Nuclear polymer: Spatial arrangement of protons and neutrons in the nucleus

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Abstract

A theory is developed for the physical layout of protons and neutrons in the nucleus, starting from a non-local hidden-variable (NLHV) design for the strong force. Specifically, the paper shows the application of the Cordus mechanics for the synchronous interaction (strong force) to nuclear structure. This interaction provides for different types of synchronous bonds based on frequency phase, and thus predicts that protons and neutrons have several bonding options and hence spatial interactions. Given that in this NLHV design the nucleons also have physical size, these interactions have consequences for the shapes that the assembly takes. The theory predicts that the nucleus structure is an assembly of rod-like structures into three-dimensional chains of protons and neutrons, hence nuclear polymer. The principles of this mechanics are sketched out, and successfully applied to explain the stability trends and discontinuities in the helium nuclides.

Keywords: nuclides; isotopes; nuclear physics; strong force; nuclear structure; helium

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1 Introduction

Explaining the structure of the nucleus is an unsolved problem. Models exist, such as Gamow's liquid-drop model [1], the semi-empirical mass formula (SEMF) [2], Ivanenko's shell model [3] and derivatives. However they fit mathematics around the empirical measurements, rather than explain causality, and are therefore ontologically incomplete. Furthermore, there is no conceptual connection between the strong force described by quantum chromodynamics (QCD), and the bonding of protons and neutrons in nuclear structures or the variables included in the drop/shell models.

The present paper addresses the ontological part of this problem by providing a theory for how the protons and neutrons are arranged in the nucleus. This solution is based in the non-local hidden-variable (NLHV) sector, specifically the *particule* structure of matter proposed in the Cordus conjecture [4]. The strong force is explained in the Cordus theory as a synchronous interaction between the discrete forces emitted by particules [5]. This synchronicity is proposed to provide an interlocking

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between particules. Hence the repulsive/strong/weak ranged characteristics conventionally attributed to the strong force can readily be explained by this NLHV theory. Furthermore this Cordus theory predicts that the synchronous interaction (strong force) permits not one but two types of bonds. Specifically that it assembles particules in- and out-of-phase (cis- and trans-phasic respectively). In this way the theory predicts that protons and neutrons form two types of bonds, with different stability [6]. The theory also identifies the role of the neutrons in nuclear bonding, and how the proton and neutron are bonded, and the advantages to both in doing so, when otherwise there would seem no reason for such a bond.[2]

The current paper uses this *synchronous interaction* to develop a Cordus theory for the bonding interactions between protons and neutrons. More specifically, we propose that protons (p) and neutrons (n) bind to form *nuclear polymers*, and we propose the mechanics for how this happens. This is relevant to the explanation of the nuclides, which we demonstrate by application to the helium series.

2 Where does the complexity arise?

The existing models of the nucleus are binding energy, shell model [3], liquid-drop model [1], and semi-empirical mass formula (SEMF) [2]. These models provide mathematical approximations for key nuclear characteristics, and identify the interplay of the strong and electrostatic forces as important in determining stability. The shell and liquid-drop 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. 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 [7]. A different approach is offered by the *interacting boson model* [8-9] which assumes that nucleons exist in pairs. However this severely limits the model to nuclides where p=n, which is obviously a 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. A related problem is how the volume of the nucleus arises. The models can

[2] **Causality from the strong force to the nuclides:** The Cordus theory offers answers to several key questions. How does the strong force operate? *By synchronicity between the discrete forces emitted by neighbouring particules, with a resulting geometric interlocking of reactive ends.* What binds the protons together, despite their mutually repulsive electric charge? Why are the neutrons necessary? *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 not charge per se.*

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.

Also deeply problematic is the disconnect between the QCD strong force and the nuclear models, as already mentioned. 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, the repulsive nature of the strong force at short-range is excluded from the nuclear models. Nor can QCD explain nuclear structures.

This critique suggests that the assumption of independence of the nucleon particles is unlikely to be valid. The difficulty is determining how protons and neutrons might interact. A sufficient nuclear theory will also need to explicitly include the strong force, which also has proved problematic. It is possible that the slow progress towards solving these problems is due to a fundamental limitation of the 0-D point premise that underlies the Standard Model and the nuclear models.[3] In which case we might expect better solutions by admitting the possibility for particles to have internal structure, a possibility to which we now turn.

3 Purpose and approach

This paper prospects for a better understanding of the relationships between nucleons, starting from the NLHV sector. We use a systems design approach whereby we extend the existing Cordus theory for the synchronous interaction (strong force) [5] and cis/trans-phasic bonding [6], to a theory for the assembly of nucleons. The Cordus conjecture [4] provides the conceptual model for such a NLHV structure. While such a solution may seem precluded by the Bell-type inequalities [11-12] there is reason to doubt the universality of those constraints [13-14] and we propose that the Cordus theory falsifies them [15]. [4] The result is a theory

[3] **Standard model of physics:** This partitions matter particles into quarks (dsb, uct) and leptons (eμτ, and the corresponding neutrinos) and proposes gauge bosons (photon, gluons, Z & W bosons, Higgs) as the carriers of the fundamental interactions. All these are assumed to be point objects, i.e. without internal structure. All matter is therefore assumed to be an assembly of zero-dimensional point objects: points interacting with each other via other point particles. In contrast hidden variable designs provide internal structure, and therefore possibilities for more complex interactions between particles. It is one of these possibilities that the present paper exploits.

[4] **Cordus conjecture:** This proposes that all particles are really linear structures of finite length (hence *cordus*), have two reactive ends separated by a short distance, 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*. Cis-phasic joints are where the reactive ends, one from each of two particules, are co-located, have the same frequency and are in-phase. The trans-phasic joint also involves co-location of the reactive ends, synchronous frequency, and the strong force, but the difference is that the particules are at opposite phases in their energisation sequences http://dx.doi.org/10.5539/apr.v5n5107.

that predicts a specific type of geometric layout of nucleons in the nucleus.

4 Results

4.1 Representation of proton and neutron

The Cordus theory elsewhere identifies the proposed internal and external structures of the proton and neutron [5]. Key attributes that we need in building a nuclear theory are the identity of the nucleon (proton or neutron), its orientation in space, and the energisation phase of each particule. For this we devised a simplified representation, see Figure 1.

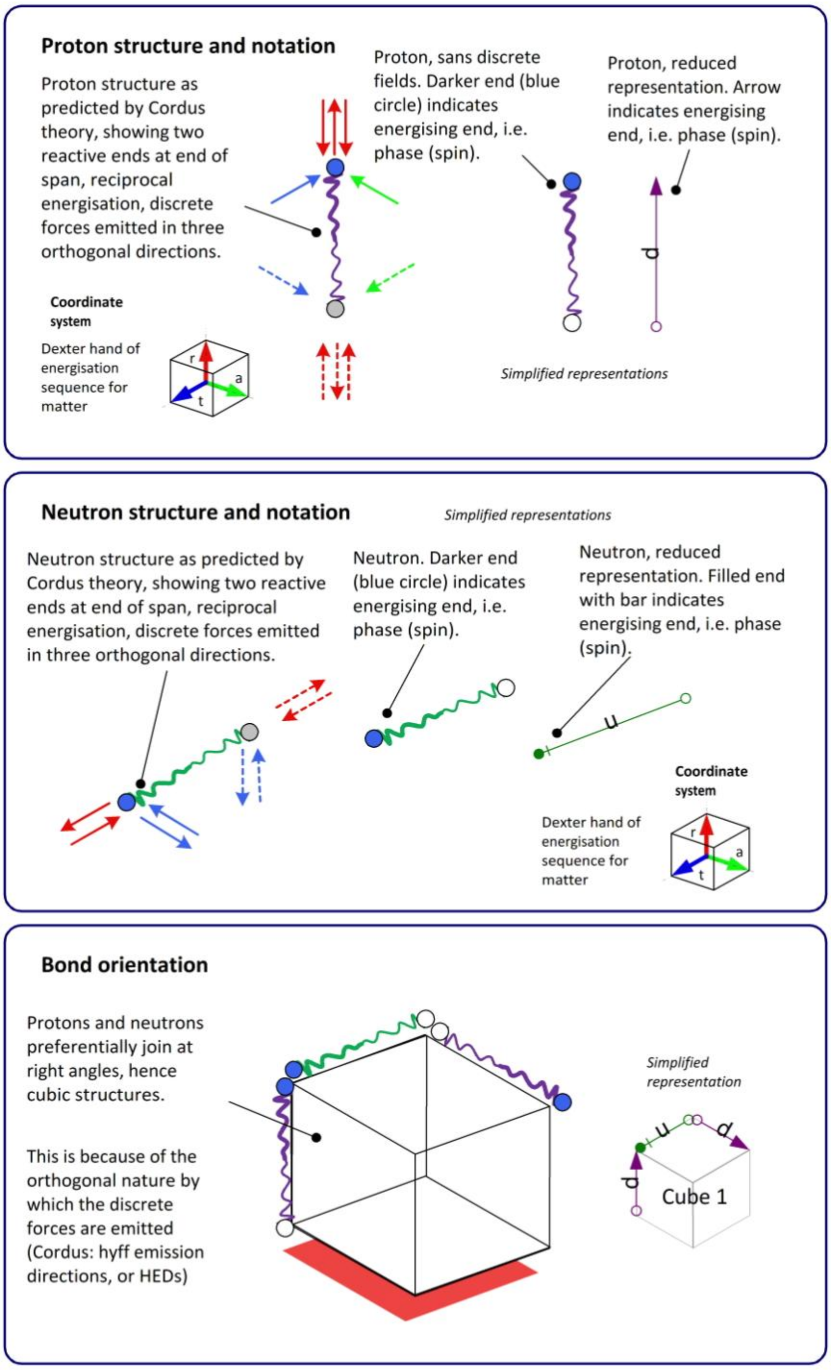


Figure 1: Simplified representation for nucleons

4.2 Tendency towards cubic structures for the nuclear polymer

A logical consequence of the three dimensional layout of the discrete forces, and the handedness thereof [5], is that protons and neutrons preferentially join at right angles, hence cubic structures. The reasons for this are explained in Figure 2.

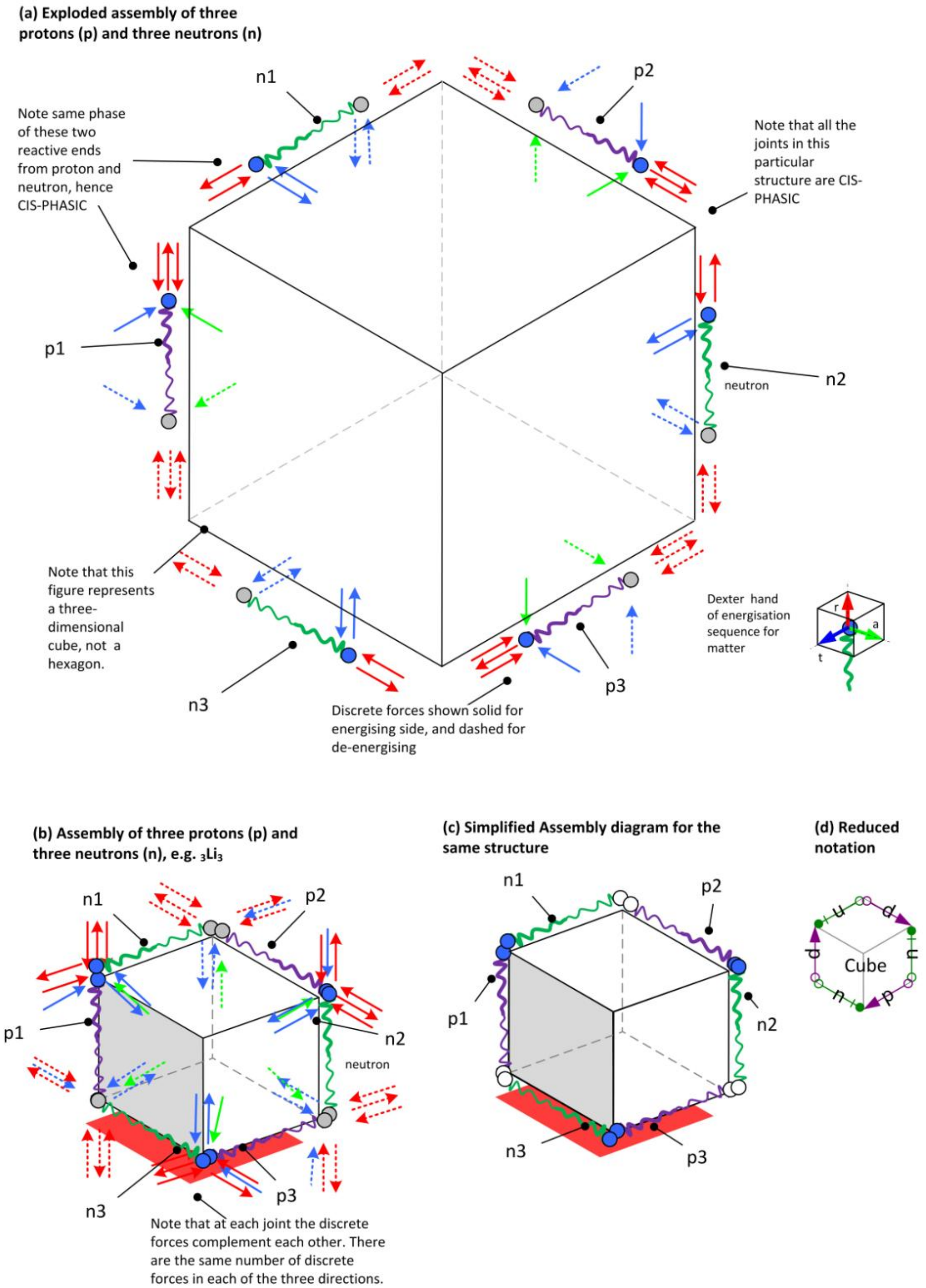


Figure 2: Cubic structures tend to arise from the bonding of protons and neutrons into a nuclear chain. The diagram shows exploded and assembly views.

At each joint, the proton and neutron complement each others' emission of discrete forces, i.e. there is a synchronous interaction, and this is proposed as the bonding mechanism. Specifically, there are three discrete forces in each direction at these junctions, which gives a balanced loading across the three emission directions. With all these discrete forces in the picture, it can be difficult to see what is happening, hence the *reduced notation*.

4.3 Linear (series) joins between nucleons

Up to here we have only considered the linear joining of protons and neutrons with cis-phasic bonds. However the synchronous theory also predicts that like-nucleons may also join, using the trans-phasic synchronous interaction. A number of combinations are predicted to exist, and it is proposed that these differentiate between bonds that are *stable, unstable,* and *non-viable.* All of these bonds employ the Cordus synchronous interaction, which as previously identified, comes in cis- and trans-phasic forms. The linear bonds, which make up the series components of the nuclear polymer, are identified in Figure 3.

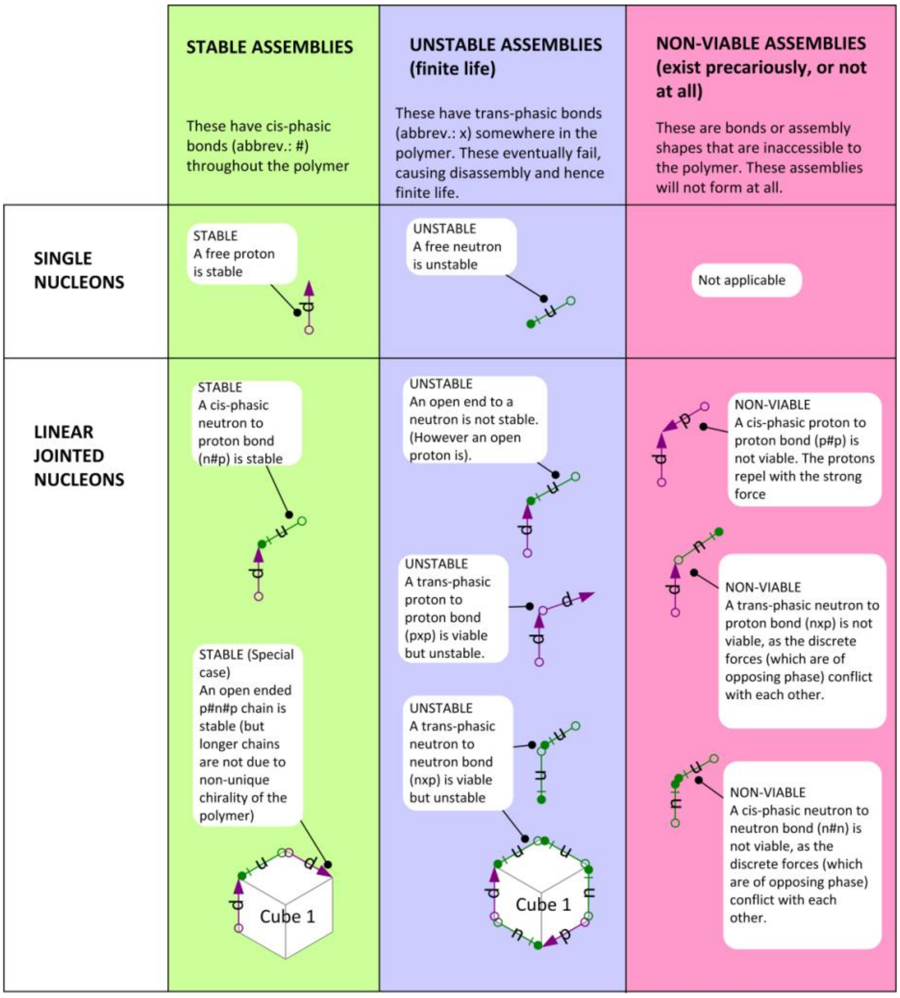


Figure 3: Linear bonds between two nucleons may be cis- or trans-phasic, and depending on the participants, result in stable, unstable, or non-viable outcomes.

Stable bonds, as the name suggests, are those that have enduring stability. *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. The reason such bonds decay is, according to the Cordus theory [16], because perturbations of external discrete forces (Cordus: *fabric)* interfere with and destabilise the synchronous interlock of the discrete forces. Trans-phasic 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 cis-phasic interactions) and are therefore the weakest link in the nuclear polymer. *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 cis-phasic 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.

Key features that differentiate this Cordus theory from other theories are: (a) the concept that the strong force is a synchronous interaction between discrete forces, as opposed to merely an exchange of bosons, (b) the concept that the synchronous interaction permits cis- and trans-phasic bonds, as opposed to merely the single interaction envisaged by competing theories, (c) the concept of protons and neutrons having two reactive ends, energised in turn, as opposed to the 0-D point premise of QM. Consequently this theory predicts that protons and neutrons have multiple ways of bonding together. Having multiple interactions also provides a means to differentiate between *stable* and *unstable* bonds in nuclides.

4.4 Nuclear polymer

With these concepts in place, we are now in the position to introduce the next core concept in the Cordus nuclear theory, that of the *nuclear polymer*. This comprises protons and neutrons joined in a network. The polymer has a particular morphology. 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*. See Figure 4 for the physical representation of these concepts, as applied to some example nuclides.

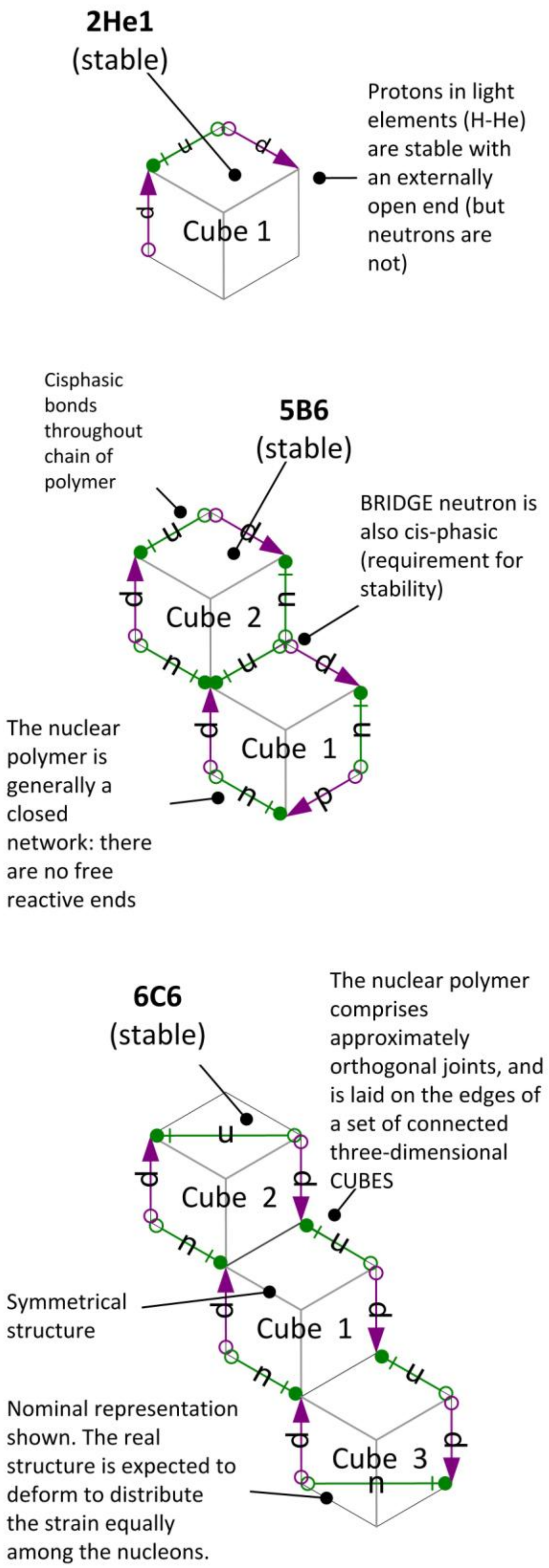


Figure 4: The synchronous interaction (strong force) bonds protons and neutrons together in a variety of way, resulting in nuclear polymer structures. These are proposed as the structure of the nucleus.

These requirements arise directly from the handed nature of the Cordus synchronous interaction (strong force), specifically the emission of discrete forces in three orthogonal hyff emission directions (HEDs).

The morphology of the polymer and the nature of the bonds are proposed as the primary determinants of stability/instability of the nuclide concerned. The network is primarily a closed loop of nucleons connected in series, with occasional cross bridges: there are no free reactive ends. Exceptions are the light elements, where open structures are permitted, terminated by protons (but not by neutrons – which are inherently unstable unless bonded at both ends).

4.5 Cross bridges

The nuclear polymer consists, in the first place, of protons and neutrons in series. However we also identify the possibility for bridges to form across the polymer. The theory for these bridges is shown in Figure 5.

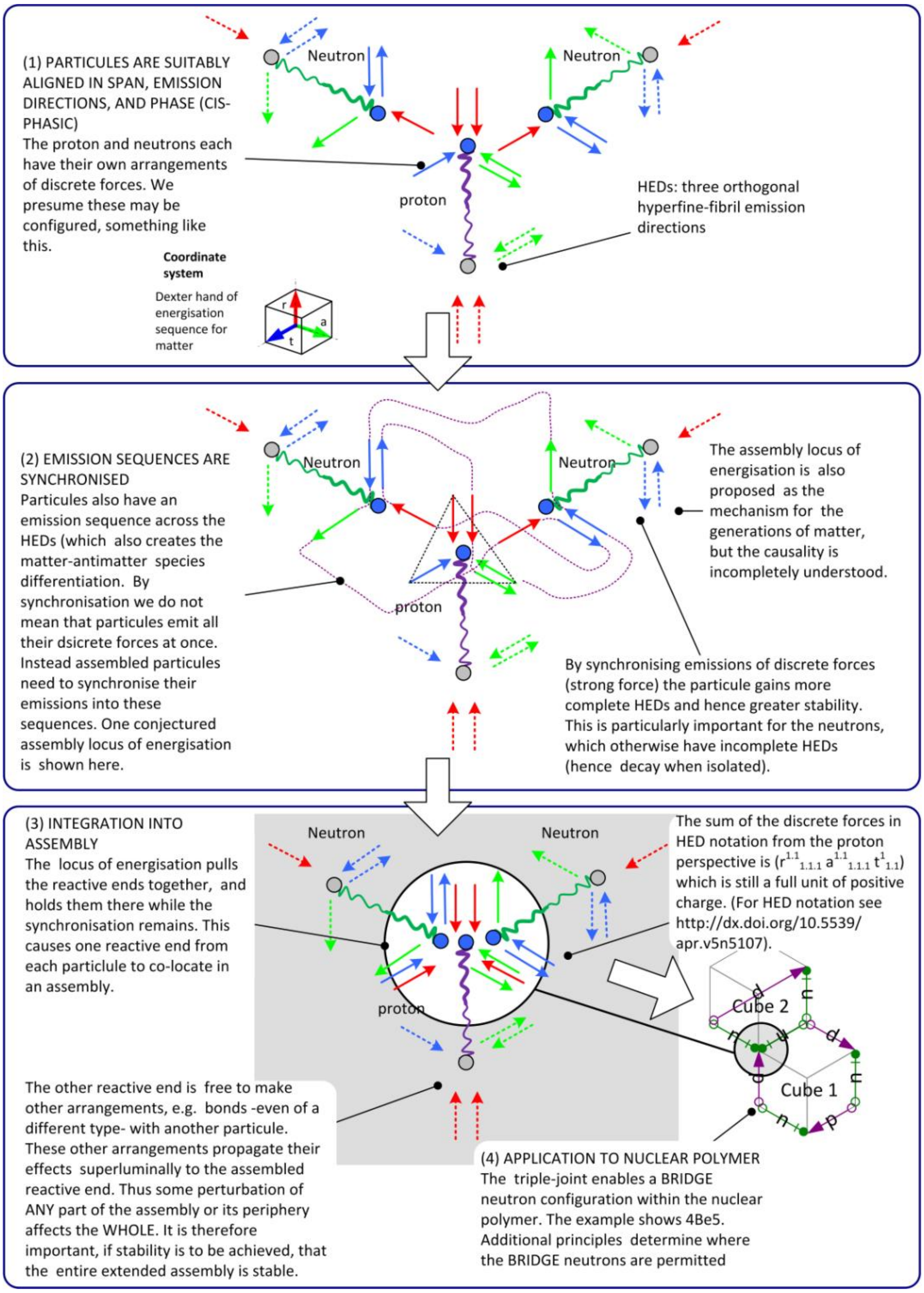


Figure 5: Neutron cross-bridges are anticipated to occur within the nuclear polymer. These result in accumulation of discrete forces at the common node. For HED notation see [5].

Having established the possibility for neutron cross bridges, we next identify the situations in which they may occur in the nuclear polymer. The results, see Figure 6, show that both proton and neutron bridges should be possible (conditions apply). Importantly, the results also indicate that certain configurations will be non-viable.

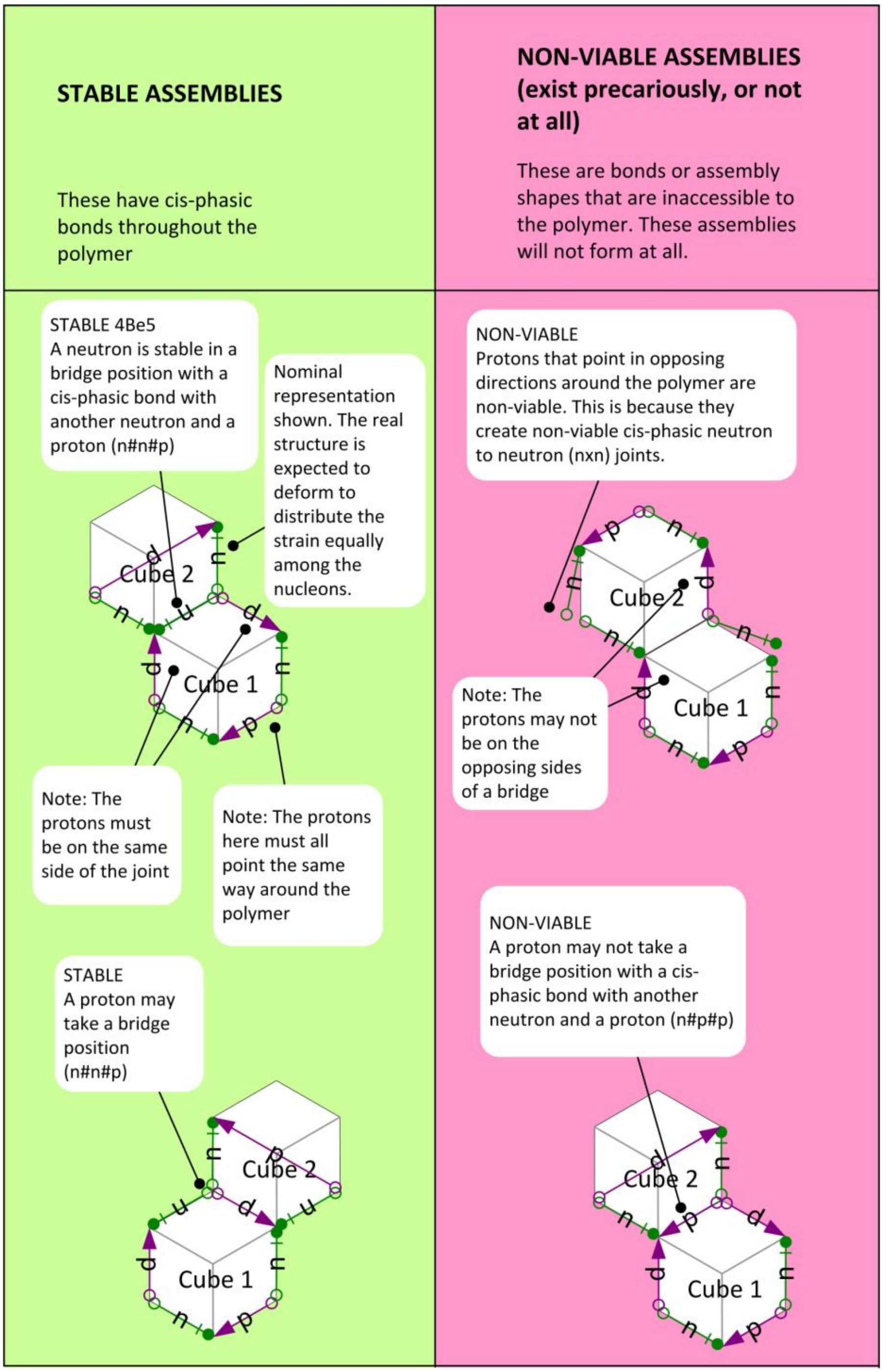
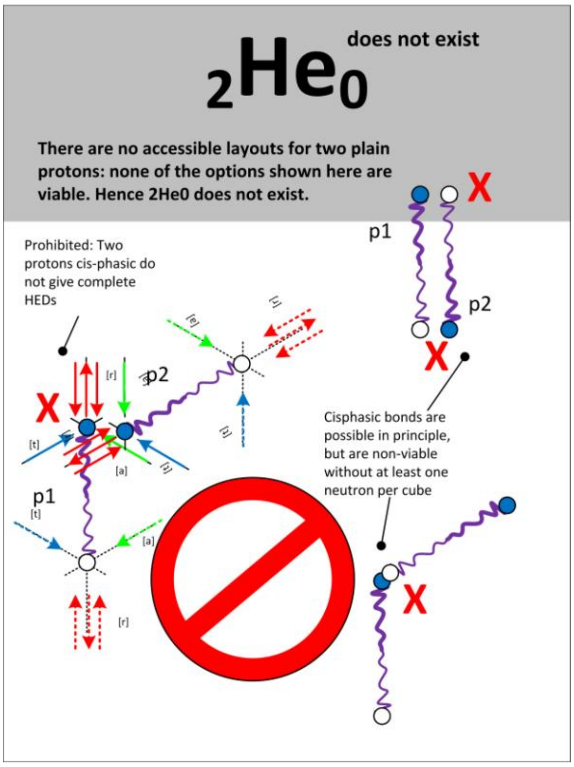
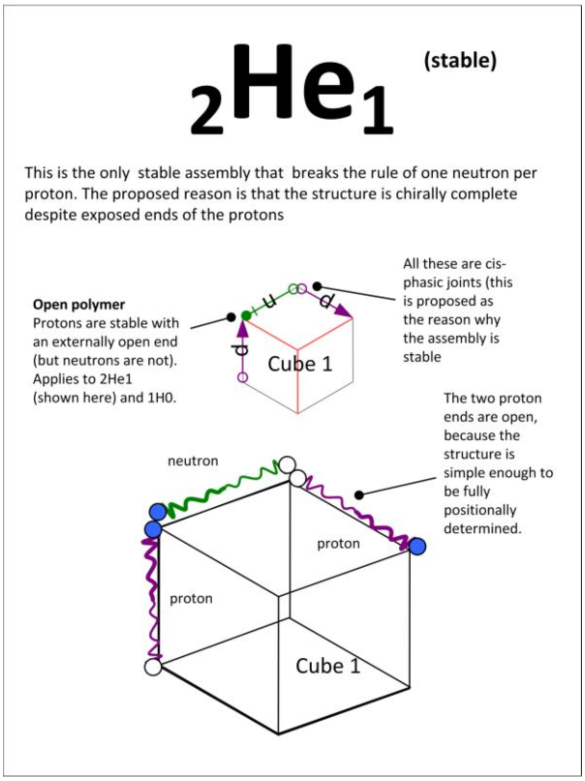


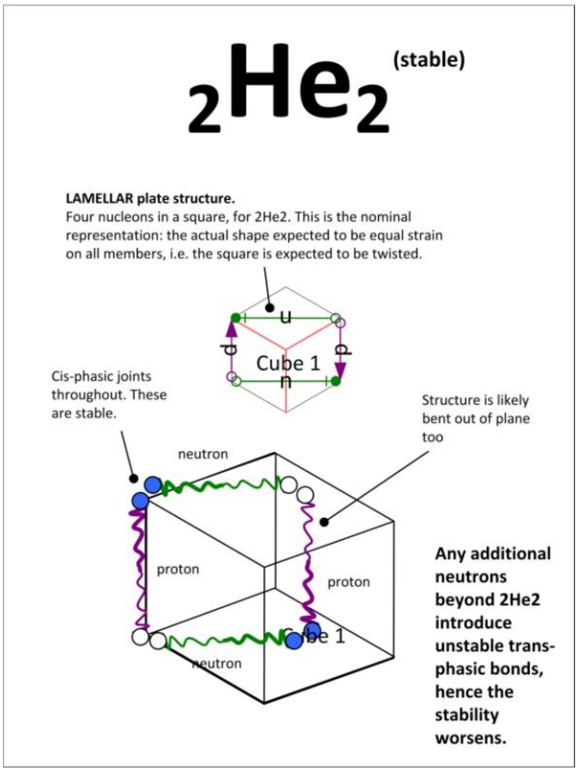
Figure 6: Specific rules emerge for the arrangement of cross-bridges. Some arrangements are non-viable.

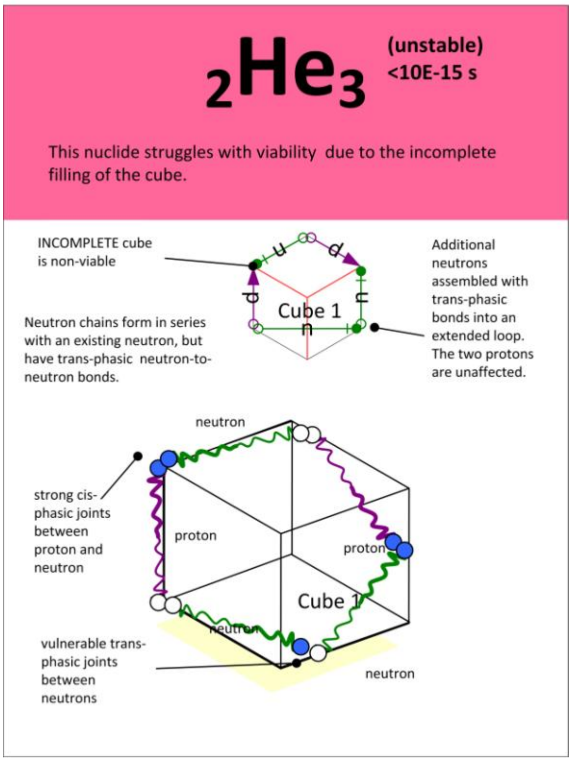
4.6 Helium nuclides

These principles are sufficient to explain most attributes of the helium nuclides, see Figure 7.


2He0
does not exist
There are no accessible layouts for two plain protons: none of the options shown here are viable. Hence 2He0 does not exist.
p1
p2
X
Prohibited: Two protons cis-phasic do not give complete HEDs
p2
p1
Cisphasic bonds are possible in principle, but are non-viable without at least one neutron per cube

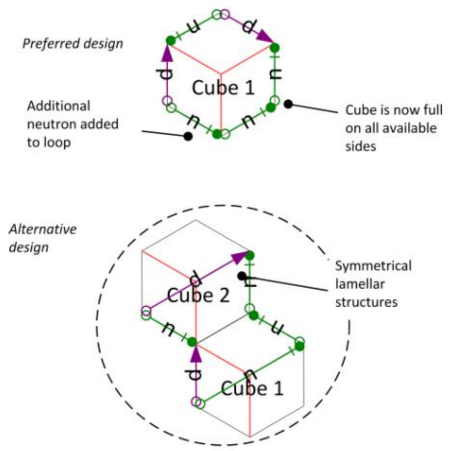

2He1
(stable)
This is the only stable assembly that breaks the rule of one neutron per proton. The proposed reason is that the structure is chirally complete despite exposed ends of the protons
Open polymer
Protons are stable with an externally open end (but neutrons are not). Applies to 2He1 (shown here) and 1H0.
Cube 1
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.
neutron
proton
proton
Cube 1


$_2He_2$ (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.
u
d
d
n
Cube 1
Cis-phasic joints throughout. These are stable.
Structure is likely bent out of plane too
neutron
proton
proton
Cube 1
neutron
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.
u
d
d
n
n
Cube 1
neutron
strong cis-phasic joints between proton and neutron
proton
proton
Cube 1
neutron
vulnerable trans-phasic joints between neutrons
neutron

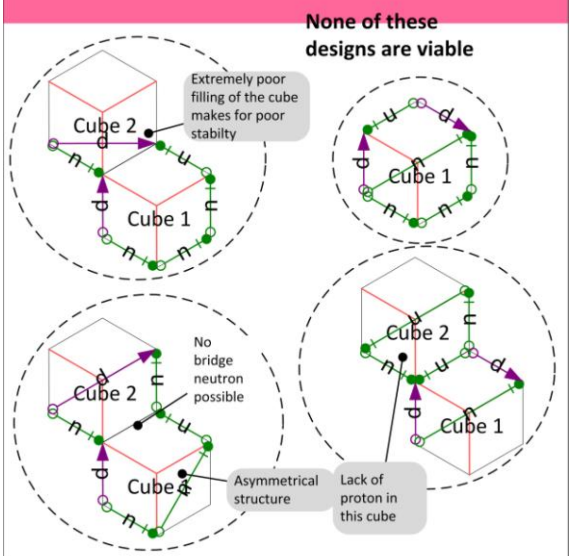
$_2He_4$ (unstable) 806 ms

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

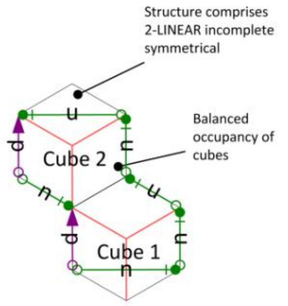
There is no accessible symmetrical structure, hence the nuclide is non-viable.



$_{2}He_{6}$

(unstable)
119 ms

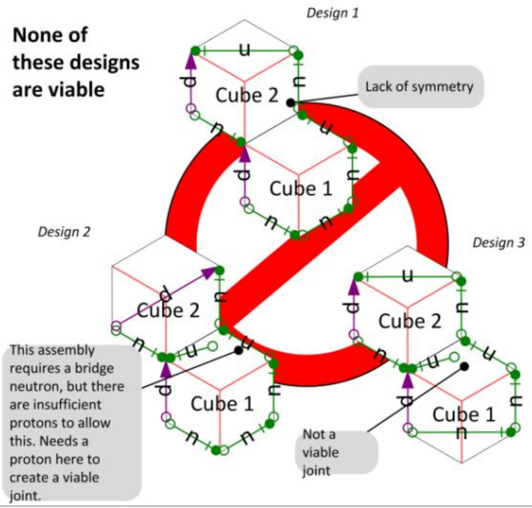
Stability improves (cf 2He5) due to a symmetrical structure becoming available for this size of polymer.

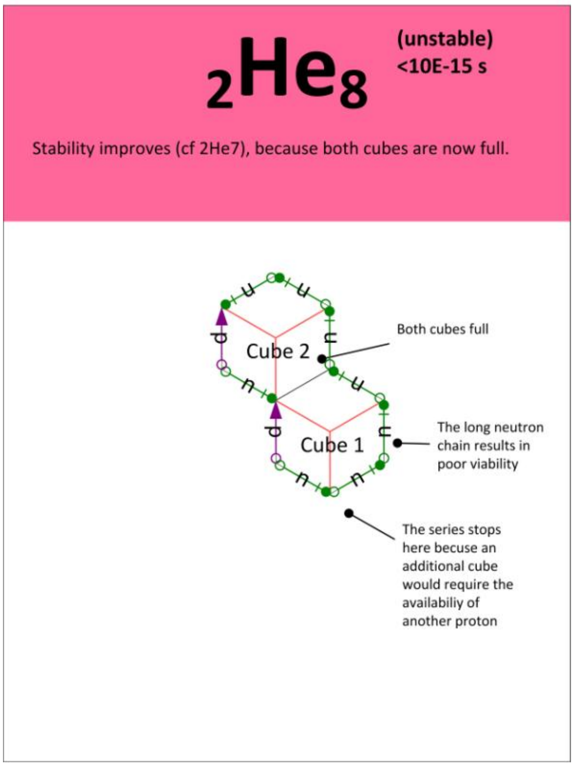


$_{2}He_{7}$

(does not exist)

Stability worsens (cf 2He6). This nuclide does not exist. The Cordus explanation is that there is no viable design available: it cannot achieve a symmetrical layout, or it can but with non-viable joint types.





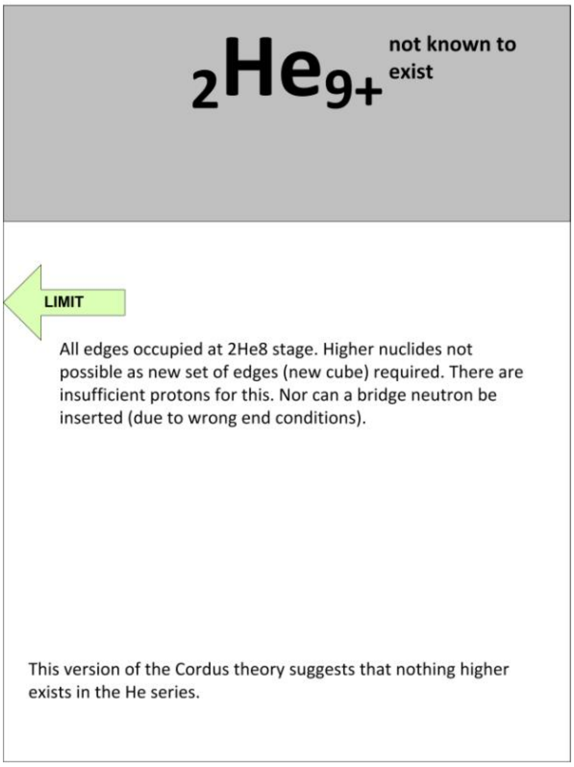


Figure 7: Internal structure of the nuclides of helium, as proposed by the Cordus theory.

The helium nuclides are a strange series, because the viability changes abruptly. The Cordus theory successfully explains these trends. 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). The shape progressions within the Cordus theory match these trends exactly. The theory is also successful at explaining why the series starts and stops where it does.

- *Why does 2He0 not exist?* Cis-phasic 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 trans-phasic 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. (These shapes are detailed in the next paper).
- *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. A full explanation is provided in the next paper in the bracket, so we do not burden the present treatment with all the details.

5 Discussion

What has been achieved?

A new concept emerges for the assembly of nuclear structures, namely the nuclear polymer. In doing so, this work makes several novel intellectual contributions. First, it explains the internal structures of nuclides, starting from the strong force at the *fundamental level*. It does this by providing a mechanics whereby the synchronisation of discrete forces of nucleons results in bonds, and hence physical layout of nucleons. Second, 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 modelling nuclear structures. This provides a natural explanation for why the nucleus has physical size. Third, *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.

A fourth and more specific contribution is the explanation of the helium nuclide series. The theory correct explains the start and end of the series, and the stability trends within it. This does not validate the theory, but does show that it has descriptive power and external validity. The fifth contribution is methodological, in that the work shows the relevance of a NLHV solution to nucleon bonding, something that has not previously been achieved with the hidden variable approach.

The present development adds to the capability of the Cordus theory to provide a logically consistent explanation across a wide range of fundamental phenomena. Also relevant here is that the Cordus theory separately provides mechanisms for the decay process itself [16], and the weak interactions (beta plus & minus decay, and electron capture) [17].

Limitations

Limitations of the work are its conceptual nature, and the lack of a mathematical formalism. The two are related: as conceptual work, there is not yet any published mathematical formalism of the theory, other than in its explanations for optics (reflection, refraction, Brewster's angle) and entanglement [4]. We identify the mathematical developments as a future opportunity.

Given the strong preference of physics for quantum mechanical solutions with zero-dimensional particles, e.g. QCD's gluons, the candidate solution offered here may seem nonsensical. Critics will, quite naturally, expect extraordinary evidence to support the Cordus theory. Some support has already been provided in the ability to explain the hydrogen and helium nuclides. In subsequent papers we show that these principles have the fitness to explain the H-Ne nuclides, and we rest the defence until then.

Implications

If the Cordus theory is correct, then we have a new model of nuclear structure involving the concept of a nuclear polymer. We would expect this to be complementary to the SEMF and liquid drop models, because they are all models for the geometric packing of the nucleons. However the point of difference for the Cordus theory is that it offers a design for the *inside* of the nucleus and the bonds between its components, whereas the other models stop at the aggregate level. The Cordus theory has the potential to provide a profoundly different conceptual framework in which to consider nuclear structure.

Future research

It has long been expected that a successful theory of the strong force should be able 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). Existing theories cannot do any of this. In contrast, we have shown that a NLHV design *is* able to explain the hydrogen and helium nuclides. Obviously there are many other nuclides to explain, hence much opportunity for future work. There is also an opportunity, which we have not explored in this paper, of developing a mathematical formulism for the nuclear polymer. Another opportunity for research is to model binding energy and charge radii.

The next paper in this bracket explains the nuclides from hydrogen to neon. We show that the same principles set out here, with some additional development, are able to explain most of these nuclides.

6 Conclusions

The conventional interpretation is that the nucleus consists of zero-dimensional point particles (protons and neutrons) held together by the strong force. In that framework the strong force is required to be repulsive at short range, strong at middle range, and weak at long range. However the resulting theory of QCD is unable to explain the causality from the strong force up to nuclear structures. We offer a solution to that problem with a design from the non-local hidden-variable sector.

This Cordus theory starts by reconceptualising the strong force as a synchronous interaction. This is a more parsimonious solution than QCD's gluons, and it also provides for different types of synchronous bonds. This is an important conceptual change, because existing models of nuclear structure, like the semi-empirical mass formula (SEMF), treat the protons and neutrons collectively, as a bag or liquid drop of point particles, and are unable to describe the detailed interaction of the nucleons.

The Cordus theory for cis- and trans-phasic bonds predicts that 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, hence nuclear polymer. This theory predicts that protons preferentially bind to neutrons (rather than other protons), with cis-phasic bonds (as opposed to trans-phasic), and that the bond is arranged with the spans of the two particules generally orthogonal. Thus it is proposed that the nucleus comprises protons and neutrons joined in chains and bridges to make networks. This concept is a novel development as it permits an entirely new approach to modelling nuclear structures.

This is important as it demonstrates, for the first time, a way to model nuclear structure starting from the strong/synchronous force at the fundamental level. That it is possible to achieve this from within the much-maligned hidden variable sector, suggests that particules may have internal structure after all. The next paper in this series applies the principles developed here to explain the Table of Nuclides from hydrogen to neon.

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