Conceptual paper

Nuclear polymer explains the stability, instability, and non-existence of nuclides

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Abstract

Problem – *The explanation of nuclear properties from the strong force upwards has been elusive.* ***Purpose –*** *This paper develops a theory to explain, from first principles, why any one nuclide is stable, unstable, or non-existent.* ***Approach –*** *Design methods were used to develop a conceptual mechanics for the bonding arrangements between nucleons. This was based on the covert structures for the proton and neutron as defined by the Cordus theory, a type of non-local hidden-variable design with discrete fields.* ***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. The synchronous interaction constrains the relative orientation of nucleons, hence the nuclear polymer takes only certain spatial layouts. The stability of nuclides is entirely 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.* ***Originality -*** *The concept of a nuclear polymer, and its associated mechanics, is novel and totally unlike any other theory. This mechanics is the first to explain the stability, instability, or non-existence of nuclides starting from the strong/synchronous force. It is also the first to explain the role of the neutron in the nucleus.*

Keywords: nuclides; isotopes; nuclear physics; strong force; atom; hydrogen; helium

1 Introduction

The internal structural relationships of the atomic nucleus are poorly understood. Although quantum chromodynamics (QCD) offers an explanation of intra-nucleon bonding in terms of colour force, the inter-nucleon bonding via the residual strong force is poorly understood. Nor is it clear how binding energy arises, or why the neutrons are necessary at all. Models exist for representing the empirical value of nuclide properties

such as binding energy. All these have their place, but are fragmentary and lack integration. None of the theories or models, singly or collectively, is able to explain nuclear properties from the strong interaction upwards. Nor has it been possible to explain, from first principles, why any one nuclide is stable, unstable, or non-existent.

This paper offers a solution to the latter problem. It shows, by using a specialised type of non-local hidden-variable (NLHV) design [1], that it is possible to explain nuclear structure from the strong force. The theory is able to successfully explain whether a nuclide is stable, unstable, or non-existent, and even the relative trends in lifetime. The role of the neutron in nuclear bonding is elucidated. The paper sets out the underlying assumptions of this theory, describes its mechanics, and applies these to the nuclides of hydrogen and helium. Other work extends this further, to include all the nuclides up to an including neon. This is potentially a profound break-though, as no other mechanics has come close to this level of explanatory power. That it is possible to achieve this from a NLHV basis is compelling evidence that the next physics may be based on particles having covert structures rather than being zero-dimensional points as at present.

2 Existing approaches to nuclear structure

The interaction between nucleons is not known with confidence. Consequently a direct computation of the Schrodinger equation is not feasible for anything but the simplest atoms [2]. Quantum chromodynamics proposes an explanation of the bonding of quarks inside the nucleons, by the exchange of gluon in the colour force [3, 4]. It is generally believed from consideration of the density of the nucleus, that the strong force has a short range, so that nucleons are only attracted to other local nucleons, not by the bulk of nucleons as a whole (which would increase the density beyond that observed). Density considerations also suggest that the force is repulsive at closer ranges, so the nucleons are unable to come too close. However QCD does not fully explain all the characteristics of the strong force, and is unable to explain how the proton and neutron bond. It thus has little to contribute to our understanding of how *multiple* nucleons might interact.

More comprehensive nuclear models are the liquid-drop model [5], semi-empirical mass formula (SEMF) [6], and Ivanenko's shell model [7]. The nature of these models is to approximate nuclear characteristics with mathematical representations. They include terms to accommodate the strong and electrostatic forces. However these theories 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 disconnected from any theory of the strong force. Anyway, binding energy only correlates weakly with nuclide stability. A further problem is that the models treat the neutrons and protons independently: there is an assumption that the particles are different and therefore occupy different quantum states. However it is also apparent from observation that no nucleus exists with multiple protons and no neutrons, so evidently neutrons provide an important role

within the nucleus, which is not represented in any of the existing theories. Similar problems apply to the *interacting boson model* [8, 9] which assumes that nucleons exist in pairs. However this limits the model to nuclides where p=n, which is an overly simplistic assumption.

Another problem that none of the models overcomes is how the nucleus is held together. The liquid drop and SEMF treat the nucleons as point particles uniformly distributed in a volume. The models require there to be some bonding between nucleons but do not identify the mechanism. Furthermore, the repulsive nature of the strong force at short-range is excluded from the nuclear models. A related problem is how the volume of the nucleus arises. The models can provide a mathematical fit to the empirical data for charge radii [10], yet none of the models explain *how* the aggregation of 0-D point particles creates geometric size. Deeply problematic is the disconnect between the QCD strong force and the nuclear models, as already mentioned.

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. A logically consistent physics should be able to explain how the strong force causes nuclear structure, but this has not been achieved. No existing theory, or collection of theories, can explain the mechanisms whereby the strong interaction causes nuclear structures. A core unresolved problem in nuclear theory is how protons and neutrons interact. Inspection of the empirical evidence in the table of nuclides shows that the assumption of independence of the nucleon particles cannot be valid. The stability is not determined simply by quantity of nucleons, as if protons and neutrons contributed equally. The Magic Number approach does not generalise to explain the table of nuclides as a whole. Instead stability of a nuclide is an unknown function of both the number of protons and of neutrons. Also, the evidence clearly shows that neutrons play an essential role in stability, though the trends are complex and the underlying mechanics are unknown. There is a need to find better theories describing how protons and neutrons interact, before the nuclides can be understood.

3 Purpose and approach

The purpose of this paper was to develop a systematic theory to explain the relationships between nucleons, and how this results in the e nuclides. The particular objective was to explain the stability, instability, and non-existence states of the nuclides.

The approach started with a specific design for matter. This was the covert-structure defined by the Cordus theory [1], which is a combination of a non-local hidden-variable design with externally propagating discrete fields. The hidden-variable approach was selected as it has shown excellent ability to solve many other complex problems in physics [11-14]. Seeking solutions in the hidden-variable sector is an unusual approach, as mainstream physics is generally dismissive of this sector. The usual objection is that local hidden-variable solutions are precluded by the Bell

type inequalities [15-17]. Nonetheless it is relevant to note that the inequalities do not preclude all *non-local* hidden-variable designs [18, 19]. A more serious limitation has been the inability of this sector to yield solutions, other than the de-Broglie-Bohm pilot-wave theory [20, 21] which has limited applicability. That limitation has been overcome by the advent of the Cordus theory, which is a type of NLHV design. A second reason for selecting the hidden-variable sector is that the theories based on a 0-D point premise have persistently failed to explain the nuclides, and are at an impasse. Therefore it is worth attempting other approaches. The results justify this decision by showing that it is indeed possible to explain the nuclides this way.

The method was conceptual, i.e. a gedanken experiment, using the engineering design method. This was applied to infer the structural arrangements between the nucleons that would be sufficient to provide the observed behaviour of the nuclides. The design was also required to maintain logical internal consistency, i.e. not to contravene the other parts of the theory. Necessary assumptions were recorded as lemmas. This design method is described more fully elsewhere [22, 23]. The result is a conceptual theory, expressed qualitatively.

The Cordus theory is built on the proposition that all particles have internal structures and emit discrete forces. More specifically they are proposed [24] to comprise two reactive ends some distance apart, with the reactive ends energised in turn at a frequency (the de Broglie frequency), at which time they emits discrete forces. These discrete forces propagate into the external environment, and are connected in flux lines (Cordus: *hyperfine fibril* or *hyff*) [1]. They make up the fields. The two reactive ends are joined by a fibril (hence *cordus*) that does not interact with matter, and which instantaneously coordinates the phase of the two ends. Thus there is an inner structure, and an external system of discrete forces. This structure is called a *particule*. Within this theoretical framework the strong force is mediated by the synchronicity of discrete forces emitted by NLHV particules [11]. Thus the *strong force* is reconceptualised as a s*ynchronous interactio*n. More details about the particule idea are available elsewhere, including development of the theory to explain wave-particle duality [1], unification of the electro-magneto-gravitational and strong forces [11], explanations for antimatter and the process of annihilation [12] [23], and a theory for time [13]. The present paper applies the design method to identify how such a synchronous interaction might operate on nucleons. The result is a conceptual theory that predicts a specific type of geometric layout of nucleons in the nucleus, and called a *nuclear polymer.* The mechanics of this polymer are identified and noted as lemmas in Appendix A.

4 Results

First, the predicted structures of the proton and neutron are described. A logical consequence of the theory is that such structures will form bonds with the synchronous interaction (strong force). Surprisingly, multiple types of bonds are predicted, which are termed cisphasic and transphasic for reasons which will become obvious. This is a radical departure from all

0-D point based theories and models. It leads to a conceptual break-through in the form of a predicted spatial arrangement of the nucleons. These principles are then used to determine the designs for the hydrogen and helium nuclides, and these are shown to have excellent fit to the two isotope series.

4.1 Proton and Neutron structures

The Cordus theory for the proton is shown in Figure 1. The derivation of this structure is shown in the references and is not repeated here.

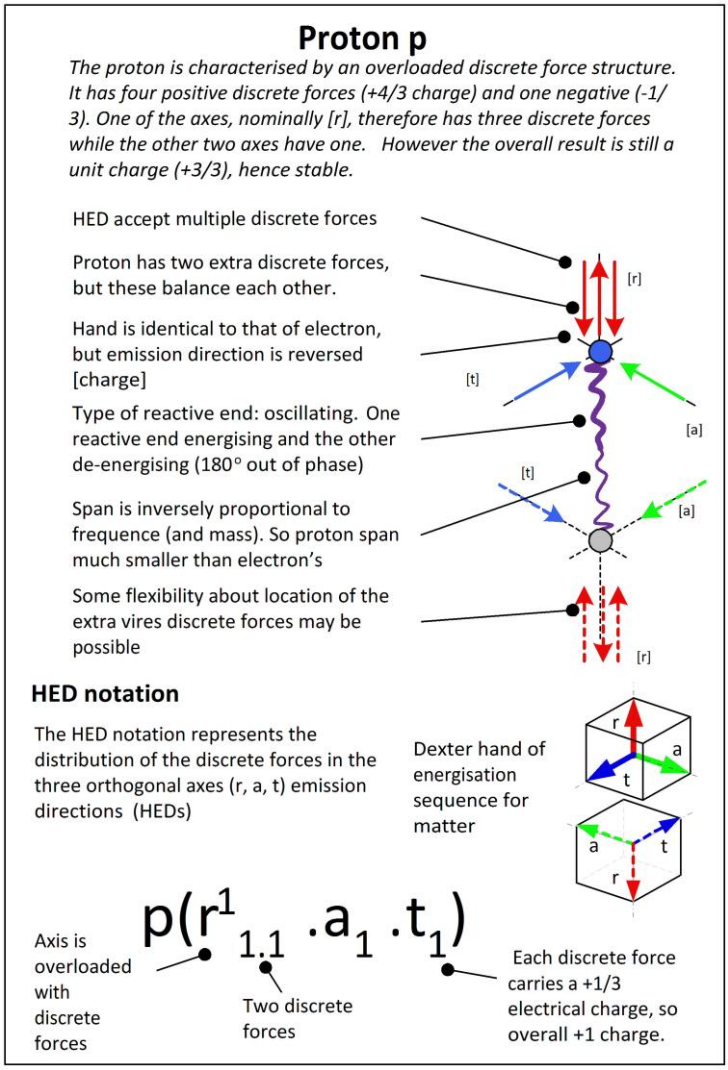


Figure 1: Cordus theory for the non-local hidden-variable structures of the proton. In the case of the proton one of these axes has an extra pair of discrete forces, giving four discrete forces in total but still a net charge of +1. The HED notation is a Cordus symbolic representation of the distribution of the discrete forces in the three emission directions, and is a unique signature for the type of particule [23]. As described in [11], the proton has two discrete forces in one of the axes, hence the designation $p(r^{1}_{1.1} .a_1 . t_1)$.

The Cordus theory for the neutron is shown in Figure 2. This theory also explains why the neutron is unstable when alone. This is because, while it has a unit charge (neutral), its HEDs are incompletely energised.

Specifically the [t] axis is un-energised, and vulnerable to disturbance by discrete forces of external origin.

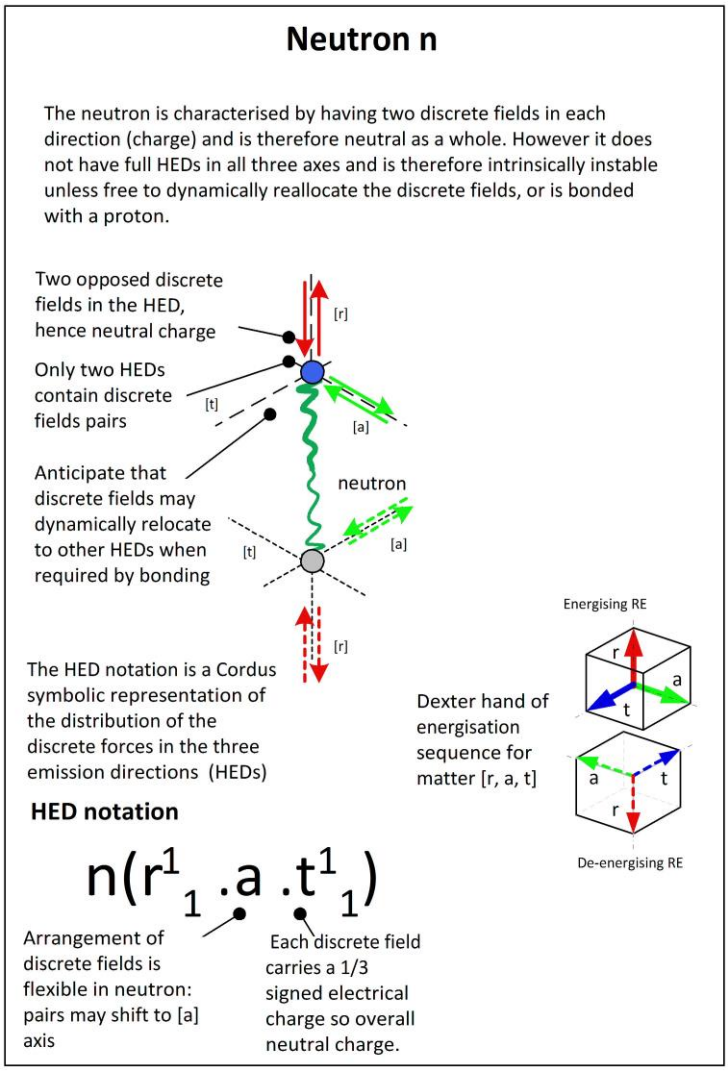


Figure 2: Cordus model for the neutron. The HED arrangements provide a neutral pair of discrete forces, comprising a positive and negative force, on two of the emission directions. The overall charge is thus neutral. It is believed that the pairs may shift to other axes as necessary.

These predicted covert structures for the proton and neutron are plausible, and not precluded by the Bell-type inequalities nor any other theory. The proton and neutron structures may look exotic, but that is only because the dominant way of thinking about particles is as 0-D points. They are not-inconsistent with other theories of physics. A coarser level representation is obtained when the span is reduced to zero, and this corresponds to the 0-D point approximation of QM. The number of parameters needed to describe a Cordus particule is consistent with the number of dimensions in some string/M theories.

Note that in this theory each particule has two ends, and there is a span, i.e. a physical distance between the two reactive ends. This means that particules and their assemblies (described below) have physical size – there is no singularity as with QM. Note also that that the particule

energises its reactive ends sequentially, at its frequency, and the reactive ends are not both simultaneously in the same state. Hence a phase exists, with further implications for bonding (described below). The concept of particules having physical size (span), phase, and spatially orientated discrete emissions is core to this theory, and permits a revolution in the understanding of the nucleus.

4.2 Phased behaviour between particules

The Cordus theory proposes that the strong force arises from the synchronisation of discrete forces between the reactive ends of different particules [11]. The emission directions represent the particule's directional engagement with the external environment, and so two particules that co-locate one of each of their reactive ends need to share this access, and this is proposed as the basis for the synchronicity requirement. This causes the emission of the particules' discrete forces to be interlocked. The discrete forces cause the reactive ends to be pulled into (or repelled from) co-location and held there. Hence the strong nature of the forces, its apparent attractive-repulsive nature, and its short range. Unexpectedly, the Cordus theory predicts that this synchronous force only applies to particules in coherent assembly. In such situations the synchronicity of emission means also that the assembled particules must energise at the same frequency (or a suitable harmonic), and either in or out of phase. Thus the synchronous interaction is predicted to be limited to particules in coherent assembly relationships, with the electro-magneto-gravitational forces being the corresponding interaction for discoherent assemblies of matter.

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.

Consider two particules that are in a coherent assembly, i.e. have a common magnitude of frequency, and share a common location for at least *one* reactive end each. There are two states that particularly interest us: the particules may be *in or out of phase* with each other at their common location, and these are termed these *cis- and transphasic* behaviour respectively [11]. The principles are believed to apply to all particules, including the electron, but the focus here is on the assembly relationships between a proton (p) and neutron (n).

4.3 Cisphasic interactions

Cisphasic bonding (denoted #) occurs where reactive ends from two or more particules are co-located and *in-phase*. The particules must have complementary discrete forces emissions, i.e. there must be some advantage gain in the combined discrete forces. Typical advantages might be summation to a whole unit of charge (e.g. the UUD quark complement of the proton), or a more spatially uniform set of emissions (e.g. the proton-neutron bond as will be shown).

By *complementary* is meant that the one particule provides discrete forces that the other lacks, and this is reciprocated. This generally means

they must be different types. The case in point is the bonding of a proton and neutron: their discrete forces arrangements are very different, but the assembly gives a neatly balanced arrangement with a unit charge *and* the same number of discrete forces in each of the three directions. This complementary state is best seen by considering the process by which a proton and neutron would come together to form a bond, see Figure 3. The basic idea is that two approaching p and n particules, that are not too dissimilar in frequency and phase, negotiate location and phase via their discrete forces, and adjust their emissions to move into synchronicity. The synchronous emissions then lock the two reactive ends together.

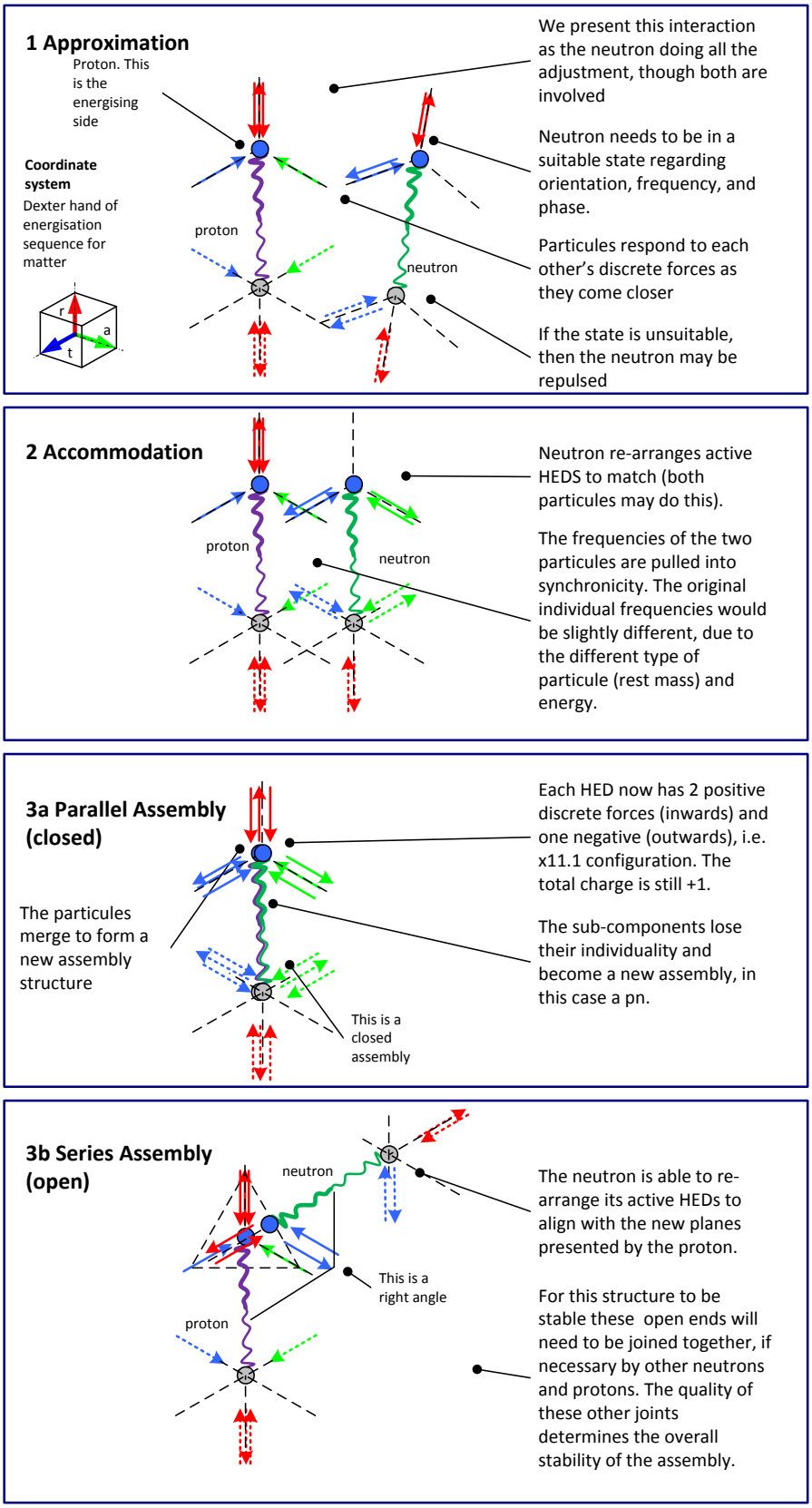


Figure 3: Cisphasic assembly of proton and neutron (p#n), showing the processes and how the two particules complement each others discrete force emissions.

The cisphasic 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. The outcome is a new assembly, in this case a pn deuteron, 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.

The proposed mechanics are set out in the lemmas (Appendix A). Note that the output HEDs are balanced regarding discrete forces: the assembled reactive end has two inward discrete forces and one outward, *in each of the three* emission directions [r, a, t]. Consequently this meets plausible expectations of stability. 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 cisphasic proton-to-neutron bond with its balanced discrete forces and in-phase synchronicity, has more stability advantage, and is therefore preferred by the nuclear polymer over the transphasic proton-to-proton bond (described below). It is important to note that all such bonds are 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. This also explains why the neutron is stable when bonded with a proton, but unstable on its own. It has incomplete and imbalanced discrete forces which are complemented exactly by the proton, whereas on its own these make it vulnerable to perturbation from random discrete forces in the external environment, hence decay [14, 24].

There are two sub-types of this interaction: parallel and series. In parallel assemblies each particule joins to the other at *both* reactive ends. A series assembly is also permitted, where there is only a single partnership between any one proton and neutron. This leads to open chains, which may be closed by other nucleons. The mechanics require that a stable chain may not be terminated by a naked neutron. The open-assembly pn deuteron therefore joins with others like it, to form a *nuclear polymer*.

4.4 Transphasic interactions

The transphasic joint (denoted 'x') also involves co-location of the reactive ends of two particules, and synchronous frequency, but the difference is that the reactive ends are at *opposite phases*, hence the name [22]. Thus the reactive end of one particule energises at the location while the other de-energises. This behaviour means that the location in question has greater temporal occupancy of discrete forces. It is believed that this protects the particules against interference from external discrete forces (from other particules) and hence promotes stability. The Cordus theory requires that the particules have *identical* discrete force structures. In contrast the cisphasic case required *complementary* structure. This means that the transphasic interaction is only between like particules, e.g. p x p, or n x n, but not p x n. The basic structure of a transphasic interaction is

shown in Figure 4. As before, both series and parallel arrangements are anticipated.

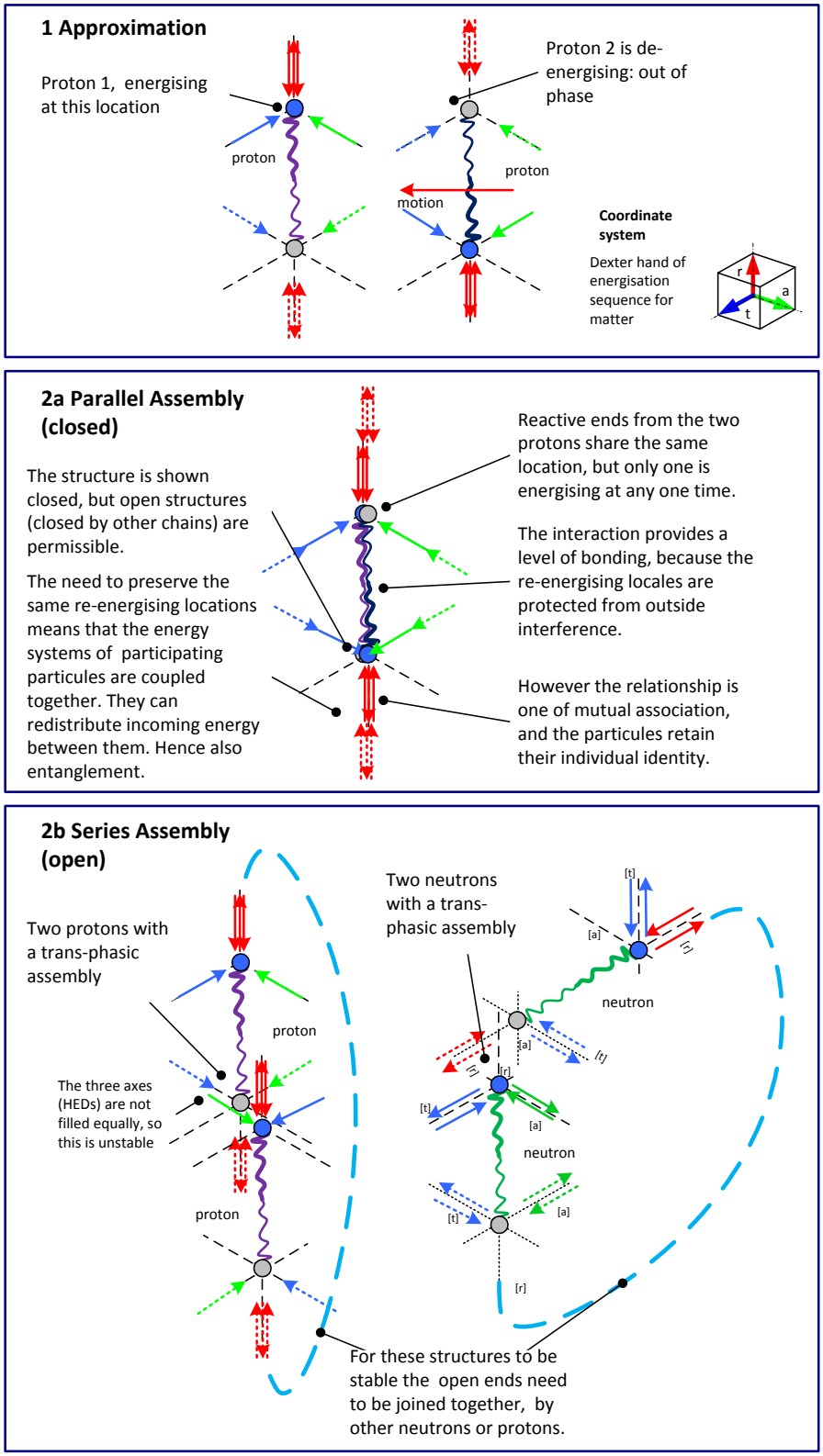


Figure 4: Transphasic joint (p x p): The joining of two particules, two protons this case, with opposite phase allows them to share the same space. Although illustrated with two protons, this type of bond is available

to any *pair of like particules, including neutron-neutron, electron-electron, etc. Parallel and series arrangements are available.*

The Cordus theory for transphasic joints permits neutrons to be joined in extended closed chains. The same transphasic relationship applies to pairs of electrons, thereby explaining electron-pairing, the Pauli Exclusion Principle, and Cooper pairs. A series transphasic relationship of a skin of electrons explains superconductors.

4.5 Joint types available to protons and neutrons

The above principles are proposed to be applicable to *all* particules, including electrons, pions, etc. Applying these principles to the specific case of the nucleons shows that certain joints are allowed and others not, see Table 1.

Cisphasic # (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.

Thus cisphasic bonds only apply to proton-to-neutron joints, and the transphasic to bonds between like particules. Thus it is proposed that the synchronous interaction, when applied to the nucleons, permits the joint types shown in Figure 5.

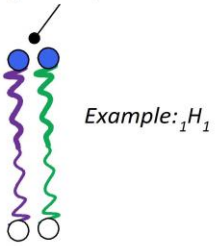
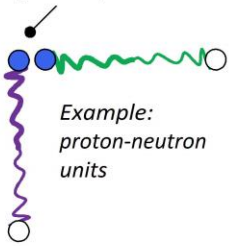
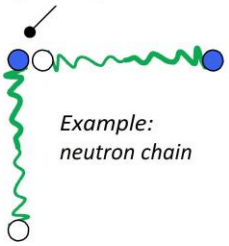
ASSEMBLY NOTATION	Cis-phasic (in-phase) #	Trans-phasic (out of phase) x
PARALLEL ASSEMBLY (CLOSED: both reactive ends match)	Cis-phasic: (p1 # n1)  *Example:* $_1H_1$ Two particules sharing geometric location of both their reactive ends, in-phase	Trans-phasic: (p1 x p2)  *Example: Pauli pairs* Two particules 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 5: Summary of the cis- and transphasic joint types and their application to parallel and series assembly structures.

Importantly, this shows that multiple different types of bonds may exist between nucleons. In contrast all extant nuclear theories and models assume only one type of strong force, and assume that the strong and electrostatic forces apply at the same time. The Cordus theory makes a major departure by proposing multiple types of bonds under the synchronous interaction. A logical consequence is that nucleons form into elaborate assembly chains in the form of a *nuclear polymer.* This too is a novel concept and entirely inaccessible from the standard Model. Next it is necessary to determine, by logical extension of the gedanken experiment, what rules apply to this polymer and whether these can explain the nuclides.

4.6 Tendency towards cubic structures for the nuclear polymer

A logical consequence of the three dimensional layout of the discrete forces, and the handedness thereof [11], is that protons and neutrons preferentially join at right angles, hence cubic structures. The reasons for this are explained in Figure 6.

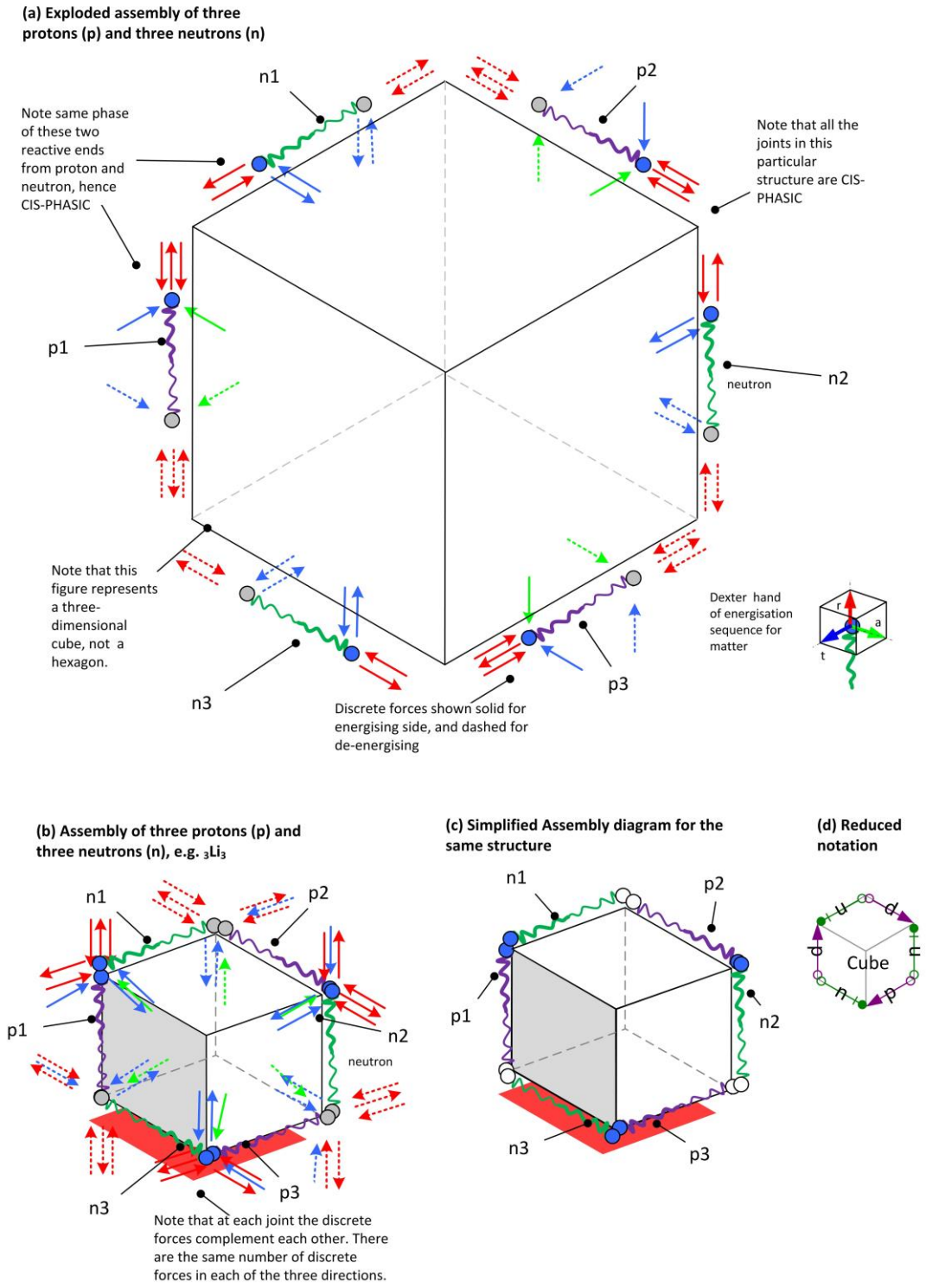


Figure 6: Cubic structures tend to arise from the bonding of protons and neutrons into a nuclear chain. The diagram shows exploded and assembly views.

At each joint, the proton and neutron complement each other's emission of discrete forces, i.e. there is a synchronous interaction. Specifically, there are three discrete forces in each direction at these junctions, which gives a balanced loading across the three emission directions. Due to the orthogonality of the discrete forces underlying the synchronous bonds, the assembly of multiple particules intrinsically follows a cubic structure. Thus the nuclear polymer follows a locus around the edges of a set of connected three-dimensional *cubes* [22].

4.7 Cross bridges

The nuclear polymer consists, in the first place, of protons and neutrons in series. However the theory logically permits bridges to form across the polymer. The theory for these bridges is shown in Figure 7.

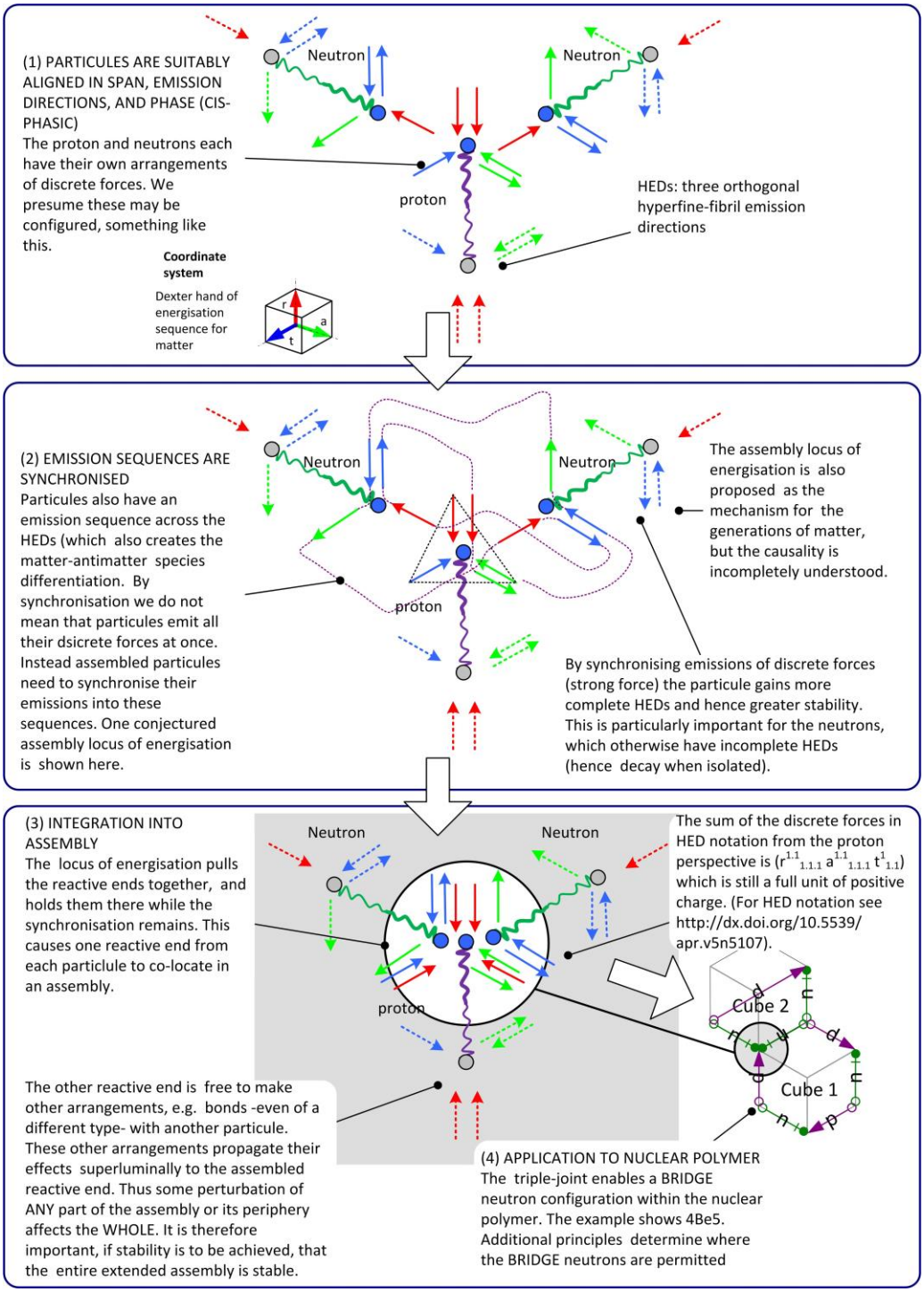


Figure 7: Neutron cross-bridges are anticipated to occur within the nuclear polymer. These result in accumulation of discrete forces at the common node.

The theory allows both proton and neutron bridges, but predicts that certain configurations will be non-viable. See the lemmas in Appendix A for details.

4.8 Nuclear polymer

To sum up the development so far, the theory proposes that the proton and neutron are linear structures (have length), bond in a variety of ways,

form polymers with linear and bridge components, with the polymer being wrapped along the edges of interconnected cubes. The network is primarily a closed loop of nucleons: there are no free reactive ends. The exceptions are certain light elements that have so few nucleons as not to be able to wrap completely around a cube, where open structures are permitted, terminated by protons [22]. However for stability reasons these may not be terminated by neutrons. Examples are provided below. These requirements arise by logical extension from the handed nature of the Cordus synchronous interaction (strong force), specifically the emission of discrete forces in three orthogonal emission directions.

With these concepts in place, the next idea in the gedanken experiment is introduced: That the morphology of the *nuclear polymer* and the nature of the bonds (cis- and transphasic) are the primary determinants of stability/instability of the nuclide concerned [22]. Next, this principle is tested by application to two case studies: the hydrogen and helium nuclides.

4.9 Application to simple nuclei

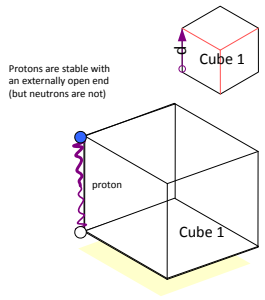
With models in place for the cis and trans applications of the strong force, there are sufficient basic concepts to identify the layout of the nuclear polymer for simple nuclides.

HYDROGEN NUCLIDES

Hydrogen 1H0 is simply the proton as already shown. It is proposed that the 1H1 deuteron is a closed (parallel) cisphasic assembly of one proton and one neutron. The 1Hn nuclides of hydrogen are expansions of the polymer by insertion of neutrons with transphasic bonds. The predicted nuclear polymers are shown in Figure 8. Note that in some cases there are alternative layouts. This is because the mechanics of the nuclear polymer theory allow more than one interpretation in certain cases.

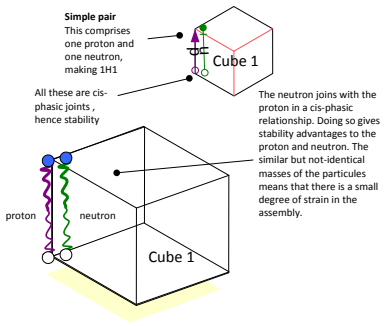
$_1H_0$ Atomic Hydrogen (stable)

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.



$_1H_1$ D, Atomic Hydrogen (stable) (deuterium)

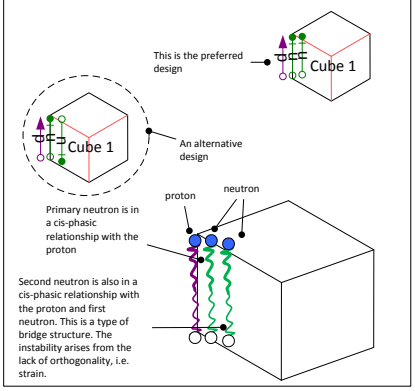
The stability of this nuclide is attributed to the single proton and neutron forming an overlapping linear structure using cis-phasic bonds.



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

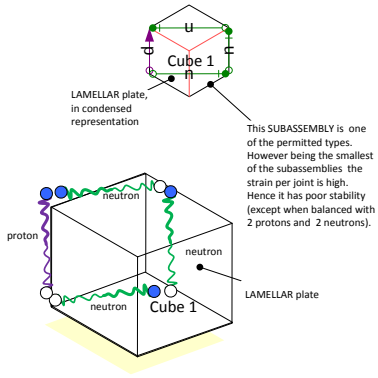
$_1H_2$ (unstable) (tritium) 12.32 yr

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



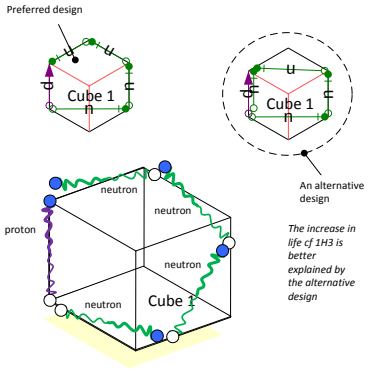
$_1H_3$ (unstable) 139E-24 s

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



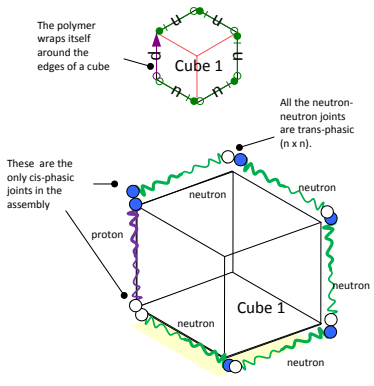
$_1H_4$ (unstable) >910E-24 s

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



$_1H_5$ (unstable) 290 E-24 s

The decreased life cf 1H4 is attributed to the poor structure and the increased number of unstable neutrons involved.



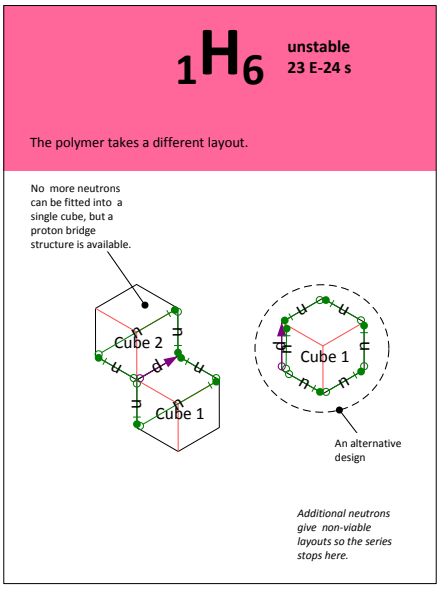


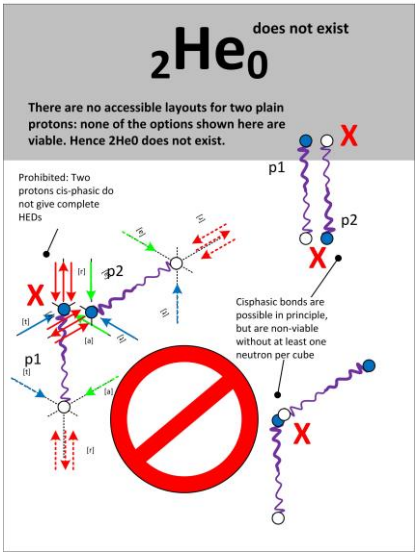
Figure 8: Internal structure of the nuclides of hydrogen, as proposed by the Cordus theory.

This theory explains the stability trends in these nuclides.

- The stability of 1H1 can be explained by the cisphasic proton-to-neutron bond.
- Likewise the long life of 1H2 is attributed to its cisphasic bonds, and its instability to the structure lacking orthogonality.
- The poor viability of all the higher nuclides is explained by their transphasic neutron chains.
- The theory also explains why the series stops where it does, at 1H6. This is because there is a neat morphological boundary at 1H6 such that the next longer polymers do not have access to a suitable layout.

HELIUM NUCLIDES

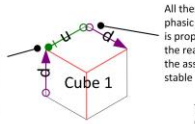
Explanations of the helium nuclides are given in Figure 9.



$_2He_1$ (stable)

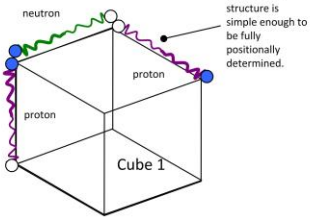
This is the only stable assembly that breaks the rule of one neutron per proton. The proposed reason is that the structure is chirally complete despite exposed ends of the protons

Open polymer
Protons are stable with an externally open end (but neutrons are not). Applies to 2He1 (shown here) and 1H0.



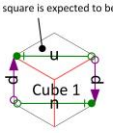
All these are cis-phasic joints (this is proposed as the reason why the assembly is stable

The two proton ends are open, because the structure is simple enough to be fully positionally determined.



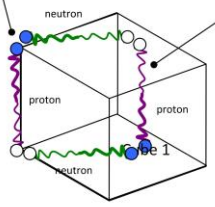
$_2He_2$ (stable)

LAMELLAR plate structure.
Four nucleons in a square, for 2He2. This is the nominal representation: the actual shape expected to be equal strain on all members, i.e. the square is expected to be twisted.



Cis-phasic joints throughout. These are stable.

Structure is likely bent out of plane too

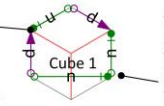


Any additional neutrons beyond 2He2 introduce unstable trans-phasic bonds, hence the stability worsens.

$_2He_3$ (unstable) <10E-15 s

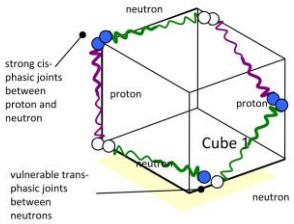
This nuclide struggles with viability due to the incomplete filling of the cube.

INCOMPLETE cube is non-viable



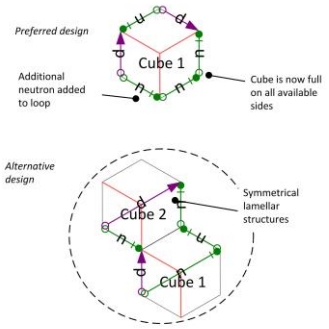
Additional neutrons assembled with trans-phasic bonds into an extended loop. The two protons are unaffected.

Neutron chains form in series with an existing neutron, but have trans-phasic neutron-to-neutron bonds.



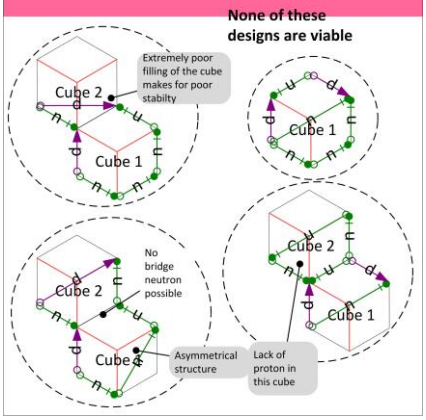
$_2He_4$ (unstable) 806 ms

The improved stability here is attributed (depending on the design) to the completion of a cube, or of two lamellar structures. Either way the structure meets the stability criteria.



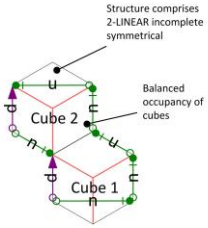
$_2He_5$ (unstable) <10E-15 s

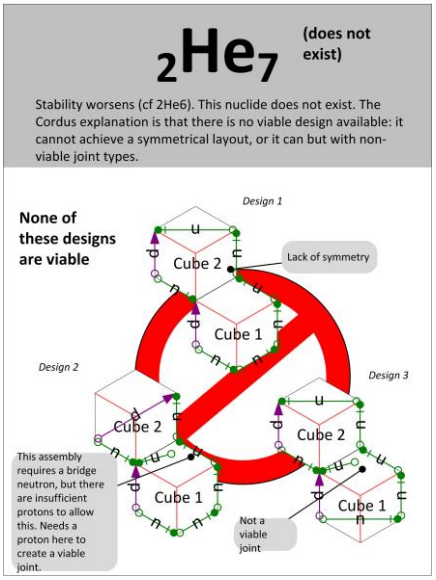
There is no accessible symmetrical structure, hence the nuclide is non-viable.



$_2He_6$ (unstable) 119 ms

Stability improves (cf 2He5) due to a symmetrical structure becoming available for this size of polymer.





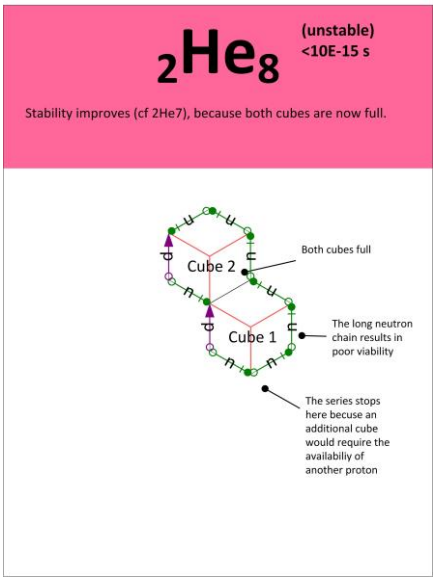


Figure 9: Internal structure of the nuclides of helium, as proposed by the Cordus theory.

The helium nuclides are a strange series, because of abrupt changes and reversal in viability. This has historically been a difficult, even impossible, area for other theories. It is so problematic that some theories omit the light elements altogether. The Cordus theory has no such difficulties. It successfully explains the trends in stability. The explanation is entirely morphological, and is based on the principle that certain combination of protons and neutrons cannot find a suitable shape, and therefore cannot exist (except fleetingly). Hence the difficult questions, which have troubled many other theories, can now be answered:

- *Why does 2He0 not exist?* Cisphasic bonds are possible in principle, but are non-viable without at least one neutron per cube.

- *Why is 2He1 stable, when the nuclides generally require n >= p?* Protons are stable with an externally open end (but neutrons are not).
- *Why are only 2He1 and 2He2 stable?* Any additional neutrons beyond 2He2 introduce unstable transphasic bonds, hence the stability worsens.
- *Why do 2He3 and 2He5 have unexpectedly poor viability compared to the nuclides on each side?* Their nuclear polymers are of a length that they do not have access to one of the viable cube-filling shapes.
- *Why are 2He4 and 2He6 viable whereas the nuclides on each side are not?* The nucleons are sufficient to have access to viable shapes.
- *Why is the viability especially poor for 2He7?* There is no viable layout available.
- *Why does 2He8 have such poor viability?* The structure is sound, but the long neutron chain results in poor viability.
- *Why does the series stop at 2He8?* There are insufficient protons to expand into another cube structure. Nor can a bridge neutron be inserted into 2He8 due to wrong end conditions.

Some of these explanations require further details about the way the nuclear polymer fills the cubes, which is available elsewhere [22]. The shape progressions within the Cordus theory match the stability trends exactly. The theory is also successful at explaining why the series starts and stops where it does.

4.10 System model

The concepts that have been presented here are a radical departure at the fundamental level, and have profound implications for the directions taken by fundamental physics in the future. Almost all the ideas that have been presented in this paper are unorthodox, and conventional physics may need some time to evaluate their validity and digest the implications. To assist such an appraisal, a summary of the conceptual framework is shown in the system model of Figure 10. This diagram is represented in integration definition zero (IDEF0) system modelling notation [25]. 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 cisphasic and transphasic bonding between nucleons. These are each described above, and the diagram summarises their relationships.

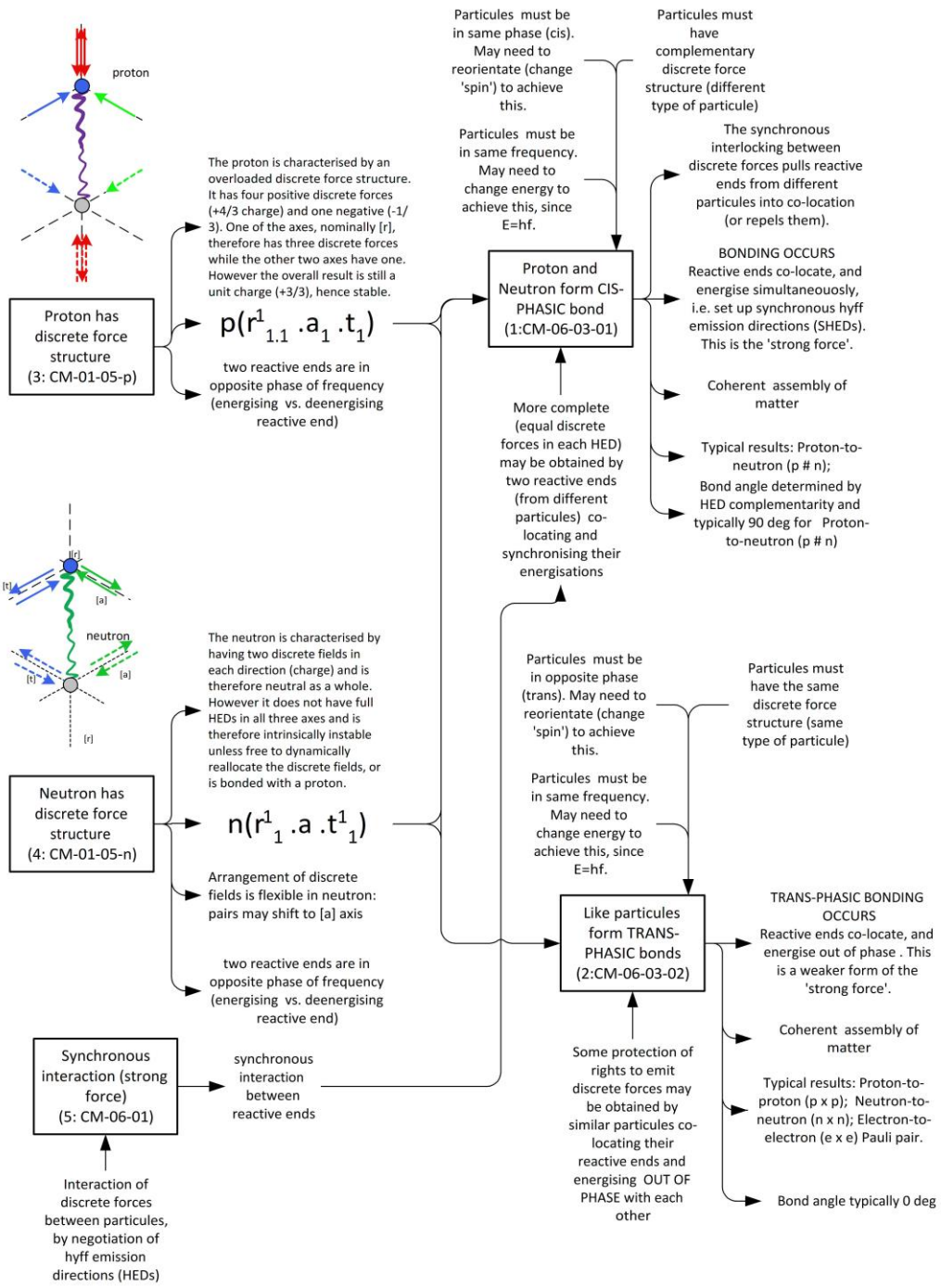


Figure 10: System overview of the causes of bonding between protons and neutrons in the nucleus. The diagram summarises the main features of the Cordus design of the proton: this is a non-local hidden variable solution and it proposes that the proton has internal structures as well as a particular signature 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 cisphasic and transphasic states.

5 Discussion

This paper provides a new mechanics for the nuclides, one totally unlike any other theory. This provides a revolutionary new explanation of nuclear mechanics. The mechanics have been developed from first principles and then applied to the hydrogen and helium nuclides. They successfully explain why each nuclide is stable, unstable, or non-existent. This is a break-through as this depth of explanation has not previously been achieved. The same mechanics also successfully explain the stability trends of all the nuclides up to and including Ne [22]. The explanations, while still at the qualitative stage of an early conceptual theory, are overwhelmingly better than anything possible from QCD theory and the nuclear models. The implications are profound, in that hidden-variable theories, not quantum mechanics, now appear to be the way forward for fundamental physics. These outcomes and their implications are elaborated below.

5.1 What has been achieved?

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). A radically different idea has been proposed for the strong interaction at the quark level and the strong nuclear force. Conventionally the strong nuclear force overcomes the electrostatic repulsion of protons. In contrast the Cordus theory 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 [11]. 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. A related contribution is the idea that the synchronous interaction makes two distinct types of bond, differentiated by same vs. opposed phase (cis- and transphasic). This concept does not exist in conventional theories of the strong force.

PROTON-NEUTRON BONDING AND THE NECESSITY OF NEUTRONS

The second 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. 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 is propose to have nothing to do with electrostatic charge per se. Thus the Cordus theory predicts, in a major departure from conventional models of the nucleus, that the protons in stable nuclei are bound through neutrons, which are essential intermediaries, and that nuclear bonding involves synchronous interactions rather than charge per se. In contrast other theories model the protons as being bound directly together, or alternatively in an amorphous collection (liquid drop) or as shells. This difference may be testable and falsifiable. The Cordus theory predicts that proton-to-proton bonds may be either cisphasic or transphasic. 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 cisphasic bonds are predicted to be more stable than the transphasic.

NUCLEAR POLYMER

A third contribution is the introduction of the concept of *nuclear polymer* including the provision of a logically consistent set of qualitative mechanics, the lemmas, governing its structure. The concept of chains and bridges of nucleons is novel and permits an entirely new approach to modelling nuclear structures. This provides a natural explanation for why the nucleus has physical size. *Morphology* is identified as the key determinant of nuclide stability, i.e. the way the polymer is draped over the available shapes. These shapes are also derivatives of the synchronous interaction. It is subsequently shown that this idea of nuclear polymers is powerful in its ability to explain other nuclides [22]. The Cordus theory predicts that the nucleus is best described as a nuclear polymer of proton-to-neutron joints with cisphasic 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 is consistent with the empirical observation that nuclei have size (measured as *charge radius*). By comparison, quantum theory cannot explain how aggregates of point particles should have physical size.

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. An associated contribution is the prediction of the internal structure of the hydrogen and helium nuclides, and an explanation of their stability trends. The Cordus theory explains qualitatively why the stability worsens with increased neutron count. It also explains the discontinuities in stability, e.g. why 2He5 is so much less stable than its neighbouring isotopes. The limits of the series, why they stop where they do, are also explained. Another important explanation is why 2He1 should be stable, as the only stable nuclide with p>n. No other theory can explain all these effects, and most of the theories, e.g. liquid drop and QCD, cannot explain any of

these. So the contribution is an improved explanation for the H and He nuclides.

A final contribution is methodological, in that the work demonstrates that (a) the vitality and relevance of non-local hidden-variable theories, which otherwise have been rejected without proper consideration, and (b) the value in using a system design approach for concept-development. The resulting Cordus theory provides new insights and fresh ideas towards an old problem. This has otherwise not been achieved with other hidden variable solutions, e.g. de Broglie-Bohm.

The explanations of the Cordus theory are consistent with empirical evidence of how matter behaves under the strong force, so the theory has *construct validity*. The theory also has good *external validity* in that it readily generalises to a wide range of different phenomena in physics, even cosmological [13, 14]. By comparison other nuclear models only apply to a limited set of situations.

5.2 Implications

The points of difference of the Cordus theory arise from several conceptual 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 and the resulting singularities that frames the orthodox paradigm into the excessively limiting idea that the nuclear bonding force is repulsive at short range, strong at middle range, and weak at long range. This odd set of properties is a consequence of the premise, and does not need to be a physical reality. The Cordus theory proposes that it is better to consider the nuclear bonding force as a synchronous interaction. The Cordus particule idea provides physical interpretations for superposition, entanglement, spin, frequency, phase, orientation angles (e.g. polarity), and parity violation which are otherwise indefinable in QM. Thus quantum mechanics (QM) is re-interpreted as a solution of averages, applicable only to coherent bodies where the size of the particles can be neglected, and otherwise not applicable 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.

The third unique feature of the Cordus theory is its concept for the strong force. This is reformulated as a synchronous interaction between discrete forces [22]. This is in contrast to the QCD concept of an exchange of

bosons. This has far-reaching and profound implications for nuclear bonding and cosmology, explored in other papers.

Unique to this theory is the concept that bonds between nucleons may take two forms: cis- and transphasic [22]. This feature arises from the nature of the proposed synchronous interaction. It is in stark contrast to the single interaction envisaged for bonding by all other theories. 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, and hence the *nuclear polymer* idea.

Consequently this theory predicts that there are several ways, not only one as in the orthodox theories, for how protons and neutrons may bond. Having multiple interactions also provides a means to differentiate between *stable* and *unstable* bonds in nuclides. The principles presented here, specifically the cis- and transphasic bonds, have the potential to support the development of a profoundly different theory of nuclear structure. It is expected that at a deeper level there may be some similarities with the liquid drop model and SEMF. This is because all of these are models that consider the 'geometric packing of the nucleons' [22]. However the point of difference is that the Cordus theory offers a solution for internal mechanics and structure of the nucleus, and how the individual protons and neutrons are bound together in space. In contrast the other theories merely consider the nucleons as an aggregated collection (hence drop or bag descriptions), and are unable to say anything about the internal distribution of the nucleons or their specific relationships to each other. In this theory the 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.

5.3 Limitations

The Cordus theory is currently mostly a conceptual work. 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. This is a limitation, but hardly a fatal one as neither does any other theory give quantitative predictions from first principles for all these variables (except by parameter-fitting and tuning).

There are two other features which might seem limitations of this theory, but are not. The fact that this is a non-local hidden-variable design is not a limitation. It is only *local* hidden-variable solutions that are precluded by the Bell-type inequalities [15, 16]. The lack of a mathematical formalism is also not a limitation. Instead it is merely a consequence of using the gedanken experiment method for conceptual development. This is a well-established method for concept development. Mathematical development can follow as a future opportunity. The real limitation is one caused by the design method. Design converges on a sufficient solution, and therefore one cannot be certain that this is the only or the best solution. Thus the design method, while good at fitting form to function, could result in spurious attribution of causal relationships. Nonetheless this theory is not

alone as other methodologies -most especially mathematical and statistical modelling- have the same limitation. The real tests are whether the theory put forward here advances the understanding of the nucleus, is internally self-consistent, and has predictive power. The evidence is that it does all those things.

5.4 Future research

The Cordus nuclear theory has potentially far-reaching and deep implications for the future direction of fundamental physics. It demonstrates that a hidden-variable design has better explanatory power than other theories and models based on the 0-D point premise. Given this, and that it subsumes quantum mechanics, the implication is that the next deeper level of physics is better described by hidden-variable designs than quantum mechanics. The consequences are wide-ranging, in that a large number of physical phenomena can be described with the Cordus mechanics. The implications for future research are therefore vast. The theory has the potential to touch every area of fundamental physics and transform the conceptual foundations on which many theories are built, thereby requiring reformulation of those theories to accommodate covert structures.

Regarding the nuclides specifically, opportunities for further work lie in several directions. One is to develop a mathematical formulism for the synchronous interaction (including its directional, discrete and phasic attributes), quantify the parameters, and evaluate the robustness of the resulting model against empirical data. There is also a need to develop a mathematical representation of the nuclear polymer and the filling of cubic structures. This would be helpful in exploring the heavier nuclides. Another opportunity is to further develop the concept and see if the theory can explain additional nuclides. There is a need, at present unfulfilled by quantum theory, QCD, nuclear models, or string/M theory, to explain why any given nuclide is stable or unstable. There are also a large number of deviations in the trends that need explaining: Why are more neutrons required for stability in heavier nuclides, i.e. why does the trend deviate from p=n? Why are some nuclides (e.g. 4Be4) unexpectedly unstable? Why are the margins of non-existence (drip lines) jagged? Why do some elements have only one stable nuclide, whereas others have multiple? No existing theory can do any of this, so it is a formidable challenge. There are many other nuclides to explain, with odd trends apparent even within one isotope series, hence much opportunity for future work and theory-building. Another opportunity for research is to model binding energy and charge radii. A complete theory of the nucleus will also need to explain the decay process itself, and the weak interactions (beta plus & minus decay, and electron capture), and the Cordus theory has already made progress in this area [24].

6 Conclusions

The purpose of this paper was to develop a systematic theory to explain the relationships between nucleons, and thereby explain the stability, instability, and non-existence states of the nuclides. This has been achieved in a gedanken experiment. The work re-conceptualises 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 assembles particules in- and out-of-phase (cis- and transphasic respectively), and into open or closed chains. The theory identifies the role of the neutrons in nuclear bonding. The protons in stable nuclei are bound through neutrons, which are essential intermediaries. Nuclear bonding therefore involves synchronous interactions rather than charge per se. In contrast other theories model the protons as being bound directly together, or alternatively in an amorphous collection (liquid drop) or as shells. The theory predicts that the assembly structures involve a *nuclear polymer*, and the mechanics of this have been anticipated. The concept of chains and bridges of nucleons is novel and permits an entirely new approach to theorising nuclear structures. This is shown to readily provide a natural explanation for why the nucleus has physical size. Furthermore, morphology is identified as the key determinant of nuclide stability, i.e. the way the polymer is draped over the available shapes. These shapes are also derivatives of the synchronous interaction. Application of the theory to the hydrogen and helium nuclides shows that it successfully explains the trends in stability. This is important as it demonstrates, for the first time, a theory for nuclear structure starting from the strong/synchronous force at the fundamental level.

This is a profoundly different conceptualisation than any other theory for the nuclides, and allows a fresh new approach to fundamental physics as applied to nuclear physics. Its explanatory power far exceeds that of quantum theory and existing nuclear models. This has been achieved from the hidden variable sector, a direction that has been often doubted, though never disproved. The fact that it has been possible to achieve this, when no theory based on quantum mechanics has been able to come close to answering these questions, shows that serious consideration must now be given to the likelihood that particules may have internal structure after all. The theory provides a profoundly different conceptual framework for nuclear mechanics, and has the potential to revolutionise fundamental physics and the understanding of the atom.

CONTRIBUTION STATEMENT

DP, ADP and AJP developed the conceptual foundation and the theory, and critically evaluated the logical consistency thereof. All authors contributed to the writing of the paper. DP created the drawings.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interests regarding the publication of this article. The research was conducted without commercial or financial benefit from a third party. There was no third-party influence in the work: its approach, interpretation of data, writing,

or submission decisions. There were no external funding bodies involved in this work.

A Appendix: Nuclear polymer Lemmas

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 [11].

NP.2 REQUIREMENTS FOR A CISPHASIC (#) ASSEMBLY

NP.2.1 The assembly must meet the HED stability criteria. These include the need for have integer charge and balanced loading of discrete forces across the three emission directions (HEDs). Cisphasic 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 cisphasic bond is highly advantageous to the proton and neutron, and next is a pxp transphasic bond, with a p#p cisphasic assembly being the least attractive to the proton.

NP.2.2 Similar frequency: 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. 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). 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 cisphasic: 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.3 REQUIREMENTS FOR TRANSPHASIC (X) ASSEMBLY

NP.3.1 The particules need to be sufficiently similar in HED structures as to confer an advantage in doing this. Proton chains (pxpxp..) and neutron chains (nxnxn..) have transphasic bonds. However protons preferentially bond cisphasically with neutrons.

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

NP.3.3 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 For reasons of creating more complete discrete force aggregates, the proton and neutron prefer both their reactive ends to be assembled with the reactive ends of other particules. In the case of the neutron this preference is strong, but weaker for the proton. Consequently nuclei tend to consist of closed chains of protons and neutrons, hence 'nuclear polymer'.

NP.4.2 A nuclear polymer is a series of nucleons bonded in a network. The polymer has approximately orthogonal joints between particules. The polymer is generally a closed loop, for reasons of HED completion (hence stability). The exception is the single proton, and proton-ended chains, which may be stable while being open.

NP.4.3 Nucleons may be bonded in series. The linear bonds, which make up the series components of the nuclear polymer, are identified in Figure A1. The chain may consist of p#n units in alternating order, using cisphasic bonds. The chain may consist of neutrons bonded end-to-end with transphasic bonds (nxn). Purely proton cisphasic chains (p#p) are forbidden. This is because they repel with the strong force and thus give no advantage to the assembly. However proton-proton transphasic joints (pxp) are acceptable.

NP.4.4 Network structures with crosslink bridge structures are possible. Specific rules apply to the arrangement of cross-bridges. Some arrangements are non-viable. See Figure A2.

NP.4.5 A variety of cis- and transphasic bonds may be used in the assembly of the nuclear polymer, but there may be consequences for stability. See Figure A3 for illustrations.

NP.4.6 The synchronous interaction (strong force) is directional and propagates to neighbouring particules. All particules in a nuclear assembly are synchronised, at least to a harmonic of the common frequency.

NP.5 ASSEMBLY STRUCTURES OF NUCLEAR POLYMERS

NP.5.1 Bonds between two nucleons may be cis- or transphasic, and depending on the participants, result in stable, unstable, or non-viable outcomes.

NP.5.2 *Stable* bonds, as the name suggests, are those that have enduring stability.

NP.5.3 *Unstable* bonds are those that will exist for a time, but will decay with time. Nuclear polymers made of these bonds will have a finite life [22]. The reason such bonds decay is attributed to perturbations of external discrete forces (Cordus: *fabric)* interfere with and destabilise the synchronous interlock of the discrete forces [22]. Transphasic bonds are much weaker at rejecting this interference, because only one reactive end in the assembly is energised (as opposed to both reactive ends

being simultaneously energised for cisphasic interactions) and are therefore the weakest link in the nuclear polymer [22].

NP.5.4 *Non-viable* bonds are specific interactions of protons and neutrons that are incompatible with the synchronous interaction. These assemblies will not form at all. An example is proton-proton cisphasic bonding, where there is no complementarity between the discrete forces: both particules are attempting to simultaneously exert three outward and two inward discrete forces and these are incompatible. These assemblies thus repel each other with the same vigour of the synchronous force that holds other particules together. Non-viable assemblies also include assembly shapes that are spatially inaccessible to the polymer, though these are not evident in the simple structures of the light nuclides.

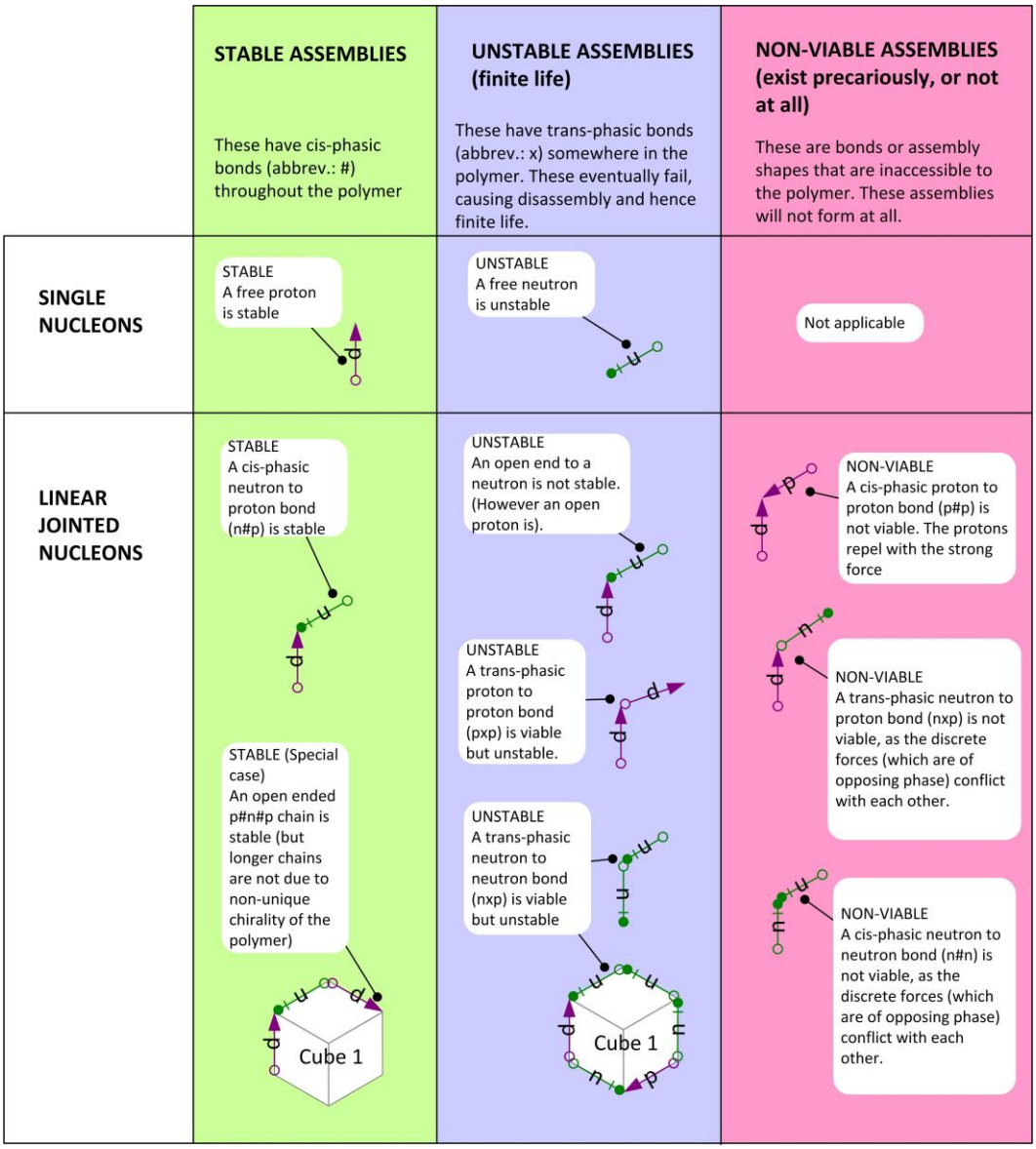


Figure A1: Linear bonds between two nucleons may be cis- or transphasic, and depending on the participants, result in stable, unstable, or non-viable outcomes.

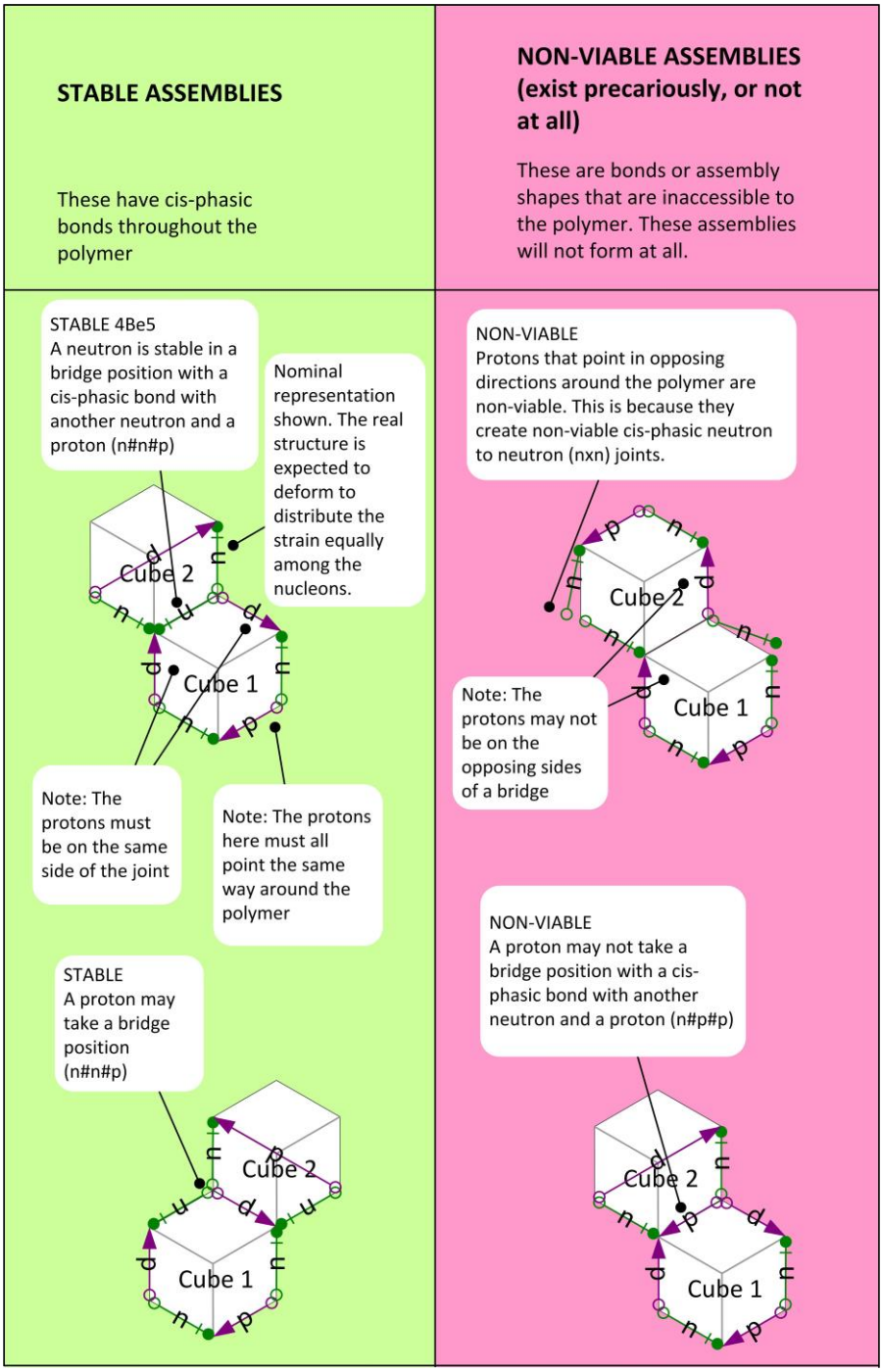


Figure A2: Specific rules emerge for the arrangement of cross-bridges. Some arrangements are non-viable.

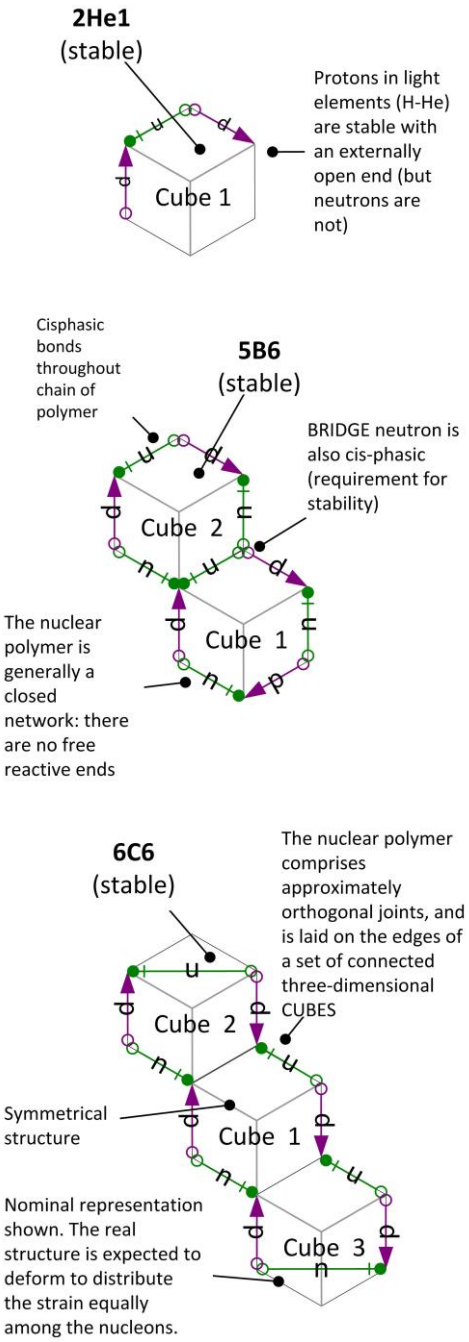


Figure A3: The synchronous interaction (strong force) bonds protons and neutrons together in a variety of way, resulting in nuclear polymer structures. These are proposed as the structure of the nucleus.

These new lemmas are consistent with those already in the wider Cordus set, so no rework of prior assumptions is necessary. This confirms the theory has internal construct validity.

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