Proton-Neutron bonds in nuclides: Cis- and Trans-phasic assembly with the synchronous interaction

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Abstract

Existing theories are unable to build nuclear structures from the strong interaction upwards. This limitation applies to quantum chromodynamics, binding energies, the shell model, liquid-drop model, and the semi-empirical mass formula. This paper solves part of this problem, starting from a non-local hidden variable (NLHV) design solution. The Cordus theory for the synchronous interaction (strong force is used to predict that protons and neutrons may form different types of bonds, with different stability. Specifically the synchronous interaction is found to be able to assemble particules in- and out-of-phase (cis- and trans-phasic respectively). We identify the role of the neutrons in nuclear bonding, and how the proton and neutron are bonded, and the advantages to both in doing so. In contrast to conventional models of the nucleus, the Cordus theory predicts that protons in stable nuclei are not bound directly together, nor in an amorphous collection (liquid drop), nor as shells, but rather through neutrons as intermediaries. The neutrons provide a set of discrete forces that are complementary to those of the proton, and it is the resulting synchronicity of discrete forces that creates the stable bonding within the nucleus, and has nothing to do with charge per se. Falsifiable predictions are identified. The internal structures of the hydrogen nuclides are derived. The work is significant in that it provides underpinning principles for explaining nuclear bonding and the nuclides. The implications are that nucleus structure is not a simple assembly of points, nor a packing of spheres, but an assembly of rod-like structures into three-dimensional chains of protons and neutrons, hence nuclear polymer.

Keywords: nuclear physics; nuclides; strong interaction; spin; hidden variable, QCD

Edition 1 > Date: Wednesday, 4 September 2013 > Document: Pons_Cordus_CM-06-03-01_ProtonNeutronBonds_E1_33.doc

1 Introduction

Explaining nuclear structures from the strong interaction has not previously been possible. There is a Standard model of particles, and also a theory of the strong interaction provided by gluon exchange between quarks in quantum chromodynamics (QCD). There are empirical data for binding energies for the nuclides. There are also theoretical models of

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nuclear stability. However all these theories are fragmentary and lack integration.

Given that the nucleus consists of protons with positive charge and neutrons that have no charge, the questions are: What binds the protons together, despite their mutually repulsive electric charge; Why are the neutrons necessary? In this paper we develop a theory that starts to offer a solution to these problems. We show that it is feasible to use a hidden variable to explain simple nuclear structures from first principles.

2 Existing nuclear models

There is no existing theory that can explain the nuclides. However there are several theories that address parts of the problem, and these are briefly reviewed.

At present the bonding of quarks inside the nucleons is best explained by quantum chromodynamics (QCD) with its conjectured exchange of gluons [1, 2]. However QCD does not fully explain all the characteristics of the strong force, and this is particularly evident in its vagueness about the mechanisms for how the proton and neutron bond. It thus has little to contribute to our understanding of how *multiple* nucleons might interact. It fails to explain nuclear structure.

More comprehensive nuclear models are the shell [3], liquid-drop [4], and semi-empirical mass formula (SEMF) [5]. These theories, particularly the SEMF, mathematically *model* rather than *explain,* the binding energy (BE) characteristics. They do this reasonably accurately, which might be considered a success if not for the fact that they are totally disconnected from any theory of the strong force. There is a further problem in that binding energy is an inaccurate predictor of nuclide stability. These theories attempt to solve the quantitative part of the problem, because that is amenable to the mathematical modelling method, but this is not the real problem. The real need is to differentiate stable from unstable nuclides, but none of these theories are able to do this. Consequently, while there logically *should be* a theoretical progression from the strong force to nuclear structure, this simply is not the case. No existing theory, or collection of theories, is able to build nuclear structures from the strong interaction upwards.

3 Purpose and approach

A non-local hidden variable (NLHV) design, called the Cordus theory, has previously demonstrated the capability to solve wave-particle duality, explain entanglement, and derive the basic optical laws [6], thereby falsifying the Bell-type inequalities [7, 8]. This theory conjectures that all particles are really linear structures of finite length (hence *cordus*), and from their two ends emit three-dimensional discrete forces that travel down flux lines (Cordus: *hyperfine fibril* or *hyff*). This structure is called a *particule*.[i] A companion paper [9] has identified how the strong interaction operates within this theoretical framework. Specifically it is proposed that the strong interaction is mediated by the synchronicity of discrete forces emitted by particules. The whole Cordus theory cannot be described here, and it is assumed that the reader has assimilated the prior material [9].

In the next stage, and the topic of the present paper, we identify how the Cordus synchronous interaction would operate on nucleons. We used a design[ii] method to develop a theory of nucleon bonding, as a logical extension of the synchronous interaction. Details of the design method are available elsewhere [9]. Assumptions are noted as lemmas in Appendix A [online only].

4 Results

We start by introducing the two components of the nucleus, the proton and the neutron. We then create a model for how they join, identifying two means for this. The synchronous interaction (strong force), which is described, is an important mechanism in these joints. The nature of the joint is identified as an important variable for the structural layout of the nucleus.

4.1 Proton and Neutron structures

The Cordus model for the proton is shown in Figure 1. The background explanations for *how* we came up with this model are described elsewhere [9].

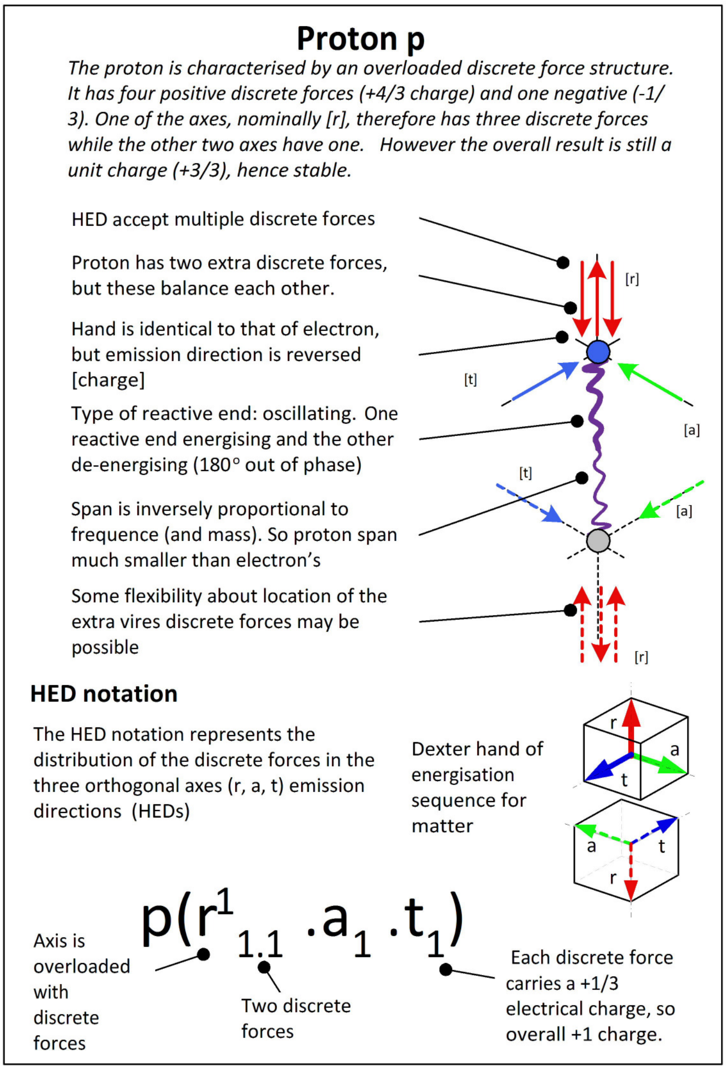


Figure 1: Cordus model for the proton. In the case of the proton one of these axes has an extra pair of discrete forces, giving four discrete forces in total but still a net charge of +1. The HED notation is a Cordus symbolic representation of the distribution of the discrete forces in the three emission directions, and is a unique signature for the type of particle. The proton has two discrete forces in one of the axes, hence the designation $p(r^1_{1.1} .a_1 . t_1)$. Note the use of $r^1_{1.1}$ as opposed to say r^1_2 . This is because the theory does not require that the two discrete forces are emitted simultaneously.

The Cordus model for the neutron is shown in Figure 2. This theory also explains why the neutron is unstable when alone [10]. This is because, while it has a unit charge (neutral), its HEDs are incompletely energised. Specifically the [t] axis is un-energised.

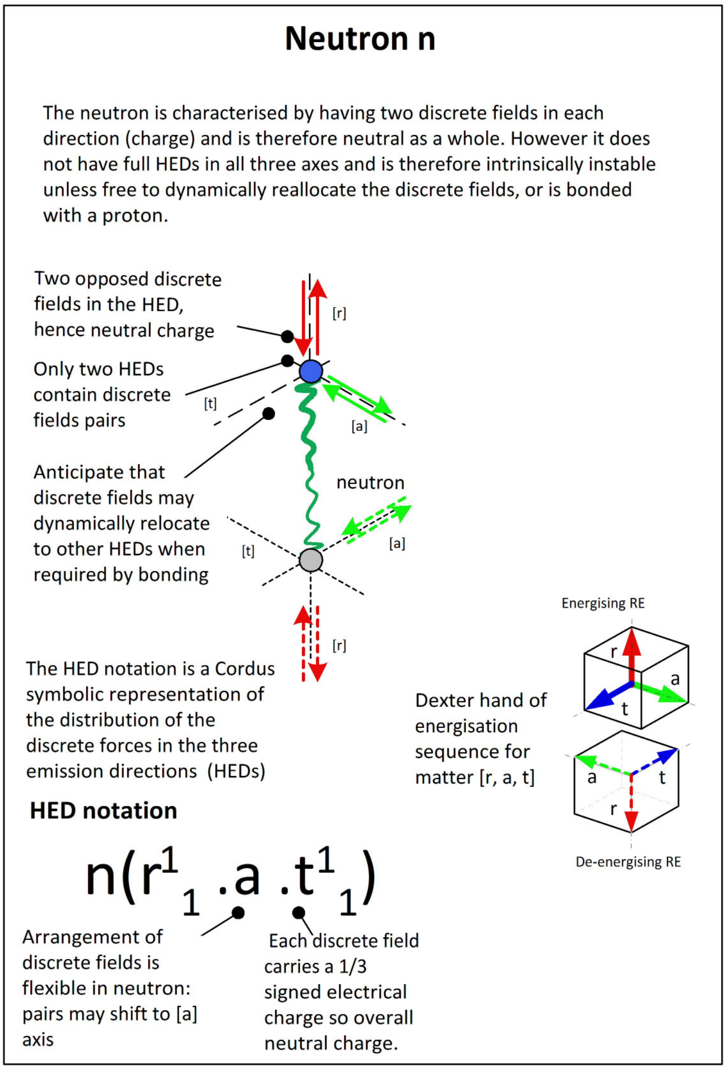


Figure 2: Cordus mode for the neutron. The HED arrangements provide a neutral pair of discrete forces, comprising a positive and negative force, on two of the emission directions. The overall charge is thus neutral. It is believed that the pairs may shift to other axes as necessary.

The Cordus theory proposes that the strong force arises from the synchronisation of discrete forces between particules [9]. The hyff emission directions represent the particule's directional engagement with the external environment, and so two particules that co-locate their reactive ends need to share this access, hence the synchronicity. This causes the participating particules to be interlocked: the interaction pulls or repels reactive ends into co-location and then holds them there, hence the apparent attractive-repulsive nature of that force and its short range. The Cordus theory predicts that this force only applies to particules in coherent assembly. It is proposed that the EMG forces and the strong force are different manifestations of a single underlying mechanism. The EMG forces are proposed to be based on the linear strength, bending, and torsional deflection (respectively) caused by these discrete forces, whereas the strong force is based on their synchronicity. By implication particules can EITHER perceive the strong force, OR the EMG forces, not both. Which it is depends on the nature of their bonding and their proximity.

The strong force is predicted to be intimately linked to matter that is in the coherent state, with the EMG forces being the associated discoherent phenomenon. This also means that there is no need to overcome the electrostatic force, because it is inoperative when the strong force operates. Calling this the *strong* force is an inappropriate way of thinking about this interaction, which is why we rename it the *synchronous* interaction.

Thus we have provided individual models for the proton and neutron. Of course these models are very different to the orthodox zero-dimensional point models for these particules, so we are already proposing a major departure. The next step in the creation of a nuclear model is to find a candidate set of principles for the assembly of protons and neutrons using this synchronous interaction.

4.2 Phased behaviour between particules

Note that in this theory each particule has two ends, and take special note of the idea of span, i.e. a physical distance between the two reactive ends. Consequently two particules only need be joined at one location, and the assembly can therefore have physical size – there is no singularity as with QM. Note also that that the particule energises its reactive ends sequentially, at its frequency. This is important because it implies that the reactive ends are not both simultaneously in the same state, and hence a phase exists. Next we consider the consequences of phase offset between two particules - this corresponds to the QM concept of 'spin'. Note the assumption that coherent particules already have a common magnitude of frequency.

Consider two particules that share a common location for *one* each of their reactive ends. There are two states that particularly interest us: the particules may be in or out of phase with each other at their common location. We term these cis- and trans-phasic behaviour. We elaborate on these below. We are particularly interested in the assembly relationships between a proton (p) and neutron (n).

4.2.1 Cis-phasic interactions

Cis-phasic bonding occurs where reactive ends, one from each of two *different* types of particules, are co-located, have the same frequency, and are *in-phase*. The two particules must have complementary discrete forces emissions, and this generally means they must be different types.[2]
The case in point is the bonding of a proton and neutron: their discrete forces arrangements are very different, but the combination gives a neatly

[2] *Cis-phasic bonding*: Like charged particles, such as electrons, have no advantage of forming cis-phasic bonds at close range, and at longer range the electrostatic force is repulsive, so does not encourage the engagement. However the Cordus theory does not preclude cis-phasic bonds for electrons. Cisphasic bonding of two protons is no better, since there is no advantage in combining two protons each with four discrete forces: the outcome is no more balanced than the components. Likewise two neutrons, of four discrete forces each, have no advantage in bonding: quite the contrary, the Cordus theory suggests this will encourage decay. However three of anything stable should have better prospects.

balanced arrangement, and therefore makes it easy for the particules to maintain the synchronicity, hence greater stability. We denote this type of joint as p # n. The cis-phasic behaviour results in the merging of the reactive ends into a new assembly characterised by high bonding forces and the sub-components losing much of their individual identity (due to efficient energy sharing). We propose this synchronicity as the mechanism for bonding the quarks into the nucleons, and the proton with the neutron in the nucleus. There are two sub-types of this interaction: parallel and series.

Parallel assembly

In parallel assemblies each particule joins to the other at *both* reactive ends. This mutually interlocks the energisation sequences of the particules at both ends, and also constrains their spans to a common length.[3] We propose this as the mechanism for single proton to neutron bonding as in $_1H_1$. We anticipate the process whereby these two particules make a cisphasic assembly, as shown in Figure 3.

The basic idea is that two approaching p and n particules, that are not too dissimilar in frequency and phase, negotiate via their discrete forces and adjust their emissions to move into synchronicity. The synchronous emissions then lock the two reactive ends together. The figure elaborates and is not repeated here. Please also see the lemmas below for the proposed basic rules and mechanics. This process is interesting in another way, because it proposes to show how the additional dimensions are involved when moving from the zero-dimensional QM construct to the 3D cordus model.

[3] *Consequences of the Synchronous interaction.* The interaction imposes a common frequency (or harmonic) on all particules in the assembly. This means, according to the Cordus theory, that the spans of the particules will also be locked (since frequency is inversely proportional to span). This common span has other interesting consequences. Firstly, there will be internal strain since dissimilar particules have different rest masses and therefore, according to the Cordus theory, proportionally different spans. The particules will have to initially transfer energy to each other to obtain the match in spans. If the particules are too dissimilar then the strain becomes an agent for disassembly. Secondly, once bonded in thus way the energies of the particules are locked together, and the energy of one particules, e.g. if it absorbs a photon, is available to the other. This too is a consequence of the mass, energy, and inverse-span correspondence proposed by the Cordus theory.

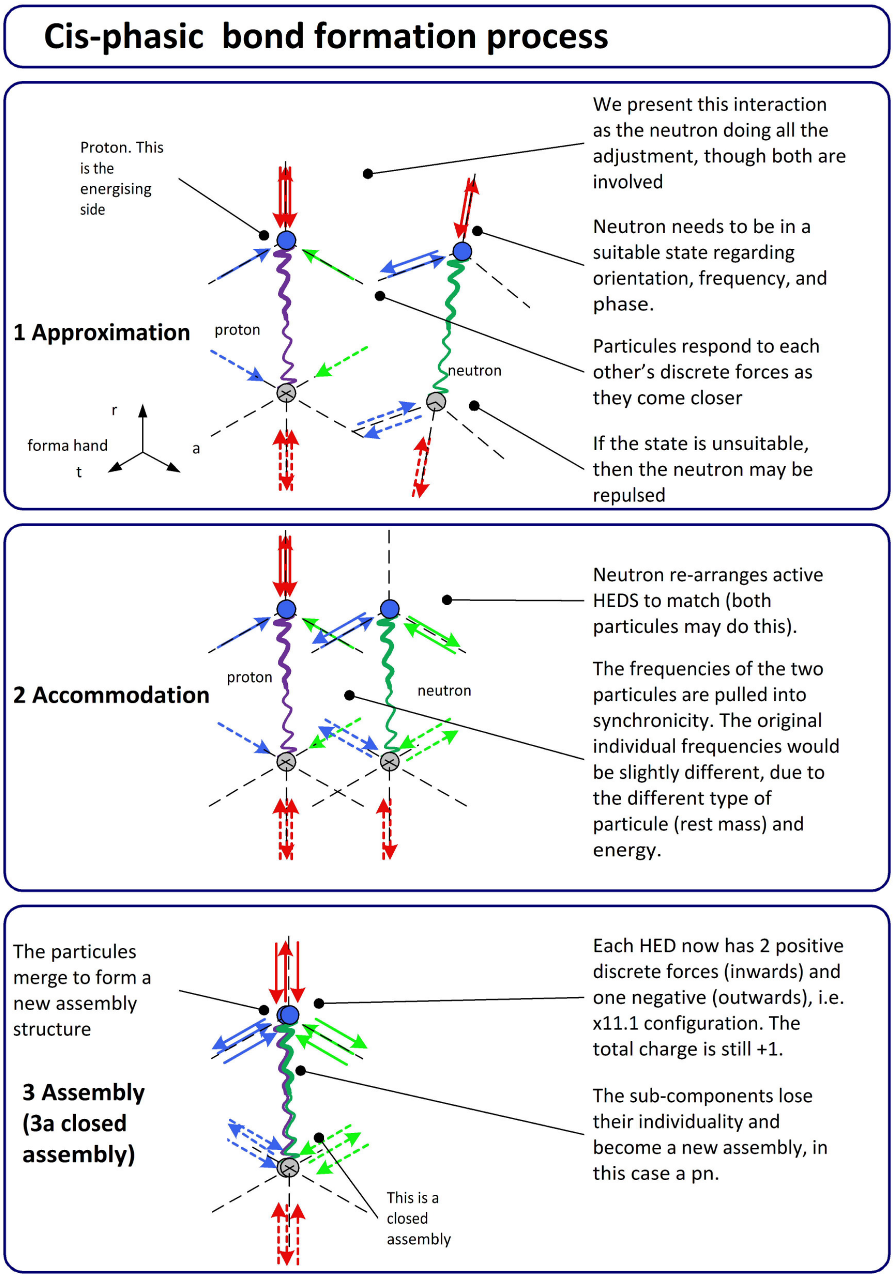


Figure 3: Cis-phasic assembly (p#n): Proposed process mechanisms for bonding of proton and neutron. Note that the reactive ends of the two particles are superimposed on each other, and have the same phase. This type of interaction is only available to a pair of particules that complement each other in HEDs. Thus a proton-neutron pair, but not proton-proton or neutron-neutron (which must instead bond trans-phasically).

The outcome is a new assembly, in this particular case a pn deuteron [10], for which the Cordus HED notation is:

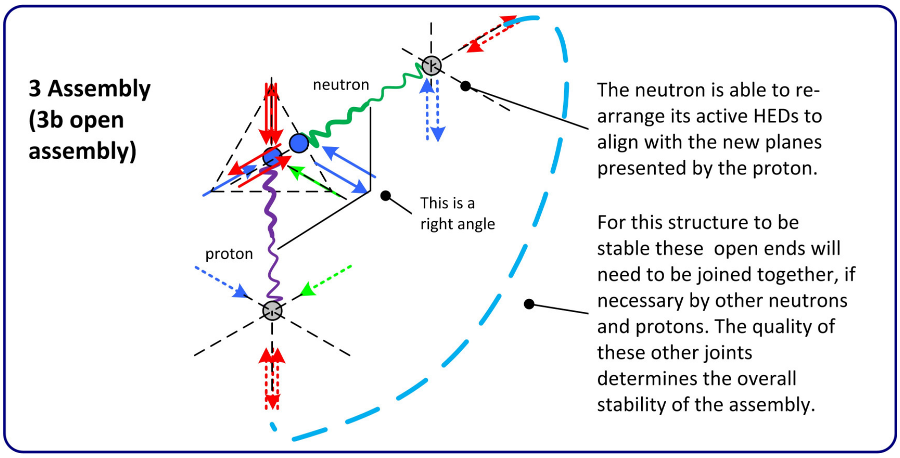
$$n(r\,.a_1^{\ 1}\,.t_1^{\ 1}) + p(r_{1.1}^{\ 1}\,.a_1\,.t_1) \Rightarrow O(r_{1.1}^{\ 1}\,.a_{1.1}^{\ 1}\,.t_{1.1}^{\ 1})$$

where O is the deuteron.

Note that the output HEDs are balanced regarding discrete forces: the assembly reactive end two inward discrete forces and one outward, *in* *each of the three* emission directions [r, a, t]. Consequently this meets the stability criteria derived in previous Cordus work [10]. Note also that the output state O is more balanced, hence better for stability, than either of the input n or p. This explains why there is advantage in the positive proton bonding with the neutral neutron. The bond is not made on the basis of charge. i.e. the bond is not electrostatic. Rather the participants are motivated to obtain a more balanced emission of discrete forces, a balance less susceptible to external interference and hence also more stable against decay.[4] This also explains why the neutron is stable when bonded with a proton, but unstable on its own.

Series assembly with cis-phasic open chains

The simple pn deuteron described above is characterised as being a closed assembly: the two reactive ends of the proton and neutron each find a partner with each other. We also anticipate a locally-open assembly, where there is only a single partnership between any one proton and neutron, and this is shown in Figure 4.



[4] *Decay and stability:* In the Cordus theory decay simply corresponds to disassembly of the structure. That which is preserved in disassembly is the net number of discrete forces, and the hand, and these can be distributed into the disassembly products in a different way to the original input particules. The Cordus theory for the decay of the neutron explains this further. Stability is an interesting concept at the particule level. From the Cordus perspective it is not so much a lower energy state (though we don't deny that interpretation) but rather a safe-guarded state. The Cordus theory suggests three mechanisms for stability. First, particules are <u>actively attracted</u> into assembly relationships with certain other particules by the HED negotiation process. That in turn is driven by mutual satisfaction of HED compatibility or completion of missing HEDs. Second, particles are <u>held</u> in such assembly positions by the ongoing synchronous emission of discrete forces. Furthermore, synchronous assemblies provide <u>protection</u> against external disruption. The protection arises because (a) in cis-phasic bonds the particules can project a more complete external presence of their discrete fields so are less vulnerable to the internal instability caused in response to externally imposed fields, or (b) in trans-phasic situations the particules look after the re-energisation locations in the absence of each other thereby protecting against external interference. The perturbation originates in the ceaseless discrete forces of other particules in the accessible universe, which makes up the fabric of space. Perturbation can also arise from the intrusion of a third particule with its own stronger field system. Once in such a synchronous assembly, particules tend to stay there, whereas non-assembled particules get buffeted by the external perturbations and are thereby randomly moved and actively drawn to other situations. So stability at this level can be understood in terms of interlocking of discrete-forces.

Figure 4: Alternative open assembly for cis-phasic joint (p#n). Here the proton and neutron are joined at only one reactive end each.

This structure is not stable on its own, according to the Cordus mechanics, because the neutron has a naked reactive end. The mechanism for instability is anticipated in companion papers on the weak decay [10, 11]. The open ends need to be joined together by other particules, to form a closed loop. This open-assembly pn deuteron can therefore join up with others like it, to form a *nuclear polymer*. The Cordus explanation for atomic structure is based on arrangement of this nuclear polymer in 3D space, as we explore in subsequent papers.

4.2.2 Trans-phasic interactions

The trans-phasic joint also involves co-location of the reactive ends, synchronous frequency, and the strong force, but the difference is that the reactive ends are at *opposite phases* (hence trans-phasic). Thus the reactive end of one particule energises at the location while the other de-energises. We denote this type of joint as p x p, or n x n as the case may be.

The basic structure of a trans-phasic interaction is shown in Figure 5. This is for two particules in a parallel arrangement. The re-energising reactive end of particule *A* keeps the common location occupied while particule *B* is de-energising. This reduces the risk that some interloper will take that location. So the interlocking of hyff in a complementary fashion protects the assembly from external perturbation, hence enhancing stability. However the effect, according to Cordus, is not so much active bonding as mutual protection, which is not quite the same thing, though a degree of forceful engagement is nonetheless expected.

We propose this form of assembly is also responsible for coherence in matter, hence also Bose-Einstein condensates and superfluids. The same trans-phasic relationship, applied to pairs of electrons, explains electron-pairing, the Pauli exclusion principle, and Cooper pairs. A series trans-phasic relationship of a skin of electrons explains superconductors.

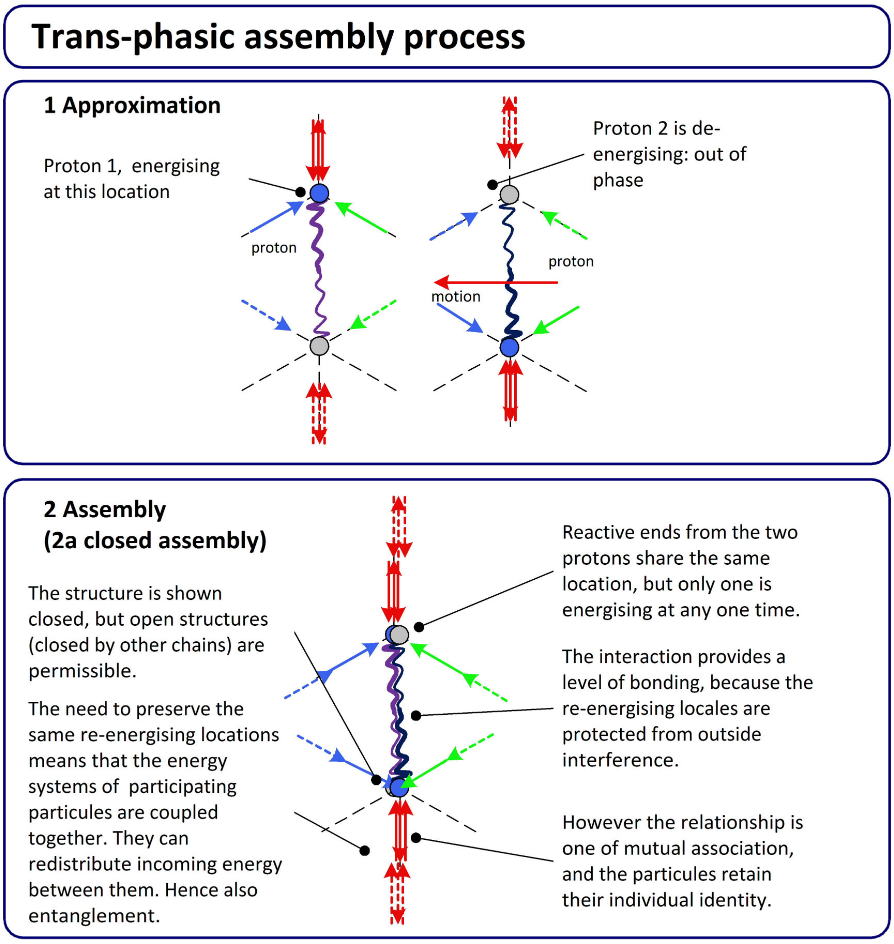


Figure 5: Trans-phasic joint (p x p): The joining of two particules, two protons this case, with opposite phase allows them to share the same space. Although illustrated with two protons, this type of bond is available to any *pair of like particules, including neutron-neutron, electron-electron, etc.*

As before, a series assembly is also anticipated, with a locally-open chain, see Figure 6.

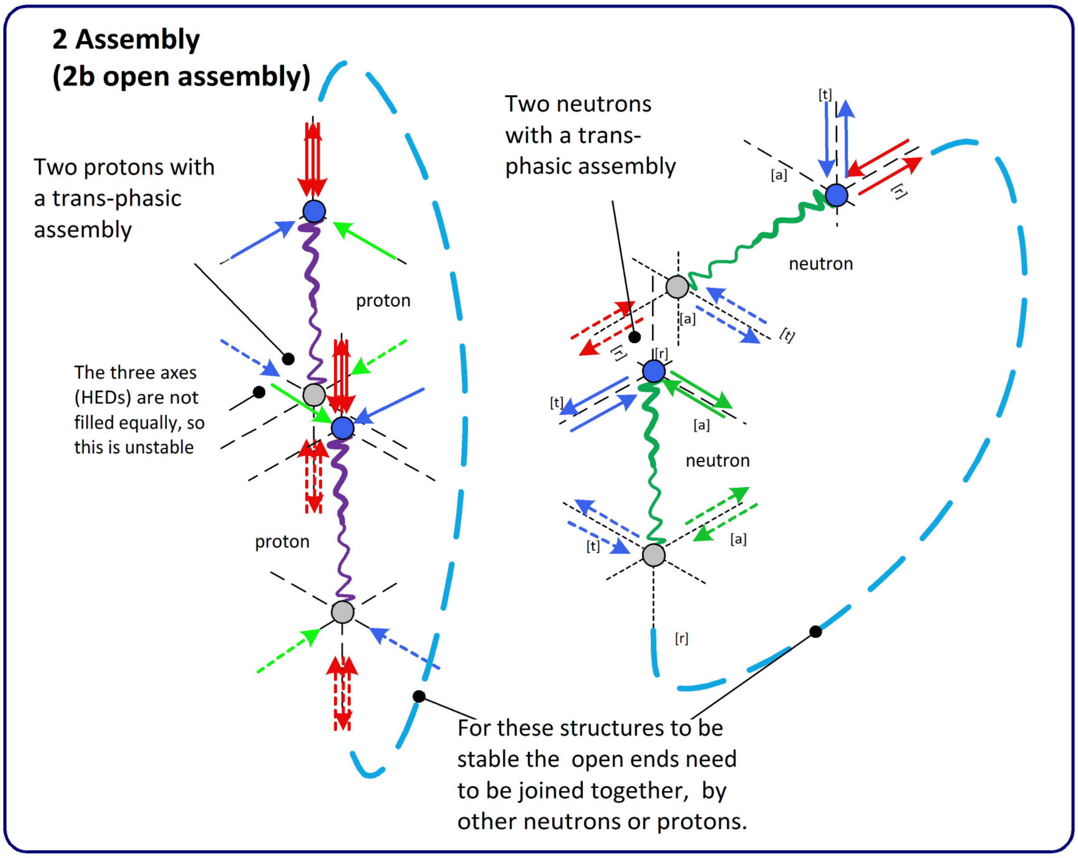


Figure 6: Trans-phasic open assembly (p x p). Two variants shown.

The Cordus theory for trans-phasic joints suggests that neutrons ought to be able to be joined in extended chains, even if these are not stable.

4.3 Joint types

Thus it is proposed that the synchronous interaction gives rise to a variety of basic joint types between particules, see Figure 7.

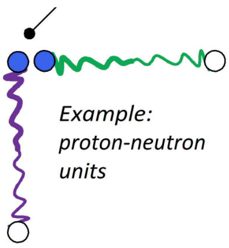
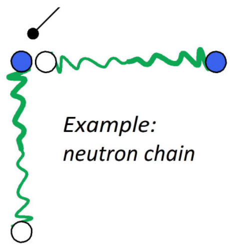
ASSEMBLY NOTATION	Cis-phasic (in-phase) #	Trans-phasic (out of phase) x
PARALLEL ASSEMBLY (CLOSED: both reactive ends match)	Cis-phasic: (p1 # n1)  *Example: $_1H_1$* Two particules sharing geometric location of both their reactive ends, in-phase	Trans-phasic: (p1 x p2)  *Example: Pauli pairs* Two particules 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*

Figure 7: Summary of the cis- and trans-phasic joint types and their application to parallel and series assembly structures.

The above are general principles that we propose apply to *all* particules, including electrons, pions, etc. Next we identify which of these principles are applicable for the nucleons, see Table 1.

Cis-phasic # (reactive ends in-phase)	Transphasic x (reactive ends out-of phase)
Two protons p # p NOT VIABLE	Two protons p x p VIABLE
Two neutrons n # n NOT VIABLE	Two neutrons n x n VIABLE
Proton joined to neutron p # n VIABLE	Proton joined to neutron p x n NOT VIABLE

Table 1: Viability of the different proton and neutron combinations.

It will be seen that the cis-phasic bond only applies to proton-to-neutron joints, and the trans-phasic to bonds between like particules. The reasons for this are self-evident from the nature of the synchronous interaction: particules only share reactive end locations when there is a HED advantage in doing so.

4.4 Application to simple nuclei

With models in place for the cis and trans applications of the strong force, we now have enough basic concepts to identify the layout of the nuclear polymer for the hydrogen nuclides, see Figure 8. Hydrogen $_1H_0$ is easy, being simply the proton as already shown. We propose that the $_1H_1$ deuteron is a closed (parallel) cis-phasic assembly of one proton and one neutron, as per Figure 8. The $_1H_n$ nuclides of hydrogen are series insertions of neutrons with trans-phasic bonds.

Understanding these nuclides requires additional principles beyond the phasic bonding principles developed here, which are fully described in companion papers. For example, the cubic structure and bridge nucleons are subsequent developments. Nonetheless it is already possible to explain some of the trends in these nuclides. The stability of $_1H_1$ can be explained by the cis-phasic proton-to-neutron bond. Likewise the long life of $_1H_2$ is attributed to its cis-phasic bonds, and its instability to the structure lacking orthogonality. The poor viability of all the higher nuclides is explained by their trans-phasic neutron chains. Also included is an explanation of why the series stops where it does, at $_1H_6$. This is because there is a neat morphological boundary at $_1H_6$ such that the next longer polymers do not have access to a suitable layout.

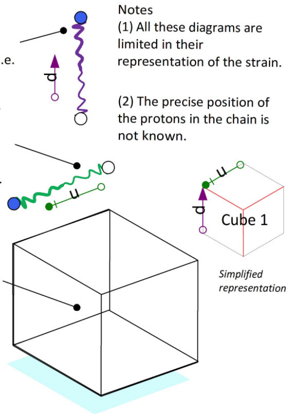
Cordus Nuclear theory:

Legend

Proton. Darker end (blue circle) indicates energising end, i.e. phase (spin).

Neutron. Darker end (blue circle) indicates energising end, i.e. phase (spin).

Protons and neutrons preferentially join at right angles, hence cubic structures.



Notes
(1) All these diagrams are limited in their representation of the strain.

(2) The precise position of the protons in the chain is not known.

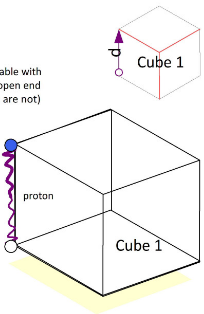
Simplified representation

$_1H_0$

Atomic Hydrogen (stable)

At the most basic level the simplest nucleus consists of a single proton with a particule structure. The single proton can exist with its ends exposed.

Protons are stable with an externally open end (but neutrons are not)



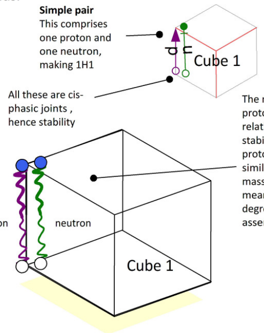
$_1H_1$

D, A tomic Hydrogen (stable) (deuterium)

The stability of this nuclide is attributed to the single proton and neutron forming an overlapping linear structure using cis-phasic bonds.

Simple pair
This comprises one proton and one neutron, making 1H1

All these are cis-phasic joints , hence stability



The neutron joins with the proton in a cis-phasic relationship. Doing so gives stability advantages to the proton and neutron. The similar but not-identical masses of the particles means that there is a small degree of strain in the assembly.

$_1H_2$

(unstable) (tritium) 12.32 yr

Relatively long half-life (12 yrs), naturally occurring.

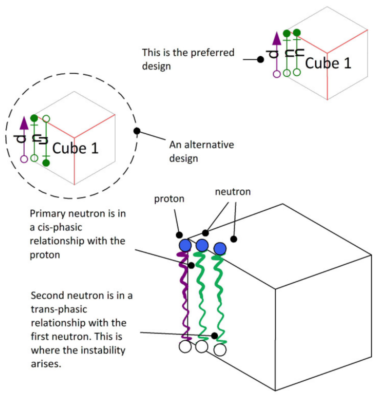
Nuclides higher than 1H1 require transphasic joints between neutrons, and these introduce instability. The longevity of 1H2 is attributed to the simple unstrained assembly.

This is the preferred design

An alternative design

Primary neutron is in a cis-phasic relationship with the proton

Second neutron is in a trans-phasic relationship with the first neutron. This is where the instability arises.



$_1H_3$

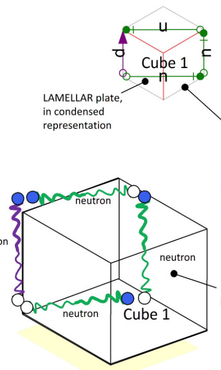
(unstable) 139E-24 s

The additional neutron (cf 1H2) causes a major shape change.

LAMELLAR plate, in condensed representation

This SUBASSEMBLY is one of the permitted types. However being the smallest of the subassemblies the strain per joint is high. Hence it has poor stability (except when balanced with 2 protons and 2 neutrons).

LAMELLAR plate

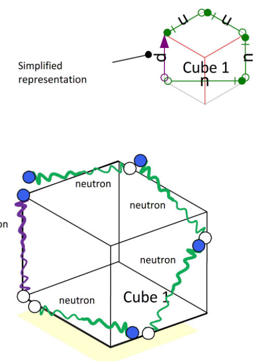


$_1H_4$

(unstable) >910E-24 s

The stability is similar across this series, as these are all non-viable structures.

Simplified representation



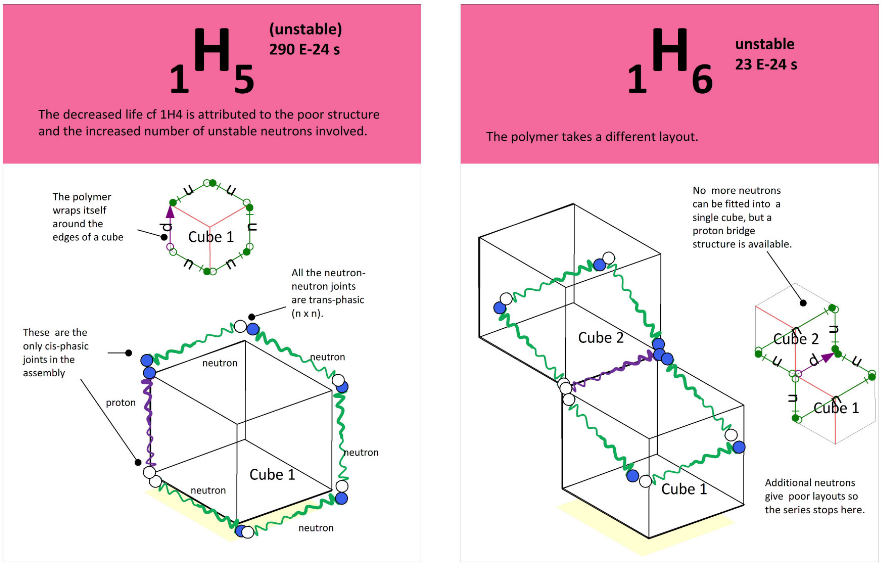


Figure 8: Internal structure of the nuclides of hydrogen, as proposed by the Cordus theory.

5 Discussion

If the Cordus theory is correct, then nucleus structure is not a simple assembly of points, nor a packing of spheres, but an assembly of rod-like structures into three-dimensional chains of protons and neutrons. We refer to this as a *nuclear polymer*.

5.1 System model

The overview of our conceptual framework is shown in the system model of Figure 9. This diagram is represented in integration definition zero (IDEF0) system modelling notation [12]. There are five conceptual components to this theory, with relationships of causality between them. Those five components are models for the internal structure of the proton, and neutron, the Cordus synchronous interaction, and proposed cis-phasic and trans-phasic bonding between nucleons. These are each described above, and the diagram summarises their relationships.

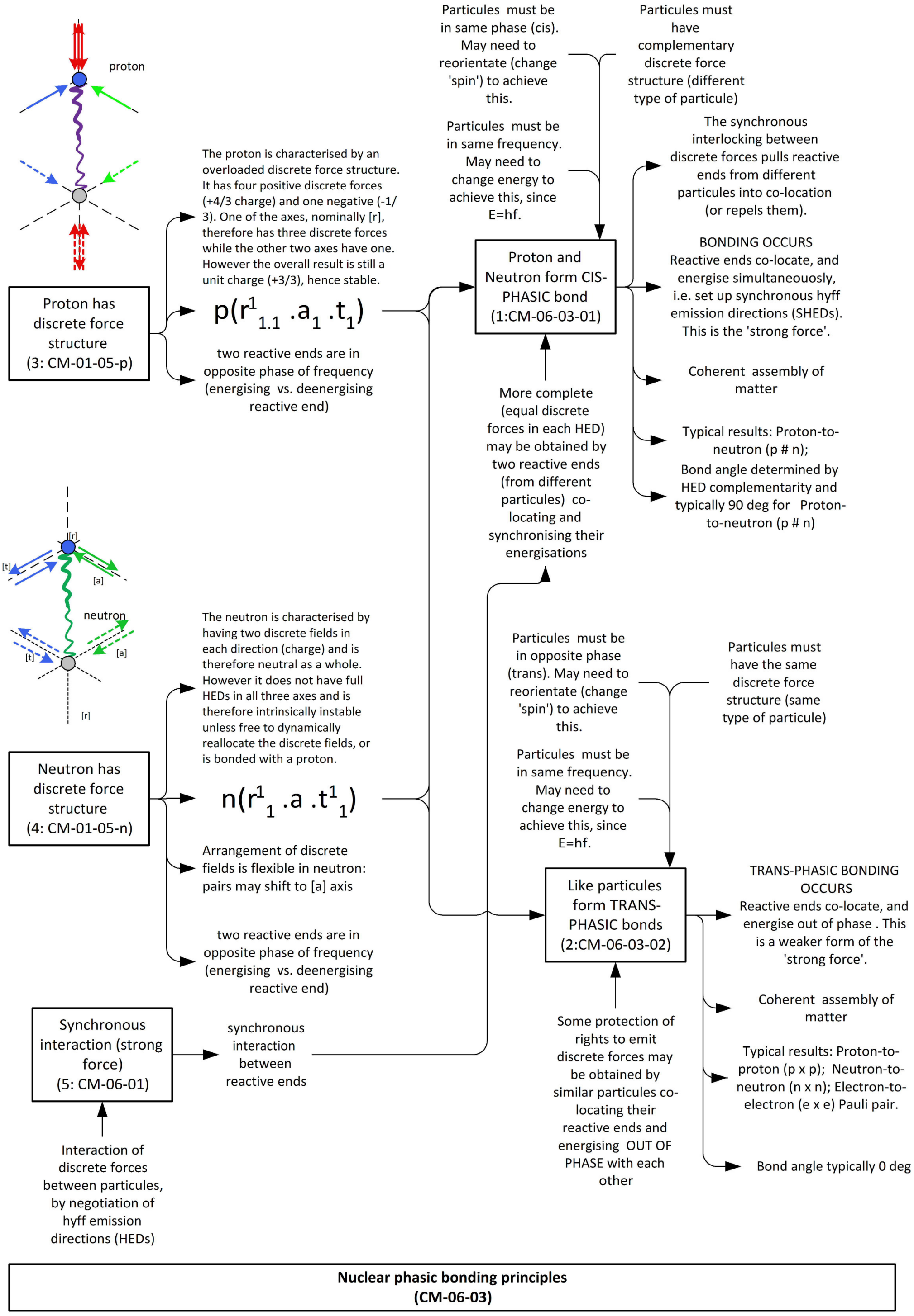


Figure 9: System overview of the causes of bonding between protons and neutrons in the nucleus. The diagram summarises the main features of the Cordus design of the proton: this is a non-local hidden variable solution and it proposes that the proton has internal structures as well as a particular signature to the discrete forces (discrete fields) that it emits. Likewise the neutron. The rest of the diagram identifies the two different types of synchronous (strong) bond being proposed here, namely the cis-phasic and trans-phasic states.

5.2 What has been achieved?

This paper makes several novel contributions, and has some testable predictions.

A richer understanding of the synchronous interaction (strong force)

The first contribution is the conceptual one of building a more nuanced concept for the strong force generally (Cordus: synchronous interaction). We propose a radically different idea to the usual construct, both for the strong interaction at the quark level, and the strong nuclear force. Conventionally the strong nuclear force overcomes the electrostatic repulsion of protons, but the Cordus theory instead proposes that the electro-magnetic-gravitational (EMG) forces, e.g. electrostatic forces between nucleons, are *inoperative* within a coherent body such as the nucleus (at least for small nuclei), and instead the synchronous force is manifest.[5] This is a radical departure from the orthodox perspective, which otherwise sees the strong and electrostatic forces as operating *concurrently.*

The Cordus theory predicts that the interaction between neighbouring protons in the nucleus is entirely synchronous (strong force) and that there is no electrostatic repulsion (at least for small nuclei). The corollary is that it predicts that the electrostatic force (and not the synchronous interaction) operates between free protons in discoherent assemblies. This may be falsifiable.

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[5] *Synchronous interaction for coherent assemblies, and EMG forces for discoherent:* The Cordus EMG forces are proposed to be based on the strength, bending, and torsional deflection caused by these discrete forces, whereas the strong force is based on the synchronicity thereof. Thus it is proposed that a particule can *either* perceive the discrete forces from another particule as synchronous force, or as EMG forces, not *both*. It is possible that immediate neighbouring nucleons would interact by the strong force, and potentially feel the effect of more distant nucleons (in the same atom or other atoms) as the electrostatic force. This is consistent with the liquid drop model of the nucleus. Note also that by providing a physical size and two reactive ends to the particule, the Cordus theory avoids the problem of a singularity developing in the nucleus. Conventional physics expects the strong force to have a repulsive component at short range, to counter the strong attraction and prevent a singularity in the nucleus. This Cordus theory obviates the need for a repulsive component to the strong force. Instead it provides for an interlocking of the fields of the particules. It also solves another problem that plaques the conventional models of the strong force: the need to explain why the strong force has such a short range. Being so powerful, why does it suddenly stop at larger ranges? The Cordus explanation is simply that the synchronous force no longer operates when the particule that receives it is not in a synchronous relationship with the emitting particule (hence physical coherence). Consequently the Cordus synchronous force is a more parsimonious theory than others: it needs fewer variables to explain more phenomena. In design terms, it is a more *efficient solution*. A further point of difference is that the Cordus theory dismisses the conventional idea of the strong nuclear force being a *residual* component of the quark strong force. The problem with the *residual* idea is that it lacks specificity about how the strong force gluons leak out of the quark confinement to affect nucleons as a whole. The Cordus interpretation suggests that the *residual* concept is unhelpful, that it is instead preferable to view the phenomenon as the discrete forces of the nucleon being a direct outcome of the quarks. The quarks are exposed in the discrete fields: this is a main effect, not a residual one.

The second contribution is the idea that the synchronous interaction makes two distinct types of bond, differentiated by same vs. opposed phase (cis- and trans-phasic). This concept does not exist in conventional theories of the strong force.

Proton-neutron bonding and the necessity of neutrons

The third contribution is showing how the proton and neutron may be bonded. This has not previously been achieved. Existing theories like the shell and liquid drop models require but do not explain this. Nor does QCD, which though it has a solution for the bonding of quarks via gluons, does not explicitly explain the bonding between nucleons. The present work identifies an advantage to the proton in being bonded to a neutron, when otherwise there would seem no reason for such a bond. That advantage is the preferential alignment of discrete forces in three orthogonal directions.

In contrast to conventional models of the nucleus, the Cordus theory predicts that protons in stable nuclei <u>are not</u> bound directly together, nor in an amorphous collection (liquid drop), nor as shells, but rather through neutrons as intermediaries. This may be testable and falsifiable.

The neutrons are necessary because they provide a set of discrete forces that are complementary to those of the proton. The stable bonding within the nucleus occurs because of this synchronous compatibility, and has nothing to do with electrostatic charge per se.

The Cordus theory predicts that proton-to-proton bonds may be either cis-phasic or trans-phasic. This should be testable, given that that the Cordus concept of frequency phase corresponds to the QM concept of spin, which in principle is measurable. The cis-phasic bonds are predicted to be more stable than the trans-phasic.

The Cordus theory predicts that the nucleus is best described as a nuclear polymer of proton-to-neutron joints with cis-phasic bonds. Coupled with the Cordus concept that these particules have finite span (distance between reactive ends), this further predicts that the nucleus has physical size. The Cordus theory specifically rejects the zero-dimensional point construct of QM. This prediction of physical size may be falsifiable.

Models of simple nuclei

A fourth contribution is the provision of candidate descriptive physical models for the proton, neutron, deuteron, and several simple nuclide assemblies thereof.

The Cordus theory predicts that the proton and neutron have specific internal structures, and specific signatures for the emission of discrete forces. This may be falsifiable.

A fifth contribution is the prediction of the internal structure of the hydrogen nuclides. This provides for open and closed chains and hence nuclear polymers. We subsequently show in companion papers that this idea of nuclear polymers is able to explain other nuclides.

Usefulness of the approach

A sixth contribution is methodological, in that the work demonstrates that a system design approach (in contrast to the more typical mathematical methods used in physics) has the potential to deliver new insights and fresh ideas towards an old problem. Whether or not the results are valid, which is a separate consideration, this method is able to provide candidate solutions. We have shown how hidden-variable solutions, in this case the NLHV solution of the Cordus conjecture, have the potential to deliver surprising insights into nuclear processes. This has otherwise not been achieved with other hidden variable solutions, e.g. de Broglie-Bohm. The principles presented here, specifically the cis- and trans-phasic bonds, have the potential to support the development of a profoundly different theory of nuclear structure.

5.3 Contrasts

The points of difference of the Cordus theory arise from three attributes that are radically different to any other theory of physics including QM and QCD.

- The first is the proposition that the nucleons have geometric span. Hence the Cordus theory rejects the zero-dimensional point construct of QM. It is the 0-D point thinking that causes the orthodox paradigm to make the attribution, which we believe is wrong, that the nuclear bonding force is repulsive at short range, strong at middle range, and weak at long range. The Cordus particule idea provides physical interpretations for spin, frequency, phase, orientation angles (e.g. polarity), and parity violation which are otherwise indefinable in QM. Thus quantum mechanics is re-interpreted as a solution of averages, applicable only to coherent bodies where the size of the particles can be neglected, and otherwise irrelevant at both the sub-atomic and macroscopic scales.

- The second is that the two ends of a particule energise and de-energise in sequence, at a frequency. Consequently the whole particule is not in a single state. This is consistent with the QM concept of geometric superposition. In QM this is attributed to a fundamental stochastic variability, but the Cordus theory rejects QM's interpretation as a simplistic and coarse approximation to a deeper deterministic causality. Furthermore the Cordus theory outright rejects the QM idea that a particle can be in a temporal superposition, and therefore also rejects those many QM interpretations (Many Worlds, Schrodinger's Cat) that depend thereon.

- The third unique feature of the Cordus theory is the idea of discrete forces and how their synchronicity causes bonding. This has far-reaching and profound implications for nuclear bonding and cosmology, explored in other papers.

Taken together, the above three features give a solution whereby nucleons can have different types of bonds, which in the Cordus theory are cis- and trans-phasic. There is nothing like this in any of the other nuclear theories, nor in QCD. Furthermore, the Cordus theory predicts that nucleons are arranged geometrically in space, according to specific rules of orientation. This also explains why the nucleus takes up volume.

5.4 Limitations and Opportunities for further research

We are quick to point out that the conjectural nature of the Cordus theory is a limitation. The theory is a set of mechanics built on a conjectured internal & external structure for particles. Furthermore the design method, while good at fitting form to function, could result in spurious attribution of causal relationships. To limit those risks we have expressed the assumptions of the Cordus theory as a set of lemmas (see Appendix A), specifically identified falsifiable predictions, and checked the theory against more phenomena than reported here. To some extent this has been successful. The explanations of the Cordus theory are consistent with empirical evidence of how matter behaves under the strong force, so the theory has demonstrable *construct validity*. The theory also has good *external validity* in that it readily generalises to a wide range of different phenomena in physics, even up to the cosmological scale. By comparison other theories like QCD, de Broglie-Bohm theory, and general relativity, arguably have poor external validity: they only apply to a limited set of situations.

The Cordus theory is currently mostly a conceptual work. It lacks a mathematical formulism to give quantitative results: this formulism is left for future work. For example it does not calculate the binding forces, lifetimes, or the charge radii. So it is not a complete description of every feature of the strong force.

Opportunities for further work lie in two directions. One is to develop a mathematical formulism for the synchronous interaction, quantify the parameters, and evaluate the robustness of the resulting model against empirical data. The other is to further develop the concept and see if the theory can explain the nuclides. The need is to explain why any given nuclide is stable or unstable, explain anomalous observations (e.g. the instability of $_4Be_4$), and explain the trends in the table of nuclides (e.g. why the drip lines are where they are). No existing theory can do this, so it is a formidable challenge. Companion papers offer solutions to this problem.

6 Conclusions

The purpose of this work was to re-conceptualise the basic principles of the bonding of protons and neutrons, using inferences from the Cordus theory for the synchronous interaction (strong force). The resulting theory predicts that protons and neutrons may form different types of bonds, with different stability. Specifically the synchronous interaction proposed here is able to assemble particules with in- and out-of-phase (cis- and trans-phasic respectively), and into open or closed chains. We have also identified the role of the neutrons in nuclear bonding. In contrast to conventional models of the nucleus, the Cordus theory predicts that protons in stable nuclei are not bound directly together, nor in an amorphous collection (liquid drop), nor as shells, but rather through neutrons as intermediaries. The neutrons provide a set of discrete forces that are complementary to those of the proton, and it is the resulting synchronicity of discrete forces that creates the stable bonding within the nucleus, and has nothing to do with charge per se. Several falsifiable predictions emerge from this theory. Thus we have developed a qualitative model of the strong force and anticipated the nature of the assemblies it can make. This is useful because it provides principles for the assembly of nuclear structures.

THE ONLINE VERSION OF THIS PAPER INCLUDES ADDITIONAL MATERIAL:
A Appendix: Nuclear polymer Lemmas

A Appendix: Nuclear polymer Lemmas NP.2 – NP.4

The following assumptions are built into or emerge from this Cordus theory, and expressed as lemmas. These should be interpreted as proposed statements of causality. The lemmas represent the Cordus mechanics, and are a mechanism to ensure logical consistency within the theory. A previous paper describes the precursor lemmas (NP.1) for the synchronous interaction [9].

Nuclear polymer Lemma 2

NP.2 Requirements for a cis-phasic (#) assembly

NP.2.1 The assembly must meet the HED stability criteria.

NP.2.1.1 These include the need for have integer charge and balanced loading of discrete forces (Cordus: vires or hyffons) across the three emission directions (HEDs). (See other lemmas for details [10]).

NP.2.1.2 Cis-phasic assemblies are only available to particules that can *complement* each other regarding filled/unfilled HEDs, such that the assembly still meets the requirements for stability. Thus a p#n cis-phasic bond is highly advantageous to the proton and neutron, and next is a pxp trans-phasic bond, with a p#p cis-phasic assembly being the least attractive to the proton.

NP.2.2 Similar frequency:

NP.2.2.1 In the typical case of dissimilar participants, the frequencies of the particules need to be sufficiently similar to enable a common assembly frequency to be negotiated. In the case of the proton and neutron their rest masses are similar.

NP.2.2.2 Assemblies of particules with disparate frequencies (rest masses) are allowed, but the lighter particule will need to be in an energetic state (hence higher frequency).

NP.2.3.3 Alternatively, the particules will need to select harmonic frequencies. This is proposed as the reason for the discrete energy levels of electron orbitals.

NP.2.3 In-phase or cis-phasic: The particules need to be in phase with each other, i.e. at least one reactive end from each needs to energise at the same time in the same location.

NP.2.4 Suitable Orientation: The particules need to be orientated to a suitable frame of reference (3D reference plane). This too can be negotiated during assembly. This generally means that the spans of particules are oriented in increments of 90^{o} to each other.

NP.2.5 Open and closed configurations are possible (see below).

NP.3 Requirements for trans-phasic (x) assembly

NP.3.1 The particules need to be sufficiently similar in HED structures as to confer an advantage in doing this.

NP.3.1.1 We cannot exclude the possibility that they may need to be identical.

NP.3.1.2 Proton chains (pxpxp..) and neutron chains (nxnxn..) occur and have trans-phasic bonds.

NP.3.1.3 Protons preferentially bond cis-phasically with neutrons.

NP.3.2 The particules are co-located at one or both reactive ends.

NP.3.3 Trans-phasic: The co-located reactive ends need to have opposite phase.

NP.3.4 Open and closed configurations are possible (see below).

NP.4 Open and closed nuclear polymers

NP.4.1 The proton and neutron prefer both their reactive ends to be assembled with the reactive end of the other particule. In the case of the neutron this preference is strong, but weaker for the proton.

NP.4.1.1 Doing this confers stability.

NP.4.1.2 Consequently nuclei tend to consist of closed chains of protons and neutrons, hence 'nuclear polymer'. These may be cis- or trans-phasic, or combinations thereof.

NP.4.1.3 Network structures with crosslink bridge structures may be possible (are not excluded).

NP.4.1.4 The polymer closure may be achieved by two particles (in which case they directly match to each other's reactive ends, hence CLOSED assembly), or by a chain of other particules (OPEN assembly). All open chains are eventually closed elsewhere.

NP.4.1.5 The quality of these other joints determines the overall stability of the assembly.

NP.4.1.5.1 The cis-phasic joints are more stable than the trans-phasic.

NP.4.2 The exception is the single proton, which is stable outside a nuclear polymer.

NP.4.3 The protons in multi-proton nuclides are arranged with the cis- and trans-phasic bonds (as opposed to the nuclear drop model).

NP.4.4 Cis- and trans-phasic joints may exist at different parts of a composite assembly.

These new lemmas are consistent with those already in the wider Cordus set, so no rework of prior assumptions is necessary. This is useful to know as it confirms the logical consistency of the model.

References

1. Gell-Mann, M., *Symmetries of Baryons and Mesons.* Physical Review, 1962. **125**(3): p. 1067-1084. DOI: http://dx.doi.org/10.1103/PhysRev.125.1067.
2. Nambu, Y. and Han, M.Y., *3 TRIPLETS, PARAQUARKS, AND COLORED QUARKS.* Physical Review D, 1974. **10**(2): p. 674-683. DOI: http://dx.doi.org/10.1103/PhysRevD.10.674.
3. Ivanenko, D., *Remarks on the establishing the theory of nuclear forces.* Progress of Theoretical Physics 1985. **85**: p. 20-26. DOI: http://dx.doi.org/10.1143/PTPS.85.20
4. Gamow, G., *Mass defect curve and nuclear constitution.* Proceedings of the Royal Society of London, 1930. **126**: p. 632-644. DOI: http://dx.doi.org/10.1098/rspa.1930.0032.
5. Weizsäcker, C.F.v., *Zur Theorie der Kernmassen (The theory of nuclear mass).* Zeitschrift für Physik, 1935. **96**: p. 431-458. DOI: http://dx.doi.org/10.1007/BF01337700.
6. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. 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.
7. Bell, J.S., *On the Einstein Podolsky Rosen Paradox.* Physics, 1964. **1**(3): p. 195-200.
8. Leggett, A., *Nonlocal Hidden-Variable Theories and Quantum Mechanics: An Incompatibility Theorem.* Foundations of Physics, 2003. **33**(10): p. 1469-1493. DOI: http://dx.doi.org/10.1023/a:1026096313729.
9. Pons, D.J., Pons, A.D., and Pons, A.J., *Synchronous interlocking of discrete forces: Strong force reconceptualised in a NLHV solution*, 2013 p. 1-28. DOI: http://vixra.org/abs/1208.0030.
10. Pons, D.J. (2011) *Stability and decay: Mechanisms for stability and initiators of decay in the neutron*. vixra **1112.0002**, p. 1-17, DOI: http://vixra.org/abs/1112.0002. Available from: http://vixra.org/pdf/1112.0002v1.pdf.
11. Pons, D.J. (2011) *Weak interaction: Reassembly of particules*. viXra **1111.0023**, p. 1-9, DOI: http://vixra.org/abs/1111.0023. Available from: http://vixra.org/pdf/1111.0023v1.pdf.
12. FIPS. *Integration Definition for Function Modeling (IDEF0)*. 1993 12 Aug 2003]; Available from: http://www.itl.nist.gov/fipspubs/idef02.doc.

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[i] *Inner and outer structure of the Cordus particule*
The basic idea is that every particle has two reactive ends, which are a small finite distance apart (span), and each behave like a particle in their interaction with the external environment. 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. Hence it is a non-local solution: the particule is affected by more than the fields at its nominal centre point: a principle of *Wider Locality* applies. 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 the particule shortens as the frequency increases, i.e. greater internal energy is associated with faster re-energisation sequence (hence also faster emission of discrete force and thus greater mass). When the reactive end is energised it emits discrete forces in up to three orthogonal directions. 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, a kind of coercive displacement. 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 hyff, 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 our previous nomenclature for the photon, 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 hyff emission directions [r,a,t] are filled (hence their fractional charge). In this theory electric charge is carried at 1/3 charge per discrete force, with the sign of the charge being determined by the direction of the discrete force element. So the number and nature of energised HEDs determines the overall electric charge of the particule. The aggregation of discrete forces from multiple particules creates the EMG fields, which are thus discrete. The combined emission discrete forces makes up a 3-D composite structure. The direct lineal effect of the discrete force provides the electrostatic interaction, the bending of the hyff flux line provides magnetism, the torsion provides gravitation interaction, and the synchronicity between discrete force elements of neighbouring particules provides the strong force. These are all carried simultaneously by the composite discrete force element as it propagates outwards on the hyff flux. Assembled massy particules compete spatially for emission directions, and may synchronise their emissions to access those spaces. Thus there is mutual negotiation in the near-field between interacting particules, based on shared geometric timing constraints. These particules interact by negotiating complementary HEDs and synchronising the emission frequencies of their discrete force elements. This synchronicity is proposed as the mechanism for the strong force and for coherent assemblies. The same mechanism, acting through coherent assemblies of electrons, explains molecular bonding. Thus the Cordus theory provides force unification by providing a model for electro-magneto-gravitational-synchronous (EMGS) interactions as consequences of lineal, bending, torsion, and synchronicity effects respectively. The discrete force element is a 3-D composite structure, with a hand defined by the energisation sequence between the axes. This hand provides the matter/anti-matter species differentiation. We acknowledge that we have not described *what* these discrete forces and flux tubes comprise. Instead, the design method used to develop the Cordus theory simply shows that having such elements is a logical necessity for this solution.

[ii] *Design methodology.* The Cordus theory is a result of application of the systems design methodology. This method seeks to infer the necessary internal structure (of matter) from the functionality required (empirically observed behaviours of nuclei). The approach involves creating various solutions and testing them in thought-experiments against known phenomena and empirical results, to select the fittest solution. That solution is then taken to the next level of abstraction and concretisation, by extracting a set of proposed mechanisms of causality, and implications for other areas, respectively. The design process is then repeated, and the solution modified as necessary. The fittest solution is that which can most parsimoniously explain as many phenomena as possible. Here we only present our final result, not all the dead-ends. The outcome we get is a design for the physical features and operating principles of particles.