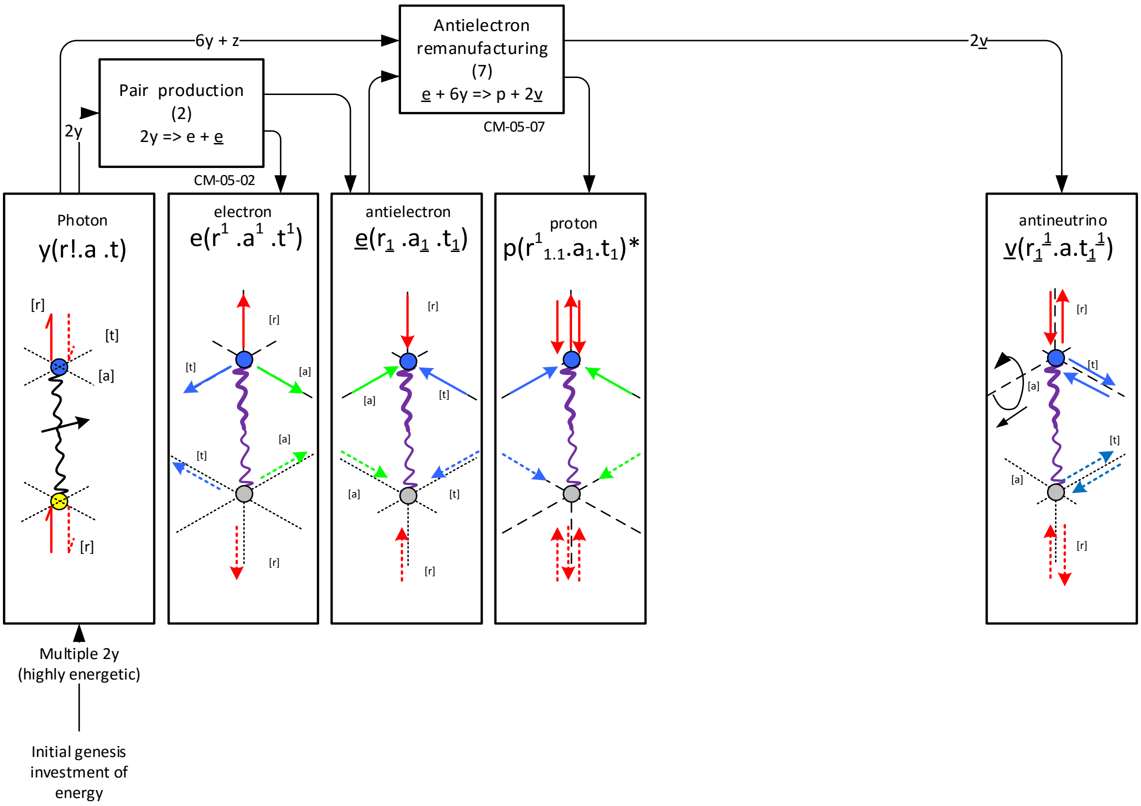


BHABHA: Cordus process diagram for scattering.

While the annihilation an electron and antielectron has been the primary focus of this paper, their interaction can instead result in elastic recoil, hence Bhabha scattering. This scattering has been thoroughly modelled mathematically, but still the ontological question remains: Why does annihilation not always occur? Since the mechanisms are strong enough to annihilate the pair, what defeats them so that scattering can take place? We believe a simple qualitative explanation is available. It is that particules interact through their discrete forces as they approach each other. The flux tubes have to negotiate mutual emission directions (HEDs) and thus they exert force on each other before the reactive ends actually coincide. The reaction forces occur at a small distance away from the reactive end. (This is a *non-local* theory, in which the conventional principle of locality at a point is replaced by a principle of Wider Locality.) Thus the scattering outcome ultimately depends on the frequency, phase, and the orientation of the particules.

8.3 Asymmetrical genesis

The theory solves the *asymmetrical baryogenesis* problem of why there is more matter than antimatter in the universe [40]. The explanation is that the antielectrons have been remanufactured into protons, and the theory predicts specific nuclear processes for this.



REMANUFACTURED ANTIELECTRONS: Solving the genesis problem.

Asymmetrical genesis production stream. The HED mechanics predicts a process whereby the antielectron from pair production is remanufactured into a proton, with two antineutrinos ejected in the waste stream.

$4y+z \Rightarrow e(r^1 .a^1 .t^1) + p(r_{11}{}^1.a_1.t_1) + \underline{v}(r_{\underline{1}}{}^{\underline{1}} .a .t_{\underline{1}}{}^{\underline{1}}) + \underline{v}(r_{\underline{1}}{}^{\underline{1}} .a_{\underline{1}}{}^{\underline{1}} .t)$

This also solves the *asymmetrical leptogenesis* problem, since the antielectrons are consumed.

8.4 General Remanufacturing processes for matter

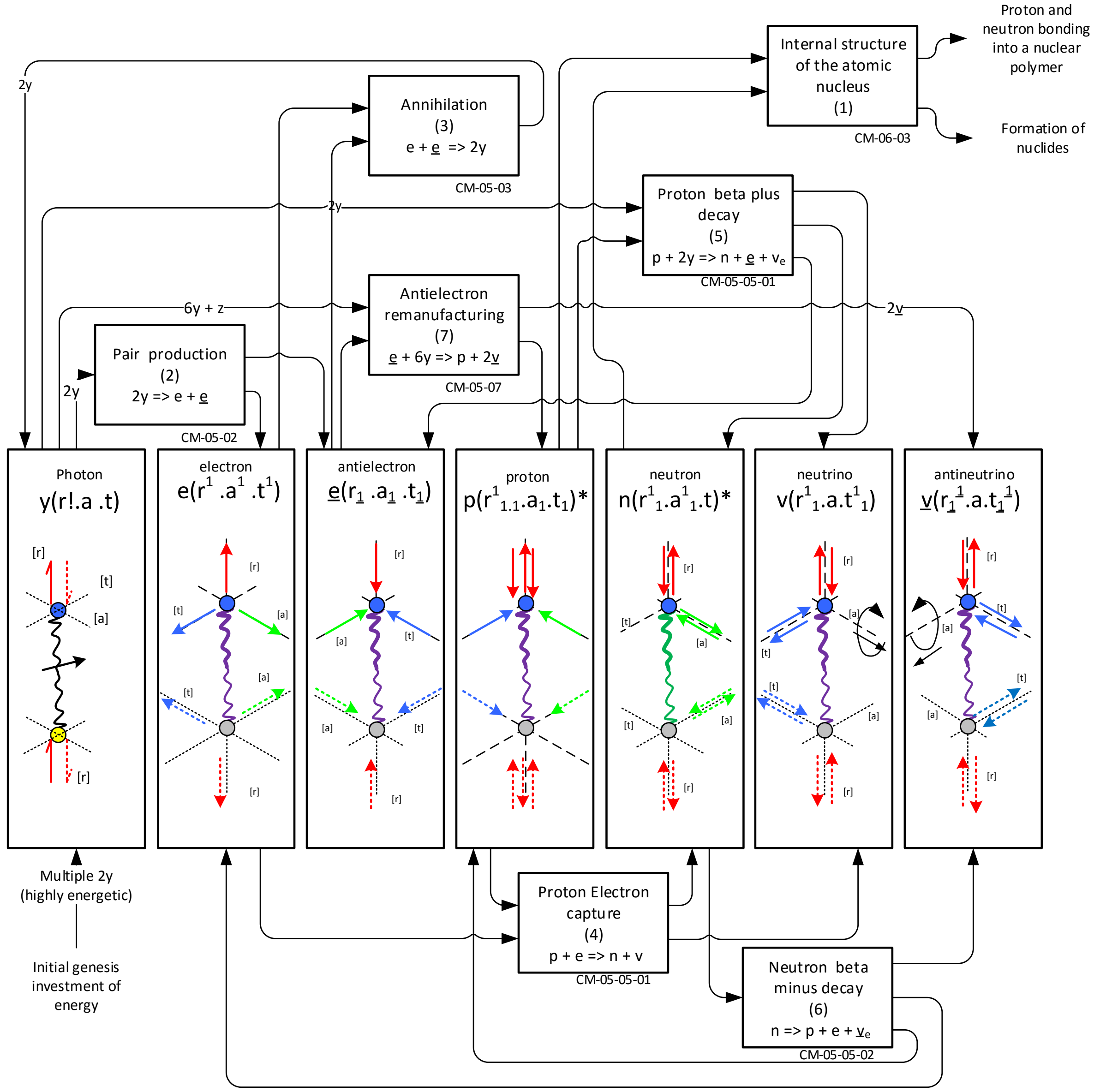
Taken together, the Cordus theory offers a complete set of forward production processes for electron, proton, and neutron, through to the nuclides.

Unified decay equation

We infer the existence of a unified decay equation for nucleons in the form of:

p + 2y + iz <=> n + $\underline{e}$ + v

where entities, other than photons, change matter-antimatter hand when transferred over the equality. This equation may be rearranged to represent β-, β+, and EC in the conventional forward directions, and the induced decays too.



CM-05-B	**Particule remanufacturing processes**

ALL ROUTES: There are proposed to be many remanufacturing paths between the particules.

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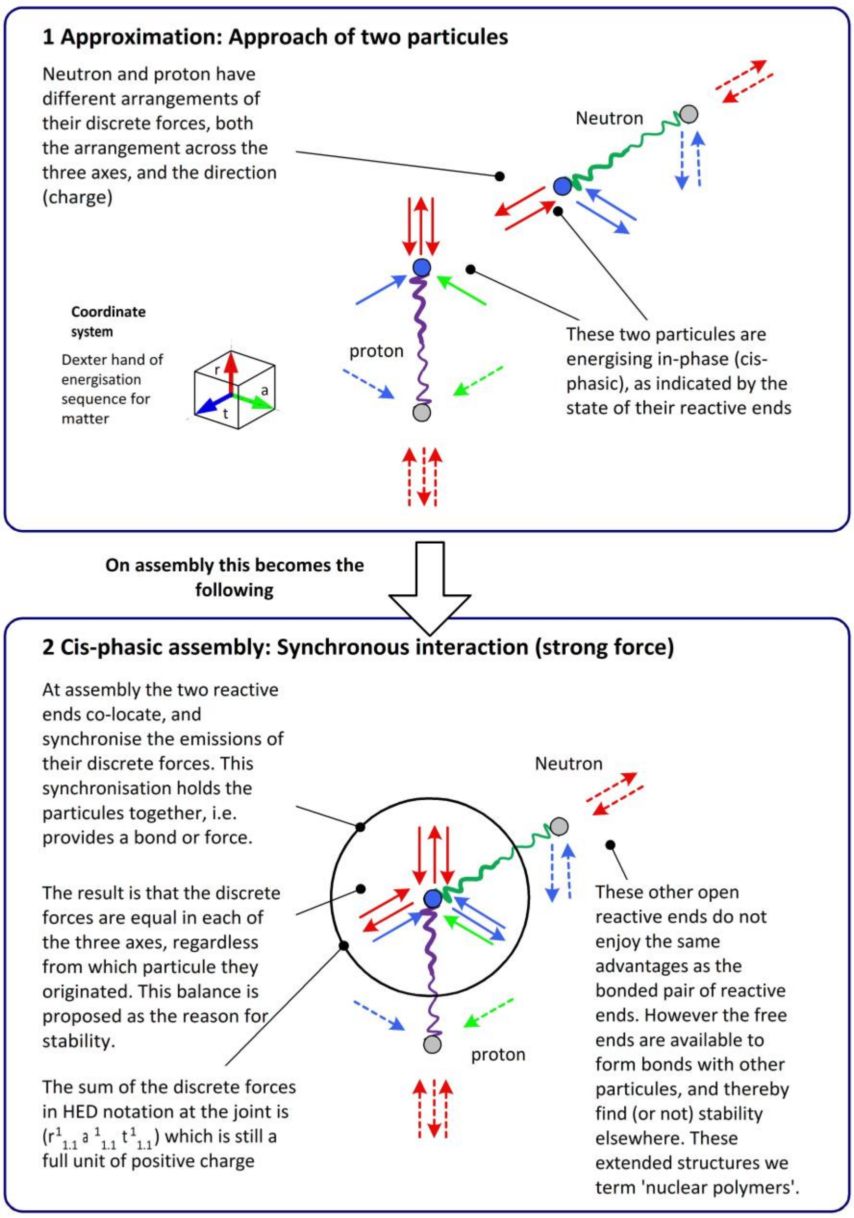
9 Nuclear theory

Problem – The explanation of nuclear properties from the strong force upwards has been elusive. It is not clear how binding energy arises, or why the neutrons are necessary in the nucleus at all. Nor has it been possible to explain, from first principles of the strong force, why any one nuclide is stable, unstable, or non-existent.

Findings - Nuclear bonding arises from the synchronous interaction between the discrete fields of the proton and neutron. This results in not one but multiple types of bond, cis- and transphasic, and assembly of chains and bridges of nucleons into a nuclear polymer.

9.1 Strong force via the Synchronous interaction

PROBLEM- The conventional requirements for the strong force are that it is strongly attractive between nucleons whether neutral neutrons or positively charged protons; that it is repulsive at close range; that its effect drops off with range. However theories, such as quantum chromodynamics, based on this thinking have failed to explain nucleus structure ab initio starting from the strong force.



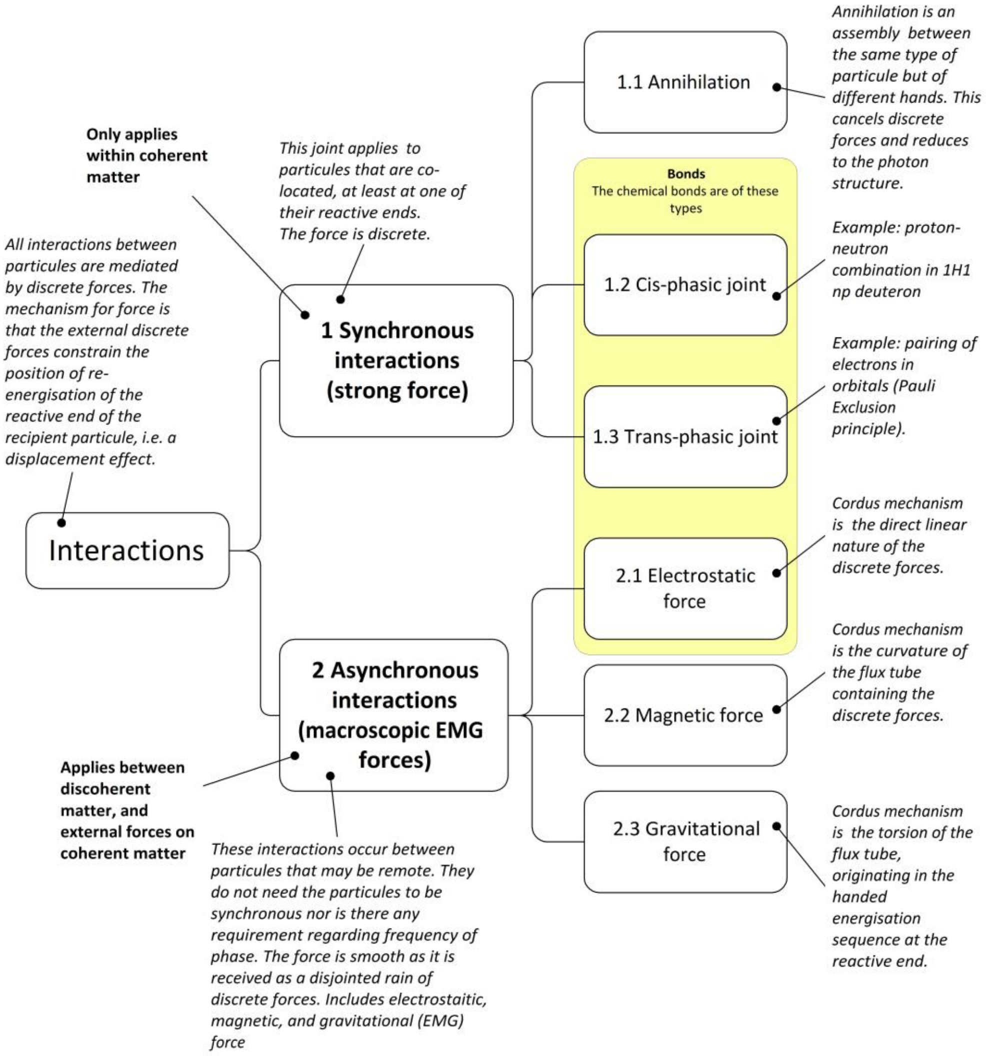
SYNCHRONISED: Cordus theory for synchronous interaction (strong force) bonding the proton and neutron.

FINDINGS- We propose that the strong force arises from particules synchronising their emission of discrete forces.
This causes the participating particules to be interlocked: the interaction pulls or repels particules into co-location and then holds them there.
Hence the apparent attractive-repulsive nature of that force and its short range.

PREDICTIONS- We make several falsifiable predictions including that there are multiple types of synchronous interaction depending on the phase of the particules, hence cis- and trans-phasic bonding. We also predict that this force only applies to particules in coherent assembly. A useful side effect is that the theory also unifies the strong and electro-magneto-gravitation (EMG) forces, with the weak force having a separate causality. The synchronous interaction (strong force) is predicted to be intimately linked to coherence, with the EMG forces being the associated discoherent phenomenon. Thus we further predict that there is no need to overcome the electrostatic force in the nucleus, because it is already inoperative when the strong force operates.

9.2 Unification of interactions

All interactions between particules are mediated by discrete forces. The mechanism for force is that the discrete forces constrain the position of re-energisation of the reactive end of the recipient particule, i.e. a displacement effect. The state of the particules, particularly the synchronicity and phase of their frequency, results in several types of forces/interactions as shown.

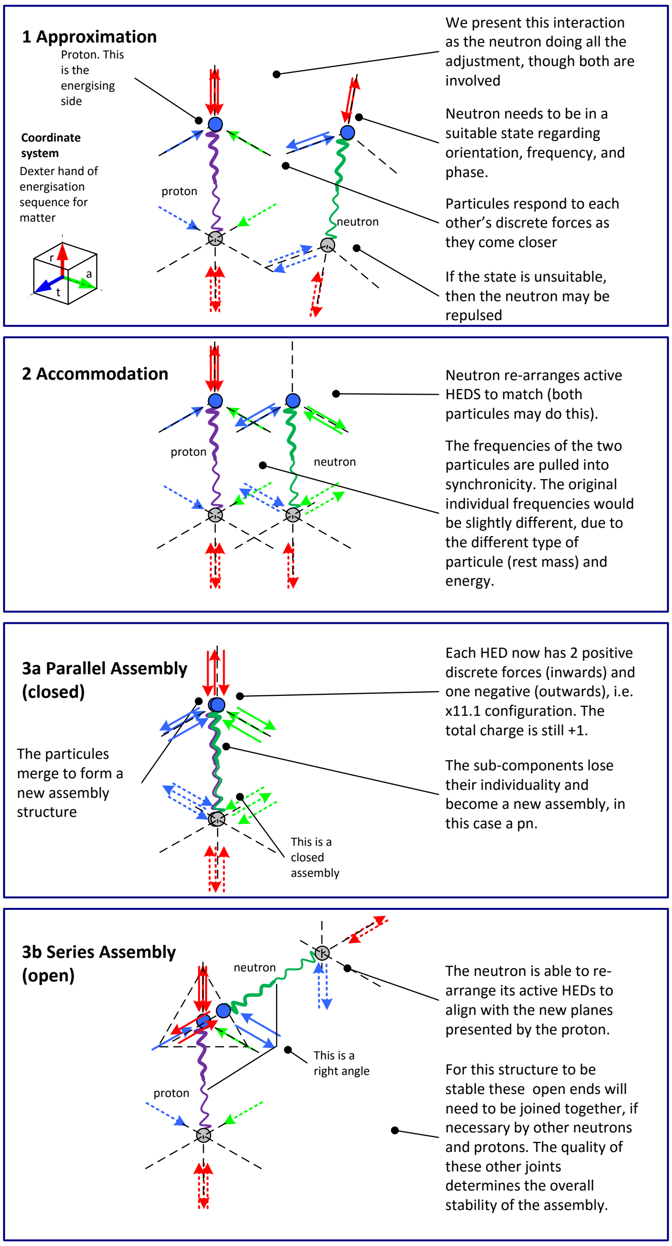


NEW WAY OF LOOKING AT THE INTERACTIONS: Cordus force hierarchy theory.

9.3 Cis- and transphasic bonds

Cisphasic

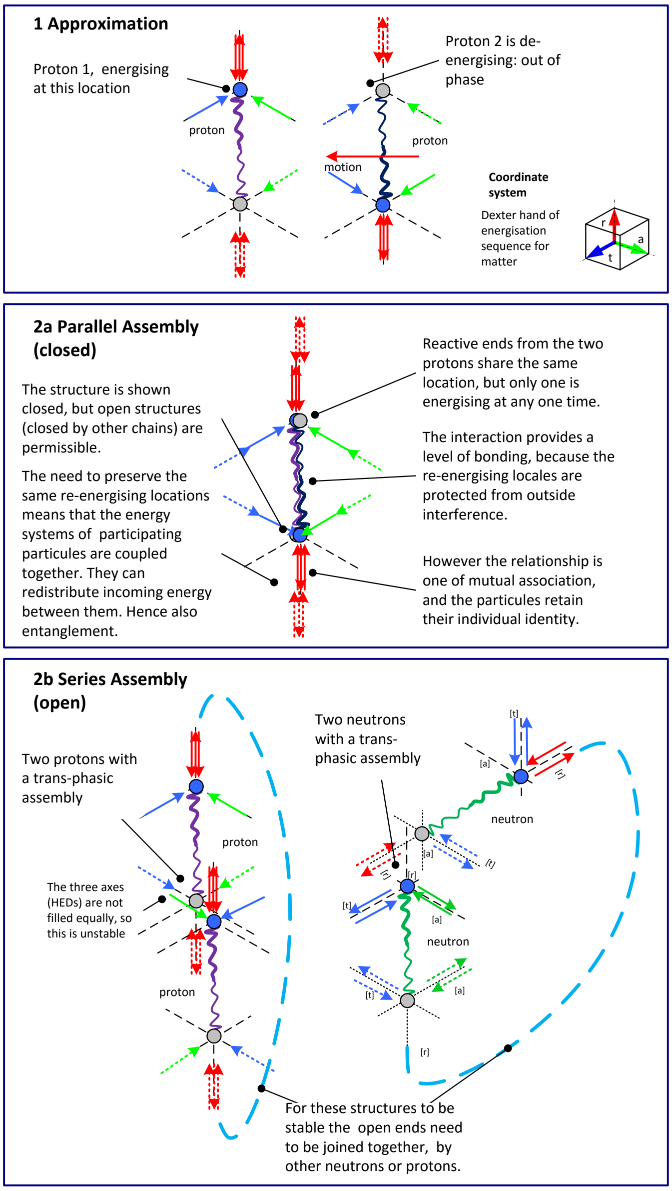
A Cisphasic assembly, e.g. of proton and neutron (p#n), involves two reactive ends, one from each of two different particles, synchronising their emission *in-phase* at the same location in space. This is especially valuable from a bonding perspective when the two particules *complement* each others' discrete force emissions to yield an assembled emission that is balanced in *all* emission directions.



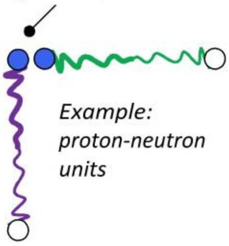
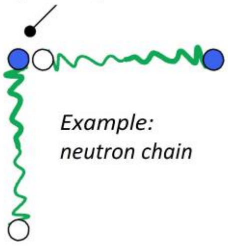
SAME PHASE: Bonding by particule reactive ends that are in-phase (cisphasic).

Transphasic

The joining of two like particules, two protons this case, with opposite phase allows them to *share* the same space. Each particule protects the location for the other, especially from external perturbation by discrete forces ex fabric. Although illustrated with two protons, this type of bond is available to *any* pair of like particules, including neutron-neutron, electron-electron, etc. A variety of layout arrangements are available as illustrated. This also explains Pauli pairs of electrons.



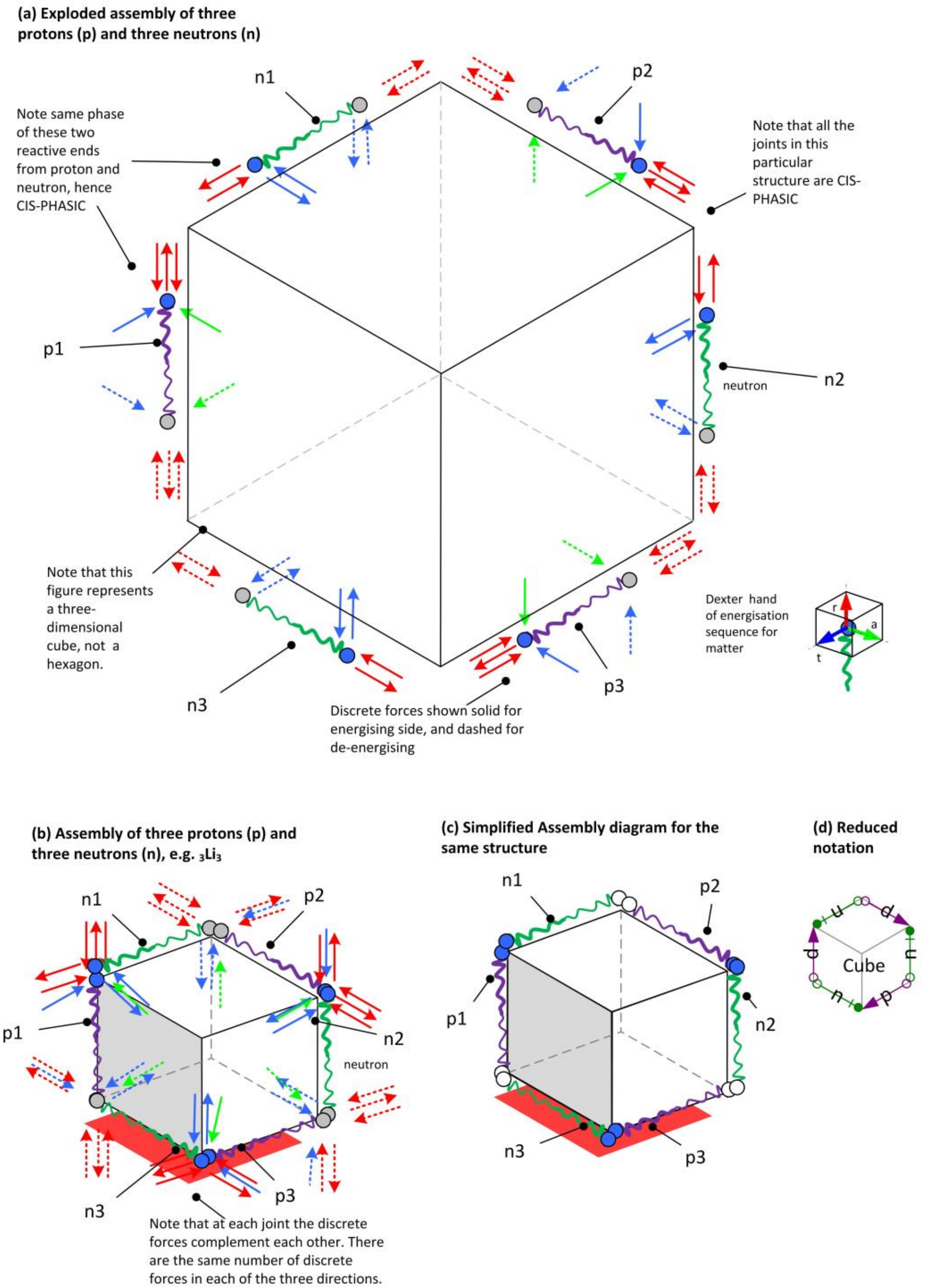
OPPOSITE PHASE: Bonding by particule reactive ends that are out-of-phase (transphasic).

ASSEMBLY NOTATION	**Cis-phasic (in-phase) #**	**Trans-phasic (out of phase) x**
PARALLEL ASSEMBLY (CLOSED: both reactive ends match)	Cis-phasic: (p1 # n1)  *Example:* $_1H_1$ Two particules sharing geometric location of both their reactive ends, in-phase	Trans-phasic: (p1 x p2)  *Example: Pauli pairs* Two particules sharing geometric location of both their reactive ends, out of phase *Mostly or only for particules of the same type*
SERIES ASSEMBLY (OPEN: only one pair of reactive end involved)	Cis-phasic: (p1 # n1)  *Example: proton-neutron units* Two particules sharing one geometric location, in-phase *This chain may need to be closed by other particules*	Trans-phasic: (n1 x n2)  *Example: neutron chain* Two particules sharing one geometric location, out of phase *This chain may need to be closed by other particules*

CIS- AND TRANSPHASIC APPLICATIONS: Summary of the cis- and transphasic joint types and their application to parallel and series assembly structures.

Assembly layout

The orthogonality of the three HED emission directions means that particles prefer orienting at 0^{o} (cisphasic), 90^{o}, or 180^{o} (transphasic). Consequently cubic structures tend to arise from the bonding of protons and neutrons into a nuclear chain. This nuclear polymer is wrapped around the outside edges of a cube.

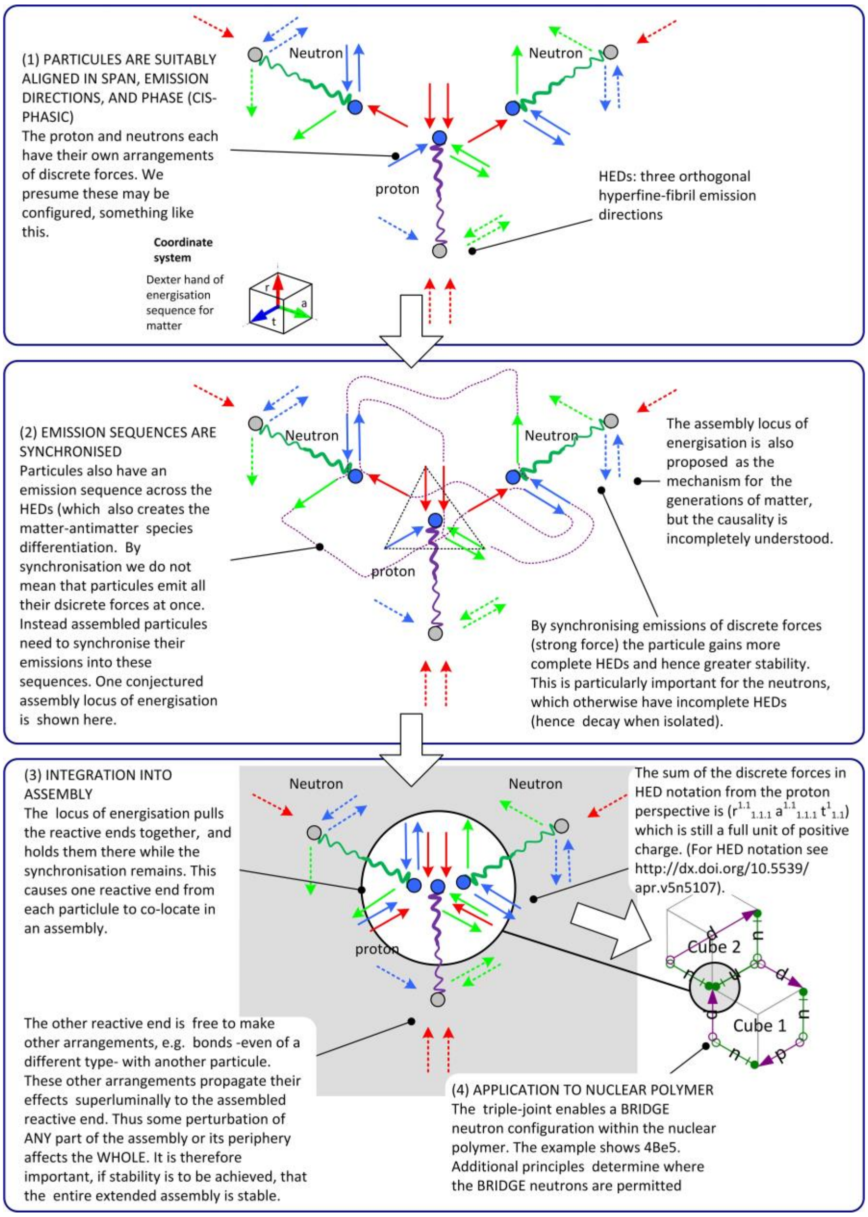


ORTHOGONAL: Cubic structures tend to arise from the bonding of protons and neutrons into a nuclear chain. The diagram shows exploded and assembly views.

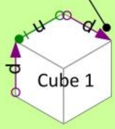
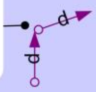
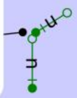
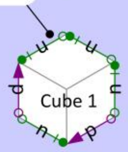
This theory shows where binding energy arises (cisphasic bonds), and why the neutrons are necessary in the nucleus (protons can only form weak transphasic bonds with each other).

9.4 Nuclear polymer

Findings - Nuclear bonding arises from the synchronous interaction between the discrete fields of the proton and neutron. This results in not one but multiple types of bond, cis- and transphasic, and assembly of chains and bridges of nucleons into a nuclear polymer.



NUCLEAR BRIDGES: Neutron cross-bridges are anticipated to occur within the nuclear polymer. These result in accumulation of discrete forces at the common node.

	STABLE ASSEMBLIES These have cis-phasic bonds (abbrev.: #) throughout the polymer	**UNSTABLE ASSEMBLIES (finite life)** These have trans-phasic bonds (abbrev.: x) somewhere in the polymer. These eventually fail, causing disassembly and hence finite life.	**NON-VIABLE ASSEMBLIES (exist precariously, or not at all)** These are bonds or assembly shapes that are inaccessible to the polymer. These assemblies will not form at all.
SINGLE NUCLEONS	STABLE A free proton is stable 	UNSTABLE A free neutron is unstable 	Not applicable
LINEAR JOINTED NUCLEONS	STABLE A cis-phasic neutron to proton bond (n#p) is stable  STABLE (Special case) An open ended p#n#p chain is stable (but longer chains are not due to non-unique chirality of the polymer)  	UNSTABLE An open end to a neutron is not stable. (However an open proton is).  UNSTABLE A trans-phasic proton to proton bond (pxp) is viable but unstable.  UNSTABLE A trans-phasic neutron to neutron bond (nxp) is viable but unstable   	NON-VIABLE A cis-phasic proton to proton bond (p#p) is not viable. The protons repel with the strong force  NON-VIABLE A trans-phasic neutron to proton bond (nxp) is not viable, as the discrete forces (which are of opposing phase) conflict with each other.  NON-VIABLE A cis-phasic neutron to neutron bond (n#n) is not viable, as the discrete forces (which are of opposing phase) conflict with each other. 

BOND QUALITY: Linear bonds between two nucleons may be cis- or transphasic, and depending on the participants, result in stable, unstable, or non-viable outcomes.

9.5 Table of nuclides

PROBLEM – Need to explain the causality from the strong force upwards to the bonding of protons and neutrons in nuclear structures. Need to explain why any given nuclide is stable or unstable, and explain anomalous states (e.g. the instability of 4Be4). Need to explain the trends in the table of nuclides, e.g. why the drip lines are where they are, why the series stop where they do. Need to explain why some elements have only one stable nuclide, and others three or more Why is n>=p for stability?

Current explanations in this area lack explanatory power.

- Shell model of Ivanenko [41] assuming a harmonic oscillator and predicts magic numbers.
- Interacting boson model (IBM) wherein nucleons are assumed to exist in pairs [42].
- cluster model, aggregates of neutrons and protons, typically alpha particles of two protons and two neutrons, *spherons,* packed in 3D space giving shells and sub-shells [43], recovers magic numbers.
- liquid-drop model, Gamow, assumes that the nucleus is comparable to an incompressible fluid made of nucleons [44].
- Collective model, which seeks to represent the collective dynamic motion or vibration of the whole set of nucleons comprising the nucleus [45-48]. It has been successful in explaining energy levels, where there are even numbers of protons and neutrons (i.e. no valence particles).
- semi-empirical mass formula (SEMF) [49] which uses coefficients of empirical origin, tuned to predict the binding energies. The factors in this model are the strong nuclear interaction (volume of whole assembly), electrostatic repulsion, surface energy (lower binding energy assumed for nucleons on the outside of the assembly), asymmetry of state (neutron and proton counts are not the same), spin state (pairing of particles in even-numbered assemblies gives greater stability), and several empirically derived calibration coefficients.

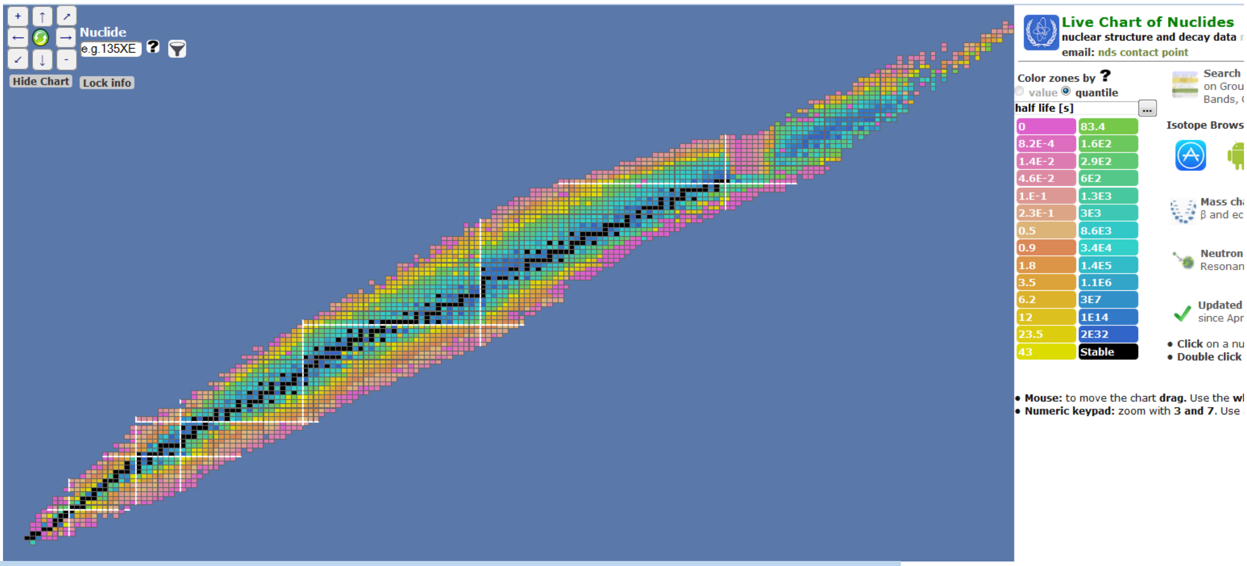
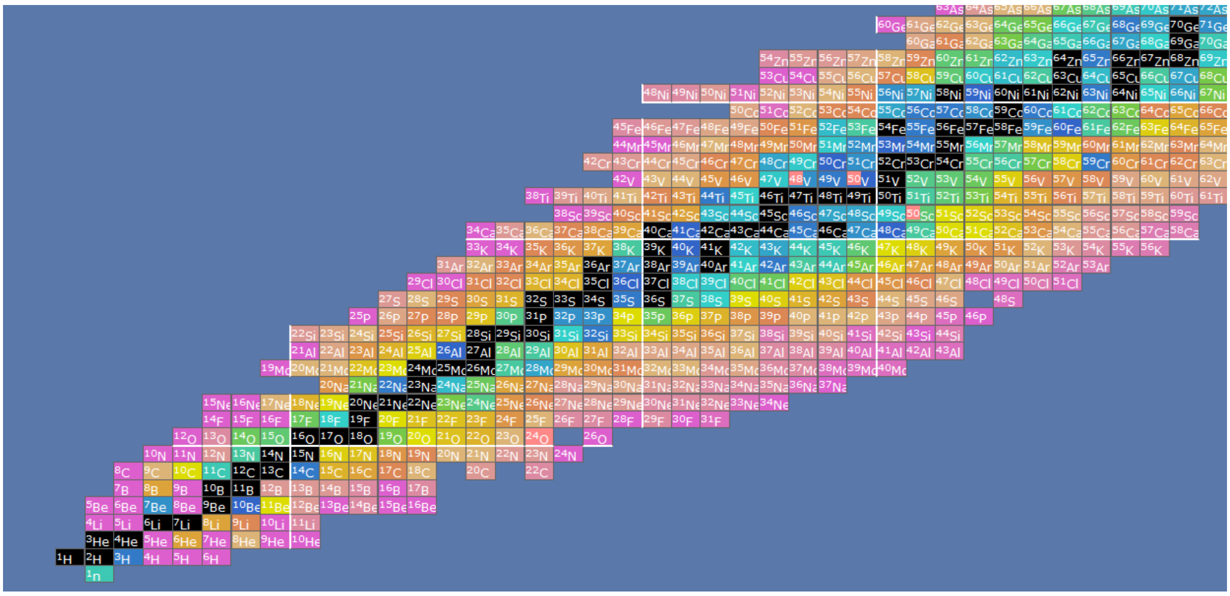
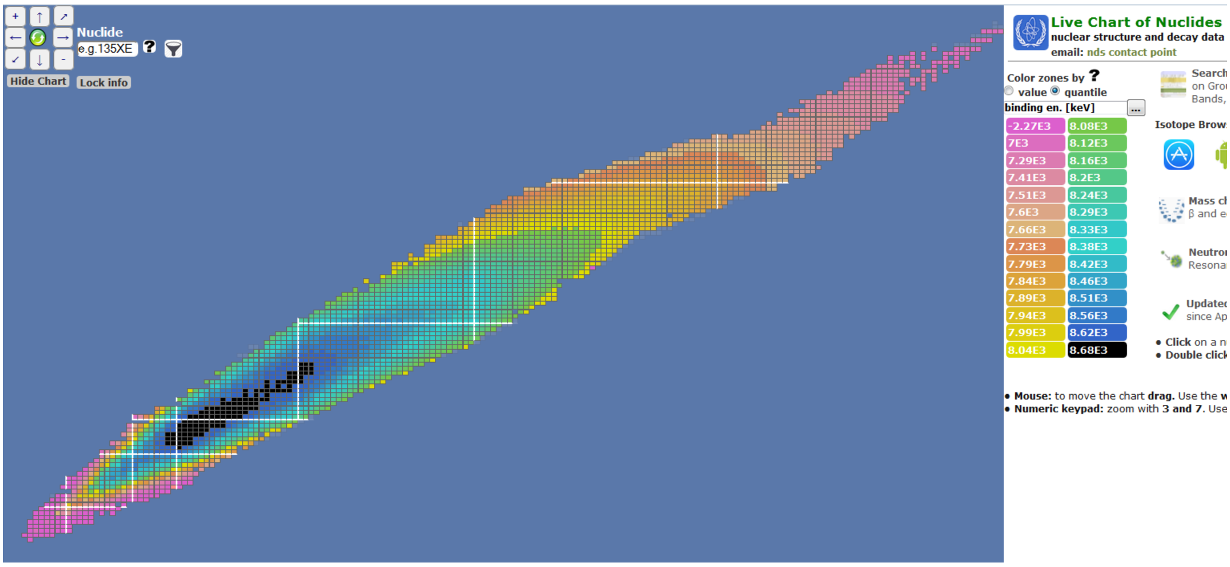


TABLE OF NUCLIDES: Half-life of nuclides. Source https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html



DIFFICULT REGION: The light end of the table of nuclides. The patterns of stability are especially difficult to explain here: many models omit this end completely. Source https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html



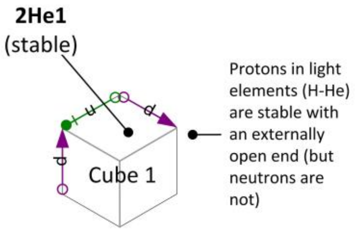
NOT RELEVANT TO STABILITY: Binding energy of nuclides
Source https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

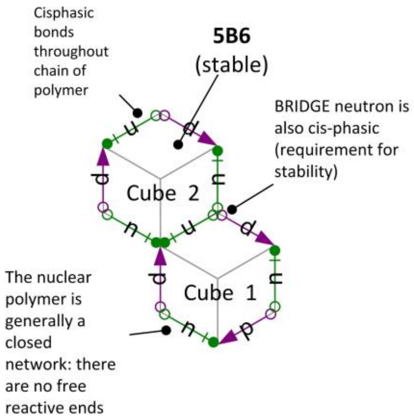
But binding energy does not correlate well with stability. Some nuclides have high binding energy yet are still unstable. And the inverse also applies: nuclides exist with low binding energy that are stable. Also binding energy is a continuous variable and does not explain the finer features of stability. Furthermore models of binding energy, such as SEMF, do not reproduce the drip lines, hence predict binding energies for nuclides that do not exist.

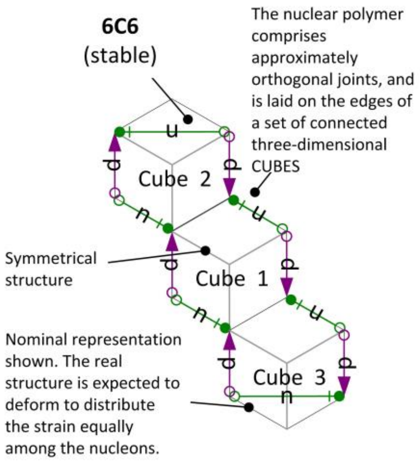
Explanation per Cordus theory

The synchronous interaction constrains the relative orientation of nucleons, hence the nuclear polymer takes only certain spatial layouts.

The stability of nuclides can be predicted by morphology of the nuclear polymer and the cis/transphasic nature of the bonds. The theory successfully explains the qualitative stability characteristics of all hydrogen and helium nuclides.



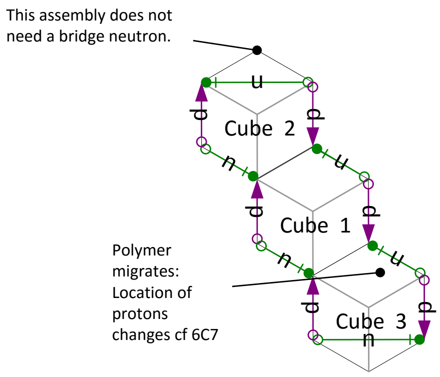




SAMPLE NUCLEI: The synchronous interaction (strong force) bonds protons and neutrons together in a variety of way, resulting in nuclear polymer structures. These are proposed as the structure of the nucleus.

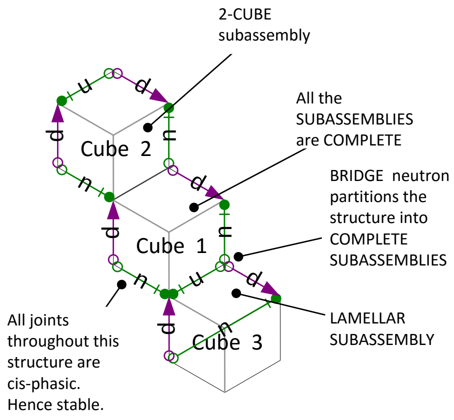
$_{6}C_{6}$ stable

This nuclide is stable with n=p=6 because there is a symmetrical structure that is available.

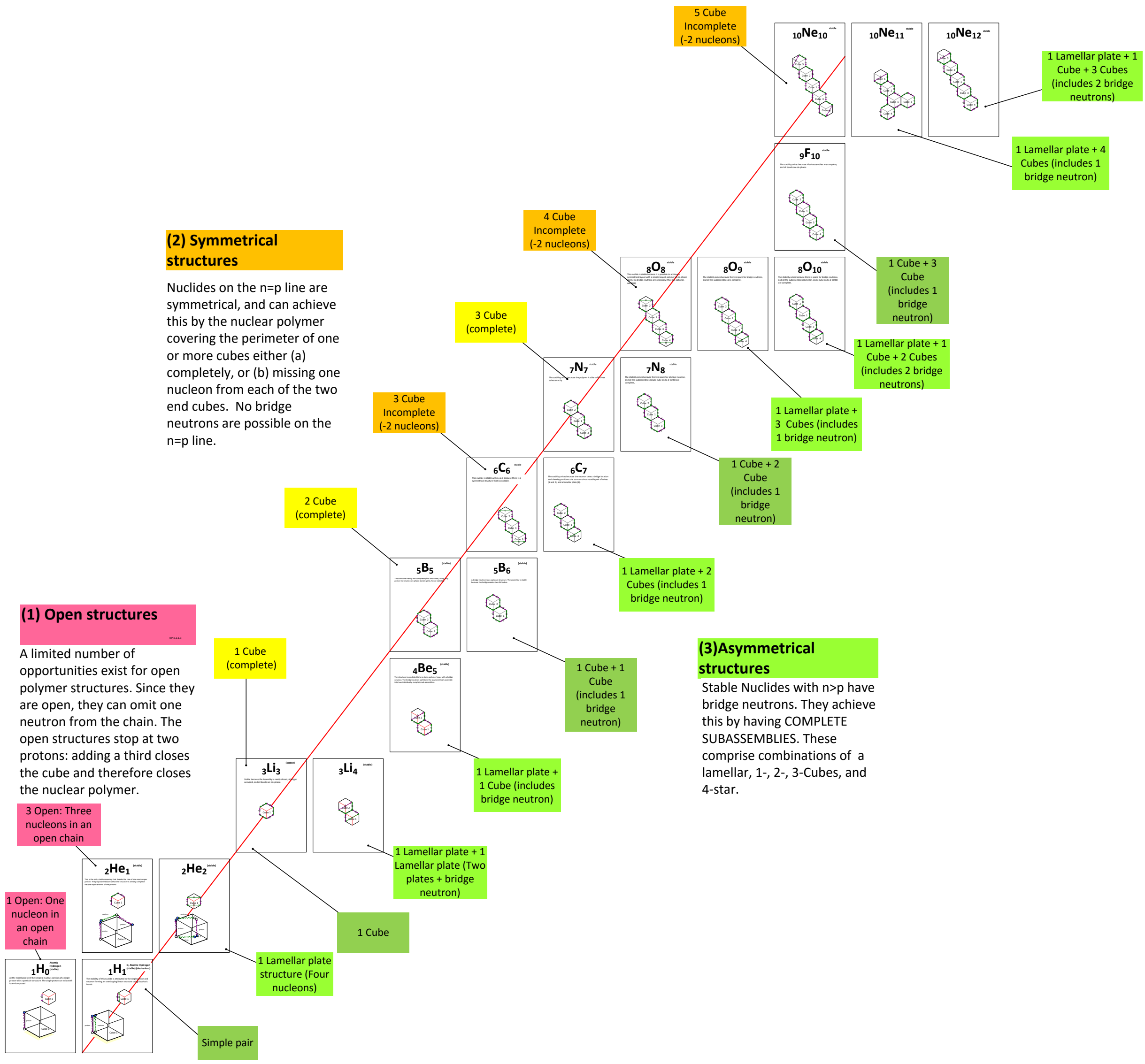


$_{6}C_{7}$ stable

The stability arises because the neutron takes a bridge location and thereby partitions the structure into a stable pair of cubes (1 and 2), and a lamellar plate (3).



CARBON ISOTOPES: Changing the number of nucleons requires morphological changes.



TRENDS FOR STABLE NUCLIDES: Structural trends for stable nuclides.

Trend for p=n for stable light nuclides

The trends whereby the stable nuclides deviate from the p=n line are also interesting, and the theory successfully explains these. The explanation is that for light elements the p=n nuclear polymer is stable, but heavier elements require bridge neutrons to divide the polymer into complete subassemblies.

Aberration of neutron-light nuclides

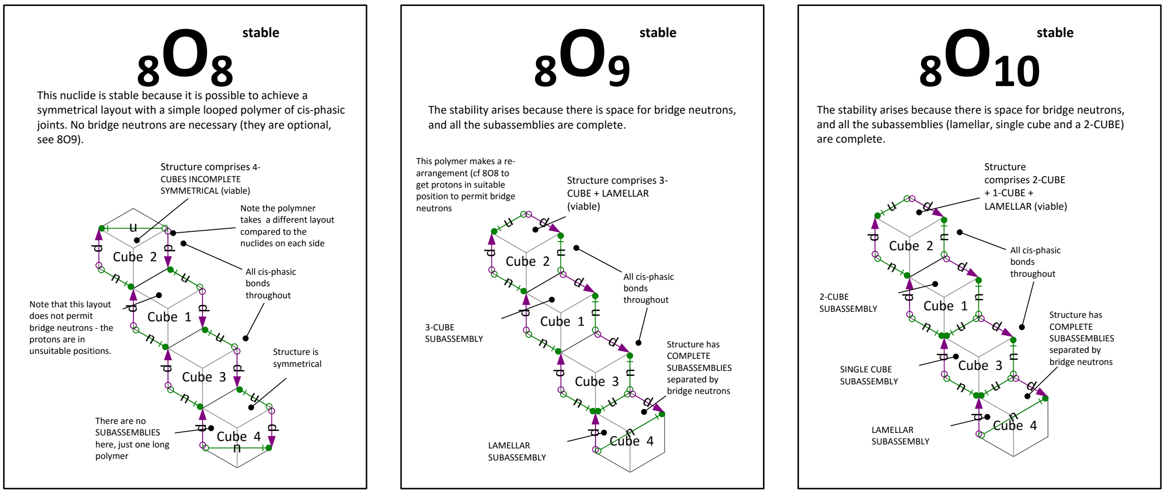
This theory explains the two aberrations, 1H0 and 2He1 which are stable despite having p<n. The 1H0 nuclide is stable without any neutron, because the single proton is stable as an open structure. Likewise 2He1 is stable with only one neutron (rather than two), because it is an open series, as opposed to the generally closed nuclear polymer.

Specific Aberrations

4Be4 and 9F9 are unstable: In both 4Be4 and 9F9 there is no stable layout that meets the morphological rules.

Stable isotopes (Horizontal runs)

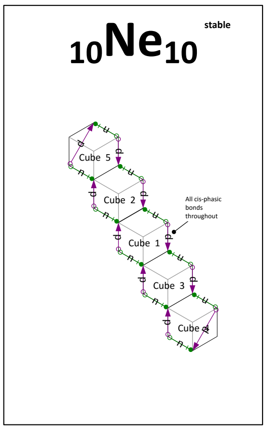
Certain elements have multiple stable isotopes, i.e. a horizontal run, the first case in point being 8O8, 8O9, 8O10, see Figure 6. These are puzzling trends that are not explained by other theories. In the Cordus theory the explanation arises naturally from consideration of the polymer filling rules. Specifically, these runs are due to the structure having the ability to accept additional bridge neutrons. This is achieved by changing the shape of the polymer as more neutrons are added.

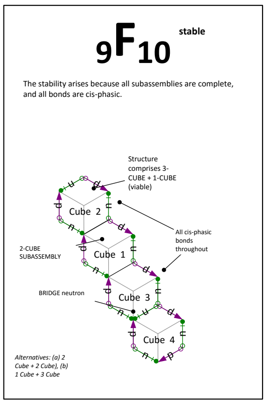


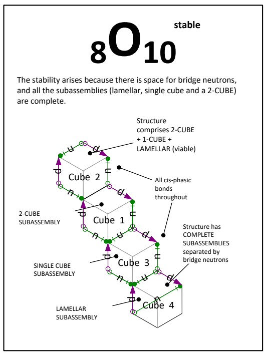
OXYGEN ISOTOPES: The stable isotopes (horizontal), for example the stable oxygen nuclides, are proposed to have a morphological origin.

Stable Isotones

The stable isotones (vertical ladders) are nuclides with the same neutron count, but different protons. The first example in the table of nuclides is 8O10, 9F10, 10Ne10. The Cordus theory explains these stable isotones (ladders) as due to the structure progressively gaining protons and thereby being able to remove bridge neutrons into the main loop.



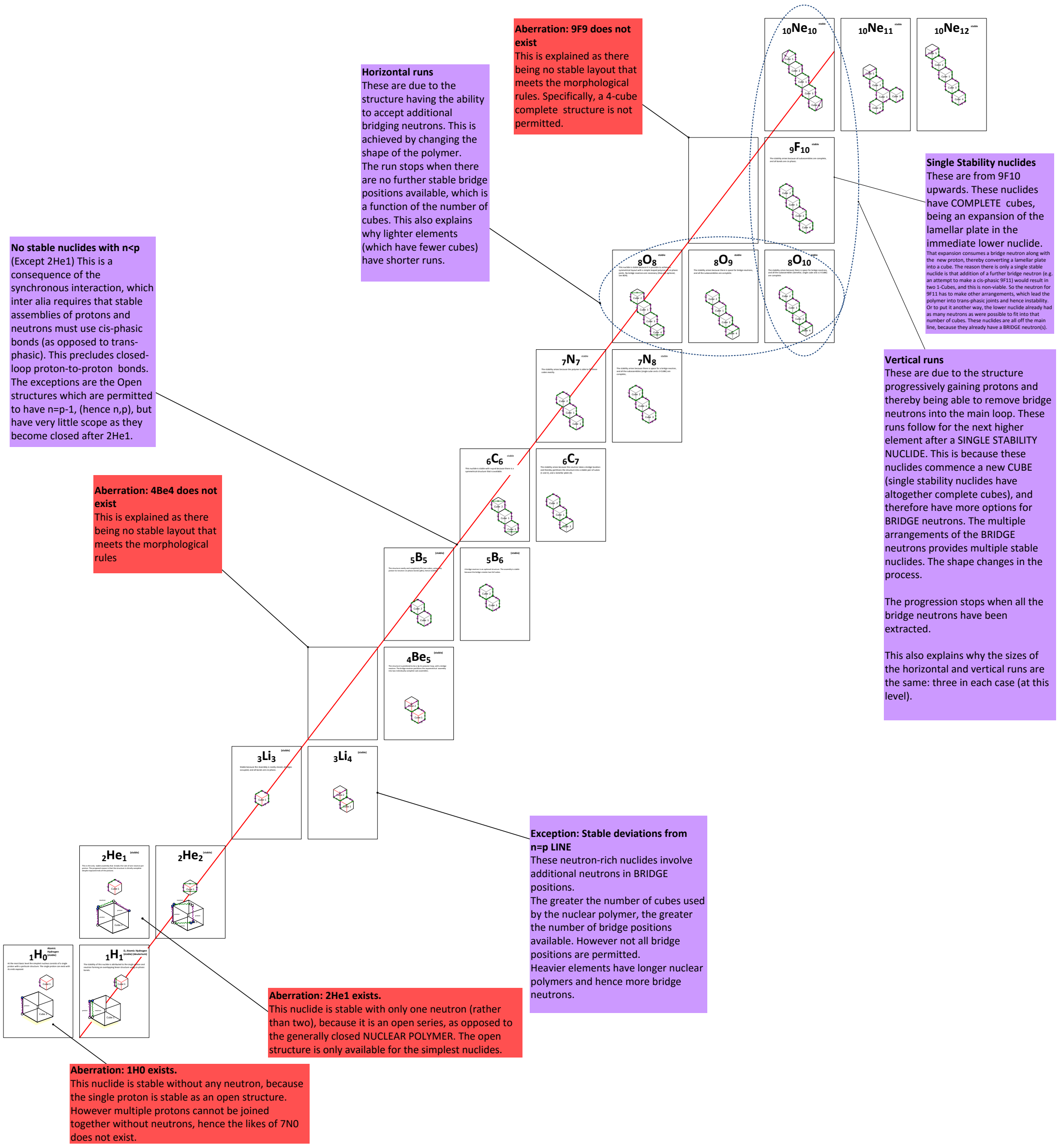




ISOTONE: Stable isotones (vertical ladders) of nuclides. These have the same number of neutrons (10 in this case) but different protons, and are all stable.

Explanations for the nuclides that deviate from the p=n

line.



DEVIATION: Stable Nuclides that deviate from p=n can be explained.

Having explained the stable nuclides and their trends, we now turn to the unstable nuclides.

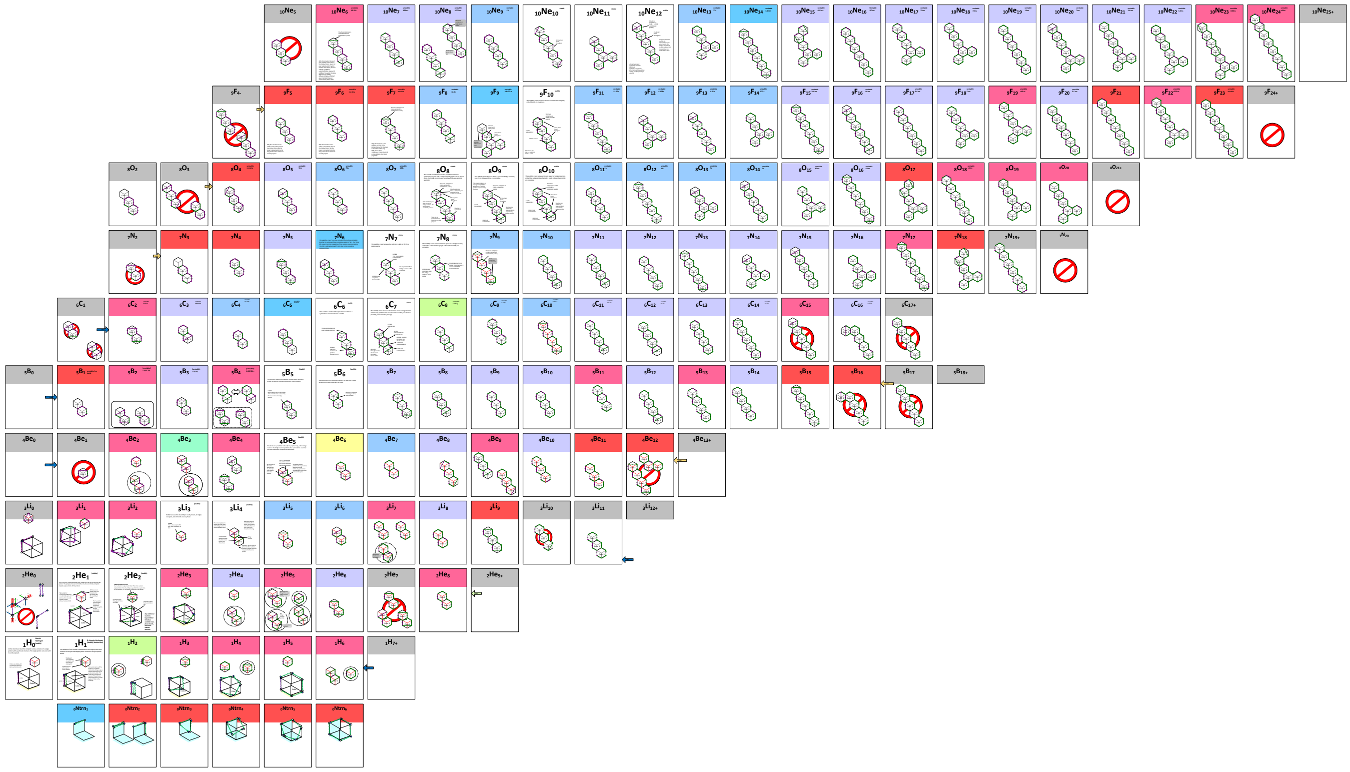


TABLE OF NUCLIDES H TO NE: Predicted shapes of all the nuclides, stable and unstable, from Hydrogen to Neon, from the Cordus theory. See paper (online) for higher resolution image.

There are no situations where the Cordus theory is totally at odds with the empirical life data. Minor discrepancies are observed for 4Be4, 4Be9, 4Be11, 5B4, 8O4, 8O17, 9F7, 10Ne6, and 9F19, where the Cordus theory suggests a slightly better viability than is observed. These are all nuclides that are highly unstable (<1E-9s) or non-viable.There is only one situation where the Cordus theory predicts a worse viability than is observed, and that is 8O20. The Cordus theory suggests this nuclide should not exist at all, whereas the empirical evidence is for a barely viable nuclide with life <100ns.

Originality – Novel contributions include: the concept of a nuclear polymer and its mechanics; an explanation of the stability, instability, or non-existence of nuclides starting from the strong/synchronous force; explanation of the role of the neutron in the nucleus. The theory opens a new field of mechanics by which nucleon interactions may be understood.

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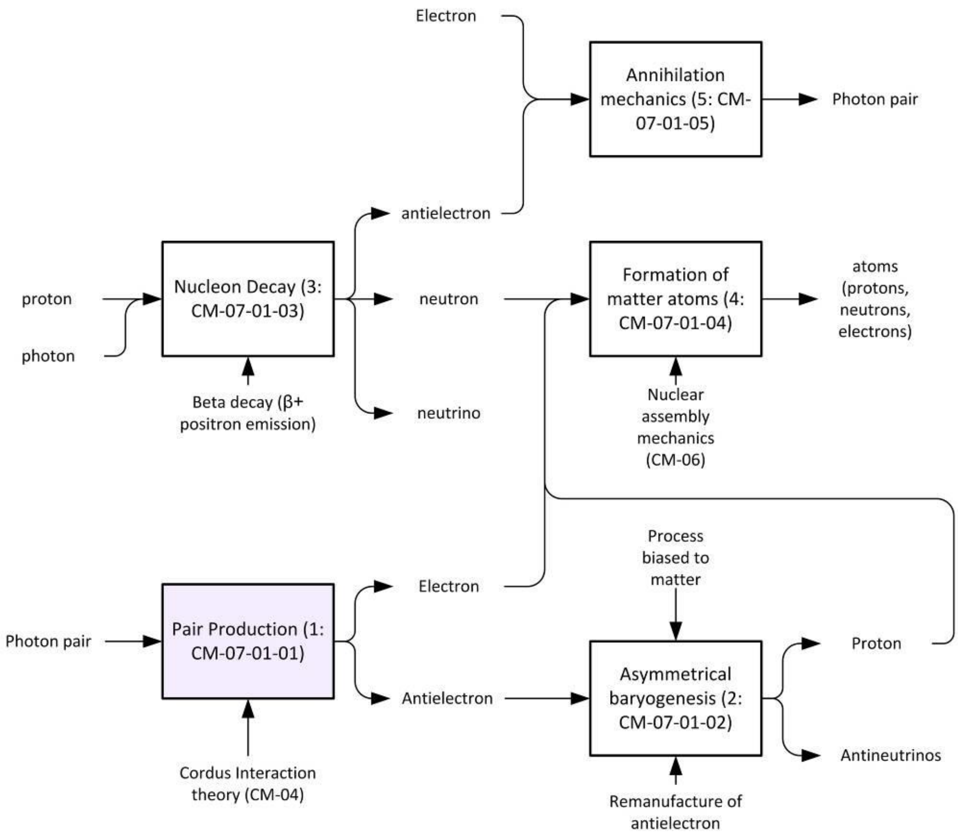
10 Cosmology

10.1 Genesis production sequence

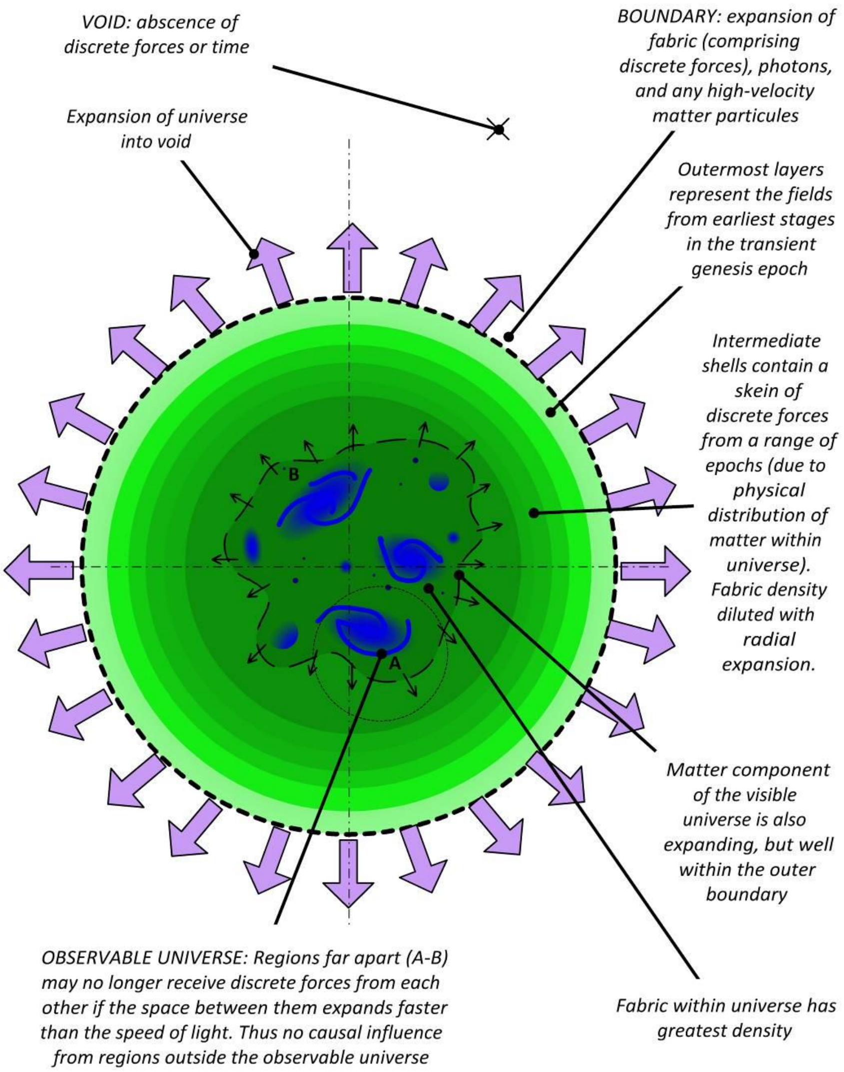


Genesis production sequence (CM-07-01)

ROUTE: The Cordus genesis production sequence describes the production route from primeval photons, through pair production and asymmetrical genesis, on to the formation of protons and neutrons and the nuclear structure.

10.1 Vacuum, Void, holographic principle

A physical interpretation of the holographic principle is derived. We start by developing an explanation for the vacuum, and differentiate this from the void into which the universe expands. In this theory the vacuum comprises a **fabric** of discrete field elements generated by matter particules.



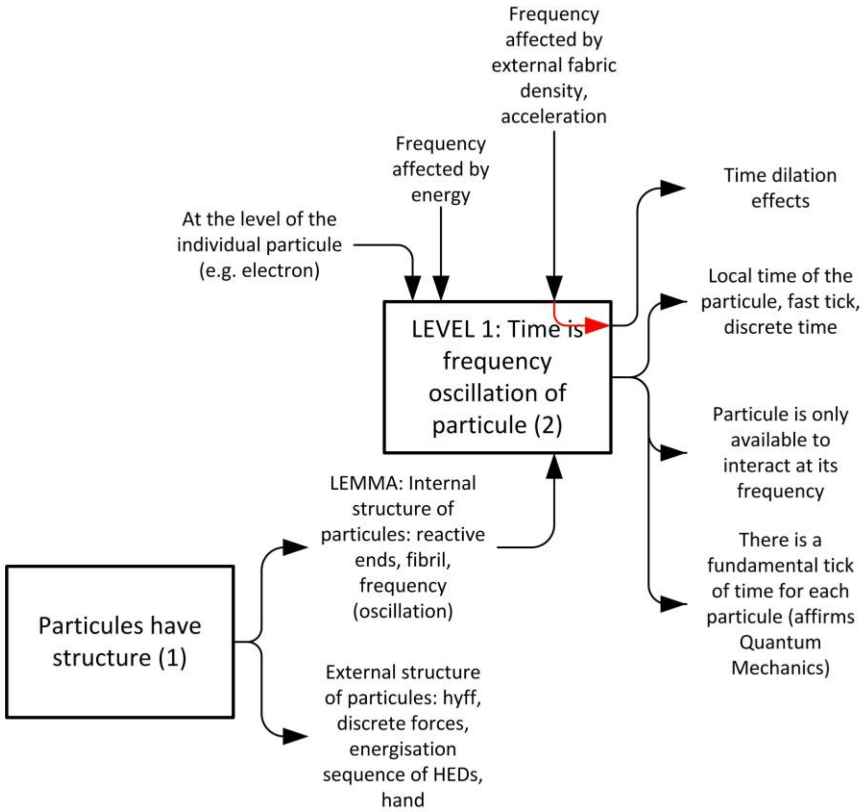
VOID, VACUUM, FABRIC: The Cordus model for the boundary of the cosmos. At the outer frontier the expanding universe colonises the void. This boundary only codes for the very first fields created at the genesis event. Inner shells code for the later states of the universe.

The outside void into which the universe expands is identified as lacking a fabric, and also being without time. From this perspective the cosmological boundary is therefore the expanding surface where the fabric colonises the void.

Thus the cosmological boundary is proposed to contain the discrete field elements of all the primal particules within the universe, and therefore contains information about the attributes of those particules at genesis. Inner shells then code for the changed locations of those particules and any new, or annihilated, particules. Regarding the notion of holographic control of inner contents of the universe from the outer surface, this theory identifies the infeasibility of placing a physical Agent at the boundary of the universe, and also predicts there is no practical way to control the universe from its outer boundary as the holographic principle suggests. It also rejects the notion that the boundary contains information about the future and past, or about all possible universes. The Cordus model suggests that there is no causality from the boundary of the universe to its inner contents.

10.2 Time: An emergent property of matter

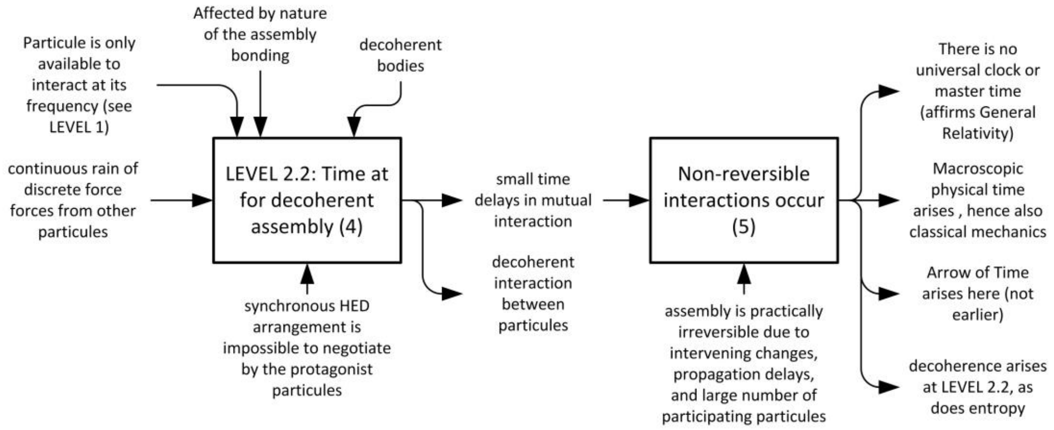
Time at the fundamental level consists of the frequency oscillations of matter particules, and thus time is locally generated and a property of matter.



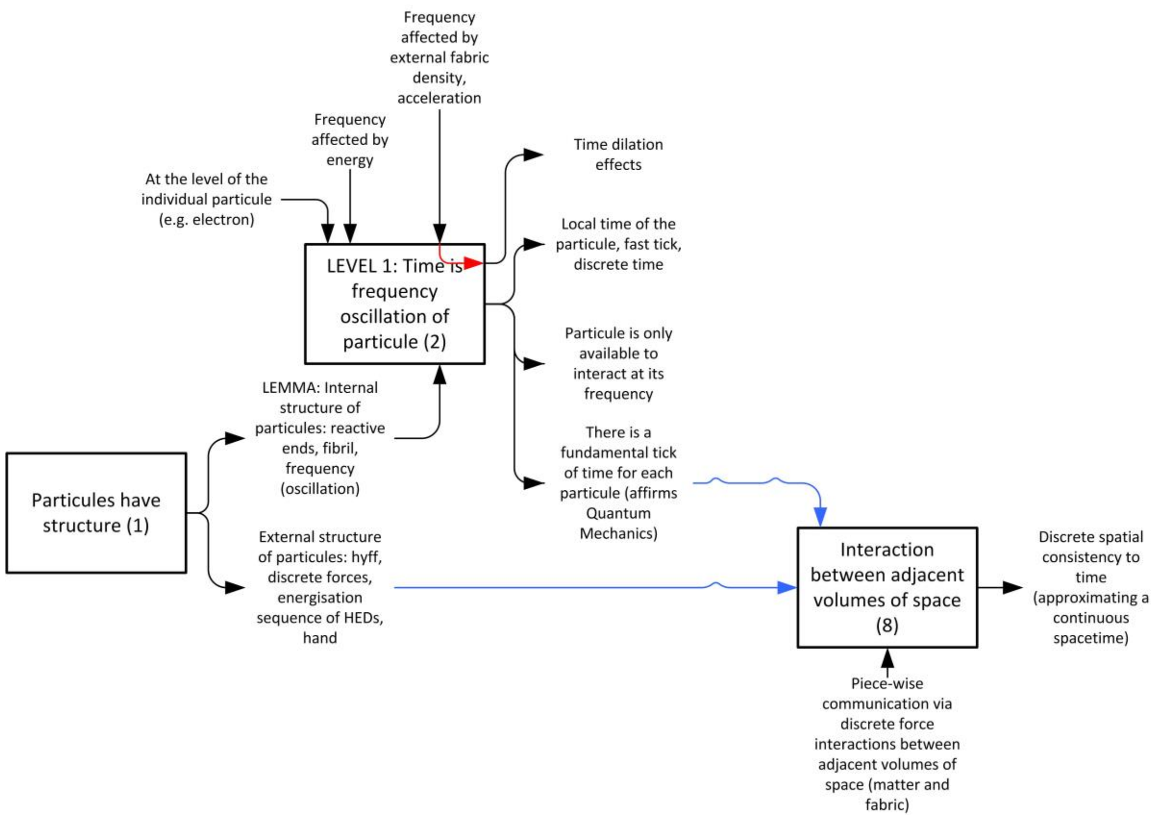
TICK OF TIME: The Level 1 Cordus theory for time is that the cycle of re-energisation of the two reactive ends, at the frequency of the particule, comprises the fundamental tick of time. At this level time is reversible. The diagram represents the causality whereby particule-structure and external events affect the tick of time for that particule.

At the next level up, that of the assembly of matter particles via bonds and fields, the interconnectedness creates a patchwork of temporal cause-and-effect, and hence a coarser time.

Entropy, classical mechanics, the arrow, and our perception of time are shown to all arise at the transition from coherence to decoherence. Time at the macroscopic level is therefore a series of delayed irreversible interactions (temporal ratchets) between sub-microscopic domains of matter, not a dimension that can be traversed in both directions.



TICK AT THE HIGHER LEVEL: Cordus theory for time in DECOHERENT assemblies of matter.



MACROSCOPIC TIME: The apparent smoothness of time at the macroscopic level is caused by the interaction between adjacent volumes of space, mediated by discrete fields.

The theory extends to time at the level of organic life. It explains how the human-perception of time arises at the cognitive level, and why we perceive time as universal.

This theory suggests that time is all of particle-based vs. spacetime, relative vs. absolute, local vs. universal, depending on the level of assembly being considered. However it is also none of those things individually.

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11 Conclusions

Originality

The Cordus theory is a conceptual framework for fundamental physics. It shows that a specific structure of particles has excellent explanatory power for many phenomena. The strengths of the theory are:

- Explanatory (ontological) power
- Coherent solution across multiple phenomena
- Offers candidate solutions to otherwise intractable problems

Implications

The Bell-type inequalities are falsified. Physical realism is re-asserted. The stochastic nature of the wave-function is subsumed in a deeper explanation.

- The theory is not inimical to quantum mechanics, which it reinterprets as a stochastic approximation of a deeper determinism.
- The relationship of the theory to string/M theory is uncertain, but the number of functional variables required by the Cordus theory is consistent with the number of dimensions required by some string theories.
- The new theory has philosophical implications because it shows that it is possible to conceive of a solution for fundamental physics that is grounded in physical realism and hidden variables. The theory therefore rebuts the idea that the deeper level of physics is purely mathematical, and it rejects the many-worlds interpretation. The weirdness of quantum mechanics is an artefact of QM, not a requirement of physics.

Limitations

The theory is a valid (strong) one, though verification (truth) has yet to be established beyond reasonable doubt. Reviewers seek mathematical proof.

Future research

The formalism is qualitative, and there are many opportunities and difficult future challenges to establish a mathematical representation of the proposed causality.

At present the theory is a conceptual framework, one that has been created using a systems design approach. Consequently its lemmas are mostly qualitative expressions of causality. Opportunities for further research are plentiful, and there is a particular need at this time to develop a mathematical formalism of the theory for the purpose of testing against competing theories and against quantified empirical phenomena.

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