Nuclear String Hypothesis

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Contents

Abstract

Nuclear string hypothesis is one of the most dramatic almost-predictions of TGD. The hypothesis in its original form assumes that nucleons inside nucleus form closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. It is also possible that neutrons and protons form their own strings. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests.

1. $A > 4$ nuclei as nuclear strings consisting of $A \leq 4$ nuclei

In this article a more refined version of nuclear string hypothesis is developed.

1. It is assumed ^4He nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings. $A \leq 4$ nuclei in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number of ^4He nuclei is maximal. Even the weak decay characteristics might be reduced to those for $A < 4$ nuclei using this hypothesis.
2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings.
3. In TGD framework tetra-neutron is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants. For heavier nuclei tetra-neutron is needed as an additional building brick.

2. Bose-Einstein condensation of color bonds as a mechanism of nuclear binding

The attempt to understand the variation of the nuclear binding energy and its maximum for Fe leads to a quantitative model of nuclei lighter than Fe as color bound Bose-Einstein condensates of pion like colored states associated with color flux tubes connecting ^4He nuclei. The color contribution to the total binding energy is proportional to n^2, where n is the number of color bonds. Fermi statistics explains the reduction of E_B for the nuclei heavier than Fe. Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand ^4He and lighter nuclei as strings of nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$, $A = 4$, and $A < 4$ nuclei are involved. The binding energies of also $A \leq 4$ are predicted surprisingly accurately by applying simple p-adic scaling to the model of binding energies of heavier nuclei.

3. Giant dipole resonance as de-coherence of Bose-Einstein condensate of color bonds

Giant resonances and so called pygmy resonances are interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei. The splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy. For ^4He de-coherence the model predicts singlet line at 12.74 MeV and triplet at ~ 27 MeV spanning 4 MeV wide range.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in rather good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet at ~ 8 MeV and MeV spacing is predicted. The prediction for the position is correct.

4. Dark nuclear strings as analogs of as analogs of DNA-, RNA- and amino-acid sequences and baryonic realization of genetic code

A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the hardware for topological quantum computation (TQC) represented by the genome is actively

developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of amino-acids coded by a given number of codons are predicted correctly. Hence genetic code would be universal rather than being an accidental outcome of the biological evolution.

1 Introduction

Nuclear string hypothesis [K18] is one of the most dramatic almost-predictions of TGD [K16]. The hypothesis in its original form assumes that nucleons inside nucleus organize to closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests. The presence of exotic light mesons in nuclei has been proposed also by Illert [C12] based on evidence for charge fractionization effects in nuclear decays.

1.1 $A > 4$ Nuclei As Nuclear Strings Consisting Of $A \leq 4$ Nuclei

In the sequel a more refined version of nuclear string hypothesis is developed.

1. The first refinement of the hypothesis is that ^4He nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings instead of nucleons which in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number of ^4He nuclei is maximal. One can hope that even also weak decay characteristics could be reduced to those for $A < 4$ nuclei using this hypothesis.

2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings and that the addition of neutrons tends to reduce Coulomb energy per string length by increasing the length of the nuclear string implying increase binding energy and stabilization of the nucleus. This picture does not explain the variation of binding energy per nucleon and its maximum appearing for ^{56}Fe.

3. In TGD framework tetra-neutron [C24, C11] is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants [K18]. For heavier nuclei tetra-neutron is needed as an additional building brick and the local maxima of binding energy E_B per nucleon as function of neutron number are consistent with the presence of tetra-neutrons. The additivity of magic numbers $2, 8, 20, 28, 50, 82, 126$ predicted by nuclear string hypothesis is also consistent with experimental facts and new magic numbers are predicted [C42, C9].

1.2 Bose-Einstein Condensation Of Color Bonds As A Mechanism Of Nuclear Binding

The attempt to understand the variation of the nuclear binding energy and its maximum for Fe leads to a quantitative model of nuclei lighter than Fe as color bound Bose-Einstein condensates of ^4He nuclei or rather, of pion like colored states associated with color flux tubes connecting ^4He nuclei. The crucial element of the model is that color contribution to the binding energy is proportional to n^2 where n is the number of color bonds. Fermi statistics explains the reduction of E_B for the nuclei heavier than Fe. Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand ^4He and lighter nuclei as strings formed from nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$ nuclei, $A = 4$ nuclei and $A < 4$ nuclei are thus involved. The binding energies of also lighter nuclei are predicted surprisingly accurately by applying simple p-adic scaling to the parameters of model for the electromagnetic and color binding energies in heavier nuclei.

1.3 Giant Dipole Resonance As De-Coherence Of Bose-Einstein Condensate Of Color Bonds

Giant (dipole) resonances [C4, C18, C29] , and so called pygmy resonances [C39, C28] interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei provide a unique test for the model. The key observation is that the splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy due to the n^2 dependence of the total binding energy. For ^4He de-coherence the model predicts singlet line at 12.74 MeV and triplet (25.48, 27.30,29.12) MeV at ~ 27 MeV spanning 4 MeV wide range which is of the same order as the width of the giant dipole resonance for nuclei with full shells.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in a surprisingly good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet (7.520,8.4600) MeV at ~ 8 MeV is predicted. At least the prediction for the position is correct.

1.4 Dark Nuclear Strings As Analogs Of As Analogs Of DNA-, RNA- And Amino-Acid Sequences And Baryonic Realization Of Genetic Code

One biological speculation [K21] inspired by the dark matter hierarchy is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of dark nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of amino-acids coded by a given number of codons are predicted correctly. Hence it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. There are concept maps about topics related to the contents of the chapter prepared using CMAP realized as html files. Links to all CMAP files can be found at `http://tgdtheory.fi/cmaphtml.html` [L2]. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L3]. The topics relevant to this chapter are given by the following list.

- Applications of TGD [L1]
- Geometrization of fields [L5]
- Widom-Larsen theory from TGD point of view [L9]
- Nuclear string model [L6]

2 Some Variants Of The Nuclear String Hypothesis

The basic assumptions of the nuclear string model could be made stronger in several testable ways. One can make several alternative hypothesis.

2.1 Could Linking Of Nuclear Strings Give Rise To Heavier Stable Nuclei?

Nuclear strings (Z_1, N_1) and (Z_2, N_2) could link to form larger nuclei $(Z_1 + Z_2, N_1 + N_2)$. If one can neglect the interactions between linked nuclei, the properties of the resulting nuclei should be determined by those of composites. Linking should however be the confining interaction forbidding the decay of the stable composite. The objection against this option is that it is difficult to characterize the constraint that strings are not allowed to touch and there is no good reason forbidding the touching.

The basic prediction would be that if the nuclei (Z_1, N_1) and (Z_2, N_2) which are stable, very long-lived, or possess exceptionally large binding energy then also the nucleus $(Z_1 + Z_2, N_1 + N_2)$ has this property. If the linked nuclear strings are essentially free then the expectation is that the half-life of a composite of unstable nuclei is that of the shorter lived nucleus. This kind of regularity would have been probably observed long time ago.

2.2 Nuclear Strings As Connected Sums Of Shorter NuclearStrings?

Nuclear strings can form connected sum of the shorter nuclear strings. Connected sum means that one deletes very short portions of nuclear string A and B and connects the resulting ends of string A and B together. In other words: A is inserted inside B or vice versa or A and B are cut to open strings and connected and closed again. This outcome would result when A and B touch each other at some point. If touching occurs at several points more complex fusion of nuclei to a larger nucleus to a composite occurs with piece of A followed by a piece of B followed... For this option there is a non-trivial interaction between strings and the properties of nuclei need not be simply additive but one might still hope that stable nuclei fuse to form stable nuclei. In particular, the prediction for the half-life based on binding by linking does not hold true anymore.

Classical picture would suggest that the two strings cannot rotate with respect to each other unless they correspond to rather simple symmetric configurations: this applies also to linked strings. If so then the relative angular momentum L of nuclear strings vanishes and total angular momentum J of the resulting nucleus satisfies $|J_1 - J_2| \leq J \leq J_1 + J_2$.

2.3 Is Knotting Of Nuclear Strings Possible?

One can consider also the knotting of nuclear strings as a mechanism giving rise to exotic excitations of nuclear. Knots decompose to prime knots so that kind of prime nuclei identified in terms of prime knots might appear. Fractal thinking suggests an analogy with the poorly understood phenomenon of protein folding. It is known that proteins always end up to a unique highly folded configuration and one might think that also nuclear ground states correspond to unique configurations to which quantum system (also proteins would be such if dark matter is present) ends up via quantum tunnelling unlike classical system which would stick into some valley representing a state of higher energy. The spin glass degeneracy suggests an fractal landscape of ground state configurations characterized by knotting and possibly also linking.

3 Could Nuclear Strings Be Connected Sums Of Alpha Strings And Lighter Nuclear Strings?

The attempt to kill the composite string model leads to a stronger formulation in which nuclear string consists of alpha particles plus a minimum number of lighter nuclei. To test the basic predictions of the model I have used the rather old tables of [C41] for binding energies of stable and long-lived isotopes and more modern tables [C7] for basic data about isotopes known recently.

3.1 Does The Notion Of Elementary Nucleus Make Sense?

The simplest formulation of the model assumes some minimal set of *stable* "elementary nuclei" from which more complex *stable* nuclei can be constructed.

1. If heavier nuclei are formed by *linking* then alpha particle $^4He = (Z, N) = (2, 2)$ suggests itself as the lightest stable composite allowing interpretation as a closed string. For connected sum option even single nucleon n or p can appear as a composite. This option turns out to be the more plausible one.

2. In the model based on linking $^6Li = (3, 3)$ and $^7Li = (3, 4)$ would also act as "elementary nuclei" as well as $^9Be = (4, 5)$ and $^{10}Be = (4, 6)$. For the model based on connected sum these nuclei might be regarded as composites $^6Li = (3, 3) = (2, 2) + (1, 1)$, $^7Li = (3, 4) = (2, 2) + (1, 2)$, $^9Be = (4, 5) = 2 \times (2, 2) + (0, 1)$ and $^{10}Be = (4, 6) = (2, 2) + 2 \times (1, 2)$. The study of binding energies supports the connected sum option.

3. ^{10}B has total nuclear spin $J = 3$ and $^{10}B = (5, 5) = (3, 3) + (2, 2) =^6 Li +^4 He$ makes sense if the composites can be in relative $L = 2$ state (^6Li has $J = 1$ and ^4He has $J = 0$). ^{11}B has $J = 3/2$ so that $^{11}B = (5, 6) = (3, 4) + (2, 2) =^7 Li +^4 He$ makes sense because ^7Li has $J = 3/2$. For the model based on disjoint linking also 10^B would be also regarded as "elementary nucleus". This asymmetry disfavors the model based on linking.

3.2 Stable Nuclei Need Not Fuse To Form Stable Nuclei

The question is whether the simplest model predicts stable nuclei which do not exist. In particular, are the linked ^4He composites stable? The simplest case corresponds to $^8B = (4, 4) =^4 He +^4 He$ which is not stable against alpha decay. Thus stable nuclei need not fuse to form stable nuclei. On the other hand, the very instability against alpha decay suggests that ^4B can be indeed regarded as composite of two alpha particles. A good explanation for the instability against alpha decay is the exceptionally large binding energy $E = 7.07$ MeV per nucleon of alpha particle. The fact that the binding energy per nucleon for ^8Be is also exceptionally large and equal to 7.06 MeV $< E_B(^4He)$ supports the interpretation as a composite of alpha particles.

For heavier nuclei binding energy per nucleon increases and has maximum 8.78 MeV for Fe. This encourages to consider the possibility that alpha particle acts as a fundamental composite of nuclear strings with minimum number of lighter isotopes guaranteeing correct neutron number. Indeed, the decomposition to a maximum number of alpha particles allows a qualitative understanding of binding energies assuming that additional contribution not larger than 1.8 MeV per nucleon is present.

The nuclei ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S, ^{36}A, and ^{40}Ca are lightest stable isotopes of form $(Z, Z) = n \times^4 He$, $n = 3, ..., 10$, for which E_B is larger than for ^4He. For the first four nuclei E_B has a local maximum as function of N. For the remaining the maximum of E_B is obtained for $(Z, Z + 1)$. $^{44}Ti = (22, 22)$ does not exist as a long-lived isotope whereas ^{45}Ti does. The addition of neutron could increase E_B by increasing the length of nuclear string and thus reducing the Coulomb interaction energy per nucleon. This mechanism would provide an explanation also for neutron halos [C40].

Also the fact that stable nuclei in general have $N \geq Z$ supports the view that $N = Z$ state corresponds to string consisting of alpha particles and that $N > Z$ states are obtained by adding something between. $N < Z$ states would necessarily contain at least one stable nucleus lighter than ^4He with smaller binding energy. ^3He is the only possible candidate as the only stable nucleus with $N < Z$. ($E_B(^2H) = 1.11$ MeV and $E_B(^3He) = 2.57$ MeV). Individual nucleons are also possible in principle but not favored. This together with increase of Coulomb interaction energy per nucleon due to the greater density of em charge per string length would explain their smaller binding energy and instability.

3.3 Formula For Binding Energy Per Nucleon As A Test For TheModel

The study of ^8B inspires the hypothesis that the total binding energy for the nucleus (Z_1+Z_2, N_1+N_2) is in the first approximation the sum of total binding energies of composites so that one would have for the binding energy per nucleon the prediction

$$E_B = \frac{A_1}{A_1 + A_2} \times E_{B_1} + \frac{A_2}{A_1 + A_2} \times E_{B_2}$$

in the case of 2-nucleus composite. The generalization to N-nucleus composite would be

$$E_B = \sum_k \frac{A_k}{\sum_r A_r} \times E_{B_k} \quad .$$

This prediction would apply also to the unstable composites. The increase of binding energy with the increase of nuclear weight indeed suggests a decomposition of nuclear string to a sequence alpha strings plus some minimum number of shorter strings.

The first objection is that for both Li, B, and Be which all having two stable isotopes, the lighter stable isotope has a slightly smaller binding energy contrary to the expectation based on additivity of the total binding energy. This can be however understood in terms of the reduction of Coulomb energy per string length resulting in the addition of neutron (protons have larger average distance along nuclear string along mediating the electric flux). The reduction of Coulomb energy per unit length of nuclear string could also partially explain why one has $E_B > E_B(^4He)$ for heavier nuclei.

The composition $^6Li = (3,3) = (2,2) + (1,1)$ predicts $E_B \simeq 5.0$ MeV not too far from 5.3 MeV. The decomposition $^7Li = (3,4) = (2,2) + (1,2)$ predicts $E_B = 5.2$ MeV to be compared with 5.6 MeV so that the agreement is satisfactory. The decomposition $^8Be = (4,4) = 2\times\ ^4He$ predicts $E_B = 7.07$ MeV to be compared with the experimental value 7.06 MeV. ^9Be and ^{10}Be have $E_B = 6.46$ MeV and $E_B = 6.50$ MeV. The fact that binding energy slightly increases in addition of neutron can be understood since the addition of neutrons to ^8Be reduces the Coulomb interaction energy per unit length. Also neutron spin pairing reduces E_B. The additive formula for E_B is satisfied with an accuracy better than 1 MeV also for ^{10}B and ^{11}B.

3.4 Decay Characteristics And Binding Energies As Signatures Of The Decomposition Of Nuclear String

One might hope of reducing the weak decay characteristics to those of shortest unstable nuclear strings appearing in the decomposition. Alternatively, one could deduce the decomposition from the weak decay characteristics and binding energy using the previous formulas. The picture of nucleus as a string of alpha particles plus minimum number of lighter nuclei ^3He having $E_B = 2.57$ MeV, ^3H unstable against beta decay with half-life of 12.26 years and having $E_B = 2.83$ MeV, and ^2H having $E_B = 1.1$ MeV gives hopes of modelling weak decays in terms of decays for these light composites.

1. β^- decay could be seen as a signature for the presence of ^3H string and alpha decay as a signature for the presence of ^4He string.

2. β^+ decay might be interpreted as a signature for the presence of ^3He string which decays to ^3H (the mass of ^3H is only.018 MeV higher than that of ^3He). For instance, $^8B = (5,3) = (3,2) + (2,1) = {}^5Li + {}^3He$ suffers β^+ decay to $^8Be = (4,4)$ which in turn decays by alpha emission which suggests the re-arrangement to $(3,2) + (1,2) \rightarrow (2,2) + (2,2)$ maximizing binding energy.

3. Also individual nucleons can appear in the decomposition and give rise to β^- and possible also β^+ decays.

3.5 Are Magic Numbers Additive?

The magic numbers $2, 8, 20, 28, 50, 82, 126$ [C42] for protons and neutrons are usually regarded as a support for the harmonic oscillator model. There are also other possible explanations for magic nuclei and there are deviations from the naive predictions. One can also consider several different criteria for what it is to be magic. Binding energy is the most natural criterion but need not always mean stability. For instance $^8B = (4,4) = {}^4He + {}^4He$ has high binding energy but is unstable against alpha decay.

Nuclear string model suggests that the fusion of magic nuclear strings by connected sum yields new kind of highly stable nuclei so that also $(Z_1 + Z_2, N_1 + N_2)$ is a magic nucleus if (Z_i, N_i) is such. One has $N = 28 = 20 + 8$, $50 = 28 + 20 + 2$, and $N = 82 = 50 + 28 + 2 \times 2$. Also other magic numbers are predicted. There is evidence for them [C9] .

1. $^{16}O = (8,8)$ and $^{40}Ca = (20,20)$ corresponds to doubly magic nuclei and $^{60}Ni = (28,32) = (20,20) + (8,8) +^4 n$ has a local maximum of binding energy as function of neutron number. This is not true for ^{56}Ni so that the idea of magic nucleus in neutron sector is not supported by this case. The explanation would be in terms of the reduction of E_B due to the reduction of Coulomb energy per string length as neutrons are added.

2. Also $^{80}Kr = (36,44) = (36,36) +^4 n = (20,20) + (8,8) + (8,8) +^4 n$ corresponds to a local maximum of binding energy per nucleon as also does $^{84}Kr =^{80} Kr +^4 n$ containing two tetra-neutrons. Note however that $^{88}Zr = (40,48)$ is not a stable isotope although it can be regarded as a composite of doubly magic nucleus and of two tetra-neutrons.

3.6 Stable Nuclei As Composites Of Lighter Nuclei And Necessity Of Tetra-Neutron?

The obvious test is to look whether stable nuclei can be constructed as composites of lighter ones. In particular, one can check whether tetra-neutron ^4n interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants is necessary for the understanding of heavier nuclei.

1. $^{48}Ca = (20,28)$ with half-life $> 2 \times 10^{16}$ years has neutron excess of 8 units and the only reasonable interpretation seems to be as a composite of the lightest stable Ca isotope $Ca(20,20)$, which is doubly magic nucleus and two tetra-neutrons: $^{48}Ca = (20,28) =^{40} Ca + 2 \times^4 n$.

2. The next problematic nucleus is ^{49}Ti.

   i) $^{49}Ti = (22,27)$ having neutron excess of 5 one cannot be expressed as a composite of lighter nuclei unless one assumes non-vanishing and large relative angular momentum for the composites. For $^{50}Ti = (22,28)$ no decomposition can be found. The presence of tetra-neutron would reduce the situation to $^{49}Ti = (22,27) =^{45} Ti +^4 n$. Note that ^{45}Ti is the lightest Ti isotope with relatively long half-life of 3.10 hours so that the addition of tetra-neutron would stabilize the system since Coulomb energy per length of string would be reduced.

   ii) ^{48}Ti could not involve tetra-neutron by this criterion. It indeed allows decomposition to standard nuclei is also possible as $^{48}Ti = (22,26) =^{41} K +^7 Li$.

   iii) The heaviest stable Ti isotope would have the decomposition $^{50}Ti =^{46} Ti +^4 n$, where ^{46}Ti is the lightest stable Ti isotope.

3. The heavier stable nuclei $^{50+k}V = (23,27+k)$, $k = 0,1$, $^{52+k}Cr = (24,28+k)$, $k = 0,1,2$, $^{55}Mn = (25,30)$ and $^{56+k}Fe = (26,30+k)$, $k = 0,1,2$ would have similar interpretation. The stable isotopes $^{50}Cr = (24,26)$ and $^{54}Fe = (26,28)$ would not contain tetra-neutron. Also for heavier nuclei both kinds of stable states appear and tetra-neutron would explain this.

4. $^{112}Sn = (50,62) = (50,50) + 3 \times^4 n$, ^{116}Sn, ^{120}Sn, and ^{124}Sn are local maxima of E_B as a function of neutron number and the interpretation in terms of tetra-neutrons looks rather natural. Note that $Z = 50$ is a magic number.

Nuclear string model looks surprisingly promising and it would be interesting to compare systematically the predictions for E_B with its actual values and look whether the beta decays could be understood in terms of those of composites lighter than ^4He.

3.7 What Are The Building Blocks Of Nuclear Strings?

One can also consider several options for the more detailed structure of nuclear strings. The original model assumed that proton and neutron are basic building blocks but this model is too simple.

3.7.1 Option Ia)

A more detailed work in attempt to understand binding energies led to the idea that there is fractal structure involved. At the highest level the building blocks of nuclear strings are $A \leq 4$ nuclei. These nuclei in turn would be constructed as short nuclear strings of ordinary nucleons.

The basic objection against the model is the experimental absence of stable $n-n$ bound state analogous to deuteron favored by lacking Coulomb repulsion and attractive electromagnetic spin-spin interaction in spin 1 state. Same applies to tri-neutron states and possibly also tetra-neutron state. There has been however speculation about the existence of di-neutron and poly-neutron states [C2, C6].

The standard explanation is that strong force couples to strong isospin and that the repulsive strong force in nn and pp states makes bound states of this kind impossible. This force, if really present, should correspond to shorter length scale than the isospin independent forces in the model under consideration. In space-time description these forces would correspond to forces mediated between nucleons along the space-time sheet of the nucleus whereas exotic color forces would be mediated along the color magnetic flux tubes having much longer length scale. Even for this option one cannot exclude exotic di-neutron obtained from deuteron by allowing color bond to carry negative em charge. Since em charges $0, 1, -1$ are possible for color bonds, a nucleus with mass number $A > 2$ extends to a multiplet containing $3A$ exotic charge states.

3.7.2 Option Ib)

One might ask whether it is possible to get rid of isospin dependent strong forces and exotic charge states in the proposed framework. One can indeed consider also other explanations for the absence of genuine poly-neutrons.

1. The formation of negatively charged bonds with neutrons replaced by protons would minimize both nuclear mass and Coulomb energy although binding energy per nucleon would be reduced and the increase of neutron number in heavy nuclei would be only apparent.

2. The strongest hypothesis is that mass minimization forces protons and negatively charged color bonds to serve as the basic building bricks of all nuclei. If this were the case, deuteron would be a di-proton having negatively charged color bond. The total binding energy would be only $2.222 - 1.293 = .9290$ MeV. Di-neutron would be impossible for this option since only one color bond can be present in this state.

The small mass difference $m(^3He) - m(^3H) = .018$ MeV would have a natural interpretation as Coulomb interaction energy. Tri-neutron would be allowed. alpha particle would consist of four protons and two negatively charged color bonds and the actual binding energy per nucleon would be by $(m_n - m_p)/2$ smaller than believed. Tetra-neutron would also consist of four protons and the binding energy per nucleon would be smaller by $m_n - m_p$ than what obtains in the standard model of nucleus. Beta decays would be basically beta decays of exotic quarks associated with color bonds.

Note that the mere assumption that the di-neutrons appearing inside nuclei have protons as building bricks means a rather large apparent binding energy this might explain why di-neutrons have not been detected. An interesting question is whether also higher n-deuteron states than ^4He consisting of strings of deuteron nuclei and other $A \leq 3$ nuclei could exist and play some role in the nuclear physics of $Z \neq N$ nuclei.

If protons are the basic building bricks, the binding energy per nucleon is replaced in the calculations with its actual value

$$E_B \rightarrow E_B - \frac{N}{A}\Delta m \ , \ \Delta m = m_n - m_p = 1.2930 \ MeV \ . \tag{3.1}$$

This replacement does not affect at all the parameters of the of $Z = 2n$ nuclei identified as ^4He strings.

One can of course consider also the option that nuclei containing ordinary neutrons are possible but that are unstable against beta decay to nuclei containing only protons and negatively charged bonds. This would suggest that di-neutron exists but is not appreciably produced in nuclear reactions and has not been therefore detected.

3.7.3 Options IIa) and IIb)

It is not clear whether the fermions at the ends of color bonds are exotic quarks or leptons. Lepto-pion (or electro-pion) hypothesis [K22] was inspired by the anomalous e^+e^- production in heavy ion collisions near Coulomb wall and states that electro-pions which are bound states of colored excitations of electrons with ground state mass 1.062 MeV are responsible for the effect. The model predicts that also other charged leptons have color excitations and give rise to exotic counterpart of QCD.

Also μ and τ should possess colored excitations. About fifteen years after this prediction was made, direct experimental evidence for these states finally emerges [C32, C33]. The mass of the new particle, which is either scalar or pseudo-scalar, is 214.4 MeV whereas muon mass is 105.6 MeV. The mass is about 1.5 per cent higher than two times muon mass. The most natural TGD inspired interpretation is as a pion like bound state of colored excitations of muon completely analogous to lepto-pion (or rather, electro-pion) [K22].

One cannot exclude the possibility that the fermion and anti-fermion at the ends of color flux tubes connecting nucleons are actually colored leptons although the working hypothesis is that they are exotic quark and anti-quark. One can of course also turn around the argument: could it be that lepto-pions are "leptonuclei", that is bound states of ordinary leptons bound by color flux tubes for a QCD in length scale considerably shorter than the p-adic length scale of lepton.

Scaling argument applied to ordinary pion mass suggests that the masses of exotic quarks at the ends of color bonds are considerably below MeV scale. One can however consider the possibility that colored electrons with mass of ordinary electron are in question in which case color bonds identifiable as colored variants of electro-pions could be assumed to contribute in the first guess the mass $m(\pi) = 1.062$ MeV per each nucleon for $A > 2$ nuclei. This implies the general replacement

$$\begin{aligned} E_B &\rightarrow E_B + m(\pi_L) - \frac{N}{A}\Delta m \text{ for } A > 2 \ , \\ E_B &\rightarrow E_B + \frac{m(\pi_L)}{2} - \frac{N}{A}\Delta m \text{ for } A = 2 \ . \end{aligned} \tag{3.2}$$

This option will be referred to as option IIb). One can also consider the option IIa) in which nucleons are ordinary but lepto-pion mass $m(\pi_L) = 1.062$ MeV gives the mass associated with color bond.

These options are equivalent for $N = Z = 2n$ nuclei with $A > 4$ but for $A \leq 4$ nuclei assumed to form nucleon string they options differ.

4 Light Nuclei As Color Bound Bose-Einstein Condensates Of ^4He Nuclei

The attempt to understand the variation of nuclear binding energy and its maximum for Fe leads to a model of nuclei lighter than Fe as color bound Bose-Einstein condensates of ^4He nuclei or meson-like structures associated with them. Fractal scaling argument allows to understand ^4He itself as analogous state formed from nucleons.

4.1 How To Explain The Maximum Of E_B For Iron?

The simplest model predicts that the binding energy per nucleon equals to $E_B(^4He)$ for all $Z = N = 2n$ nuclei. The actual binding energy grows slowly, has a maximum at ^{52}Fe, and then begins to decrease but remains above $E_B(^4He)$. The following values give representative examples for $Z = N$ nuclei.

For nuclei heavier than Fe there are no long-lived $Z = N = 2n$ isotopes and the natural reason would be alpha decay to ^{52}Fe. If tetra-neutron is what TGD suggests it to be one can guess that tetra-neutron mass is very nearly equal to the mass of the alpha particle. This would allow to regard states $N = Z + 4n$ as states as analogous to unstable states $N_1 = Z_1 = Z + 2n$ consisting of alpha particles. This gives estimate for E_B for unstable $N = Z$ states. For $^{256}Fm = (100, 156)$ one has $E_B = 7.433$ MeV which is still above $E_B(^4He) = 7.0720$ MeV. The challenge is to understand the variation of the binding energy per nucleon and its maximum for Fe.

Table 1: Representative examples of binding energy

nucleus	^4He	^8Be	^{40}Ca	^52Fe
E_B/MeV	7.0720	7.0603	8.5504	8.6104

4.2 Scaled Up QCD With Bose-Einstein Condensate Of ^4He Nuclei Explains The Growth Of E_B

The first thing to come in mind is that repulsive Coulomb contribution would cause the variation of the binding energy. Since alpha particles are building blocks for $Z = N$ nuclei, ^8Be provides a test for this idea. If the difference between binding energies per nucleon for ^8Be and ^4He were due to Coulomb repulsion alone, one would have $E_c = E_B(^4He) - E_B(^8Be) = .0117$ MeV, which is of order $\alpha_{em}/L(127)$. This would conform with the idea that flux tubes mediating em interaction have length of order electron Compton length. Long flux tubes would provide the mechanism minimizing Coulomb energy. A more realistic interpretation consistent with this mechanism would be that Coulomb and color interaction energies compensate each other: this can of course occur to some degree but it seems safe to assume that Coulomb contribution is small.

The basic question is how one could understand the behavior of E_B if its variation corresponds to that for color binding energy per nucleon. The natural scale of energy is MeV and this conforms with the fact that the range of variation for color binding energy associated with $L(127)$ QCD is about 1.5 MeV. By a naive scaling the value of M_{127} pion mass is by a factor $2^{(127-107)/2} = 10^{-3}$ times smaller than that of ordinary pion and thus.14 MeV. The scaling of QCD Λ is a more reliable estimate for the binding energy scale and gives a slightly larger value but of the same order of magnitude. The total variation of E_B is large in the natural energy scale of M_{127} QCD and suggests strong non-linear effects.

In the absence of other contributions em and color contributions to E_B cancel for ^8Be. If color and Coulomb contributions on total binding energy depend roughly linearly on the number of ^4He nuclei, the cancellation to E_B should occur in a good approximation also for them. This does not happen which means that color contribution to E_B is in lowest approximation linear in n meaning n^2-dependence of the total color binding energy. This non-linear behavior suggests strongly the presence of Bose-Einstein condensate of ^4He nuclei or structures associated with them. The most natural candidates are the meson like colored strings connecting ^4He nuclei together.

The additivity of n color magnetic (and/or electric) fluxes would imply that classical field energy is n^2-fold. This does not yet imply same for binding energy unless the value of α_s is negative which it can be below confinement length scale. An alternative interpretation could be in terms of color magnetic interaction energy. The number of quarks and anti-quarks would be proportional to n as would be also the color magnetic flux so that n^2- proportionality would result also in this manner.

If the addition of single alpha particle corresponds to an addition of a constant color contribution E_s to E_B (the color binding energy per nucleon, not the total binding energy!) one has $E_B(^{52}Fe) = E_B(^4He) + 13E_s$ giving $E_s = .1834$ MeV, which conforms with the order of magnitude estimate given by M_{127} QCD.

The task is to find whether this picture could explain the behavior of E_B. The simplest formula for $E_B(Z = N = 2n)$ would be given by

$$E_B(n) \quad = \quad -\frac{n(n-1)}{L(A)n}k_s + nE_s \quad . \tag{4.1}$$

Here the first term corresponds to the Coulomb interaction energy of n ^4He nuclei proportional to $n(n-1)$ and inversely proportional to the length $L(A)$ of nuclear string. Second term is color binding energy per nucleon proportional to n.

The simplest assumption is that each ^4He corresponds always to same length of nuclear string so that one has $L \propto A$ and one can write

$$E_B(n) \quad = \quad E_B(^4He) - \frac{n(n-1)}{n^2}E_c + nE_s \quad . \tag{4.2}$$

The value of $E_B(^8Be) \simeq E_B(^4He)$ $(n = 2)$ gives for the unit of Coulomb energy

$$E_c = 4E_s + 2[E_B(^4He) - E_B(^8Be)] \simeq 4E_s \ . \tag{4.3}$$

The general formula for the binding energy reads as

$$\begin{aligned} E_B(n) &= E_B(^4He) - 2\frac{n(n-1)}{n^2}[E_B(^4He) - E_B(^8Be)] \\ &+ [-4\frac{n(n-1)}{n^2} + n]E_s \ . \end{aligned} \tag{4.4}$$

The condition that $E_B(^{52}Fe)$ $(n = 13)$ comes out correctly gives

$$E_s = \frac{13}{121}(E_B(^{52}Fe) - E_B(^4He)) + \frac{13 \times 24}{121}[E_B(^4He) - E_B(^8Be)] \ . \tag{4.5}$$

This gives $E_s \simeq .1955$ MeV which conforms with M_{127} QCD estimate. For the E_c one obtains $E_c = 1.6104$ MeV and for Coulomb energy of ^4He nuclei in ^8Be one obtains $E = E_c/2 = .8052$ MeV. The order of magnitude is consistent with the mass difference of proton and neutron. The scale suggests that electromagnetic flux tubes are shorter than color flux tubes and correspond to the secondary p-adic length scale $L(2, 61) = L(127)/2^{5/2}$ associated with Mersenne prime M_{61}. The scaling factor for the energy scale would be $2^{5/2} \simeq 5.657$.

The calculations have been carried out without assuming which are actual composites of ^4He nuclei (neutrons and protons plus neutral color bonds or protons and neutral and negatively charged color bonds) and assuming the masses of color bonds are negligible. As a matter fact, the mass of color bond does not affect the estimates if one uses only nuclei heavier than ^4He to estimate the parameters. The estimates above however involve ^4He so that small change on the parameters is induced.

4.3 Why E_B Decreases For Heavier Nuclei?

The prediction that E_B increases as $(A/4)^2$ for $Z = N$ nuclei is unrealistic since E_B decreases slowly for $A \geq 52$ nuclei. Fermi statistics provides a convincing explanation assuming that fermions move in an effective harmonic oscillator potential due to the string tension whereas free nucleon model predicts too large size for the nucleus. The splitting of the Bose-Einstein condensate to pieces is second explanation that one can imagine but fails at the level of details.

4.3.1 Fermi statistics as a reason for the reduction of the binding energy

The failure of the model is at least partially due to the neglect of the Fermi statistics. For the lighter nuclei description as many boson state with few fermions is expected to work. As the length of nuclear string grows in fixed nuclear volume, the probability of self intersection increases and Fermi statistics forces the wave function for stringy configurations to wiggle which reduces binding energy.

1. For the estimation purposes consider $A = 256$ nucleus ^{256}Mv having $Z = 101$ and $E_B = 7.4241$ MeV. Assume that this unstable nucleus is nearly equivalent with a nucleus consisting of $n = 64$ ^4He nuclei $(Z = N)$. Assuming single color condensate this would give the color contribution

$$E_s^{tot} = (Z/2)^2 \times E_s = 64^2 \times E_s$$

with color contribution to E_B equal to $(Z/2)E_s \simeq 12.51$ MeV.

2. Suppose that color binding energy is canceled by the energy of nucleon identified as kinetic energy in the case of free nucleon model and as harmonic oscillator energy in the case of harmonic oscillator model.

3. The number of states with a given principal quantum number n for both free nucleons in a spherical box and harmonic oscillator model is by spherical symmetry $2n^2$ and the number of protons/neutrons for a full shell nuclei behaves as $N_1 \simeq 2n_{max}^3/3$. The estimate for the average energy per nucleon is given in the two cases as

$$\begin{aligned} \langle E\rangle_H &= 2^{-4/3}\times N^{1/3}E_0 \ , \ E_0=\omega_0 \ , \\ \langle E\rangle_F &= \frac{2}{5}(\frac{3}{2})^{5/3}N^{2/3}E_0 \ , \ E_0=\frac{\pi^2}{2m_pL^2} \ . \end{aligned} \quad (4.6)$$

Harmonic oscillator energy $\langle E\rangle_H$ increases as $N^{1/3}$ and $\langle E\rangle_F$ as $N^{2/3}$. Neither of these cannot win the contribution of the color binding energy increasing as N.

4. Equating this energy with the total color binding energy gives an estimate for E_0 as

$$\begin{aligned} E_0 &= (2/3)^{1/3}\times Z^{-4/3}\times (Z/2)^2\times E_s \ , \\ E_0 &= \frac{5}{4}(\frac{2}{3})^{5/3}\times Z^{-5/3}\times (Z/2)^2\times E_s \ , \\ E_s &= .1955 \ MeV \ . \end{aligned} \quad (4.7)$$

The first case corresponds to harmonic oscillator model and second to free nucleon model.

5. For the harmonic oscillator model one obtains the estimate $E_0 = \hbar\omega_0 \simeq 2.73 \ MeV$. The general estimate for the energy scale in the harmonic oscillator model given by $\omega_0 \simeq 41\cdot A^{-1/3}$ MeV [C43] giving $\omega_0 = 6.5$ MeV for $A = 256$ (this estimate implies that harmonic oscillator energy per nucleon is approximately constant and would suggest that string tension tends to reduce as the length of string increases). Harmonic oscillator potential would have roughly twice too strong strength but the order of magnitude is correct. Color contribution to the binding energy might relate the reduction of the oscillator strength in TGD framework.

6. Free nucleon model gives the estimate $E_0 = .0626$ MeV. For the size of a $A = 256$ nucleus one obtains $L \simeq 3.8L(113) \simeq 76$ fm. This is by one order of magnitude larger that the size predicted by the standard formula $r = r_0A^{1/3}$, $r_0 = 1.25$ fm and 8 fm for $A = 256$.

   Harmonic oscillator picture is clearly favored and string tension explains the origin of the harmonic oscillator potential. Harmonic oscillator picture is expected to emerge at the limit of heavy nuclei for which nuclear string more or less fills the nuclear volume whereas for light nuclei the description in terms of bosonic ^4He nuclei should make sense. For heavy nuclei Fermi statistics at nuclear level would begin to be visible and excite vibrational modes of the nuclear string mapped to the excited states of harmonic oscillator in the shell model description.

4.3.2 Could upper limit for the size of ^4He Bose-Einstein condensate explain the maximum of binding energy per nucleon?

One can imagine also an alternative explanation for why E_B to decrease after $A = 52$. One might that $A = 52$ represents the largest ^4He Bose-Einstein condensate and that for heavier nuclei Bose-Einstein condensate de-coheres into two parts. Bose-Einstein condensate of $n = 13$ ^4He nuclei would the best that one can achieve.

This could explain the reduction of the binding energy and also the emergence of tetra-neutrons as well as the instability of $Z = N$ nuclei heavier than ^{52}Fe. A number theoretical interpretation related to the p-adic length scale hypothesis suggests also itself: as the size of the tangled nuclear string becomes larger than the next p-adic length scale, Bose-Einstein condensate might lose its coherence and split into two.

If one assumes that ^4He Bose-Einstein condensate has an upper size corresponding to $n = 13$, the prediction is that after $A = 52$ second Bose-Einstein condensate begins to form. E_B is obtained as the average

$$E_B(Z,N) = \frac{52}{A}E_B(^{52}Fe) + \frac{A-52}{A}E_B(^{A-52}X(Z,N)) \ .$$

The derivative

$$dE_B/dA = (52/A)[-E_B(^{52}Fe) + E_B(^{A-52}X)] + \frac{A-52}{A}dE_B(^{A-52}X(Z,N))/dA$$

is first negative but its sign must change since the nuclei consisting of two copies of ^{52}Fe) condensates have same E_B as ^{52}Fe). This is an un-physical result. This does not exclude the splitting of Bose-Einstein condensate but the dominant contribution to the reduction of E_B must be due to Fermi statistics.

5 What QCD Binds Nucleons To $A \leq 4$ Nuclei?

The obvious question is whether scaled variant(s) of color force could bind nucleons to form $A \leq 4$ nuclei which in turn bind to form heavier nuclei. Since the binding energy scale for ^3He is much smaller than for ^4He one might consider the possibility that the p-adic length scale for QCD associated with ^4He is different from that for $A < 4$ nuclei.

5.1 The QCD Associated With Nuclei Lighter Than ^4He

It would be nice if one could understand the binding energies of also $A \leq 4$ nuclei in terms of a scaled variant of QCD applied at the level of nucleons. Here one has several options to test.

5.1.1 Various options to consider

Assume that neutral color bonds have negligible fermion masses at their ends: this is expected if the exotic quarks appear at the ends of color bonds and by the naive scaling of pion mass. One can also consider the possibility that the p-adic temperature for the quarks satisfies $T = 1/n \leq 1/2$ so that quarks would be massless in excellent approximation. $T = 1/n < 1$ holds true for gauge bosons and one might argue that color bonds as bosonic particles indeed have $T < 1$.

Option Ia): Building bricks are ordinary nucleons.

Option IIa): Building blocks are protons and neutral and negatively charged color bonds. This means the replacement $E_B \rightarrow E_B - \Delta m$ for $A > 2$ nuclei and $E_B \rightarrow E_B - \Delta m/2$ for $A = 2$ with $\Delta m = n_n - m_p = 1.2930$ MeV.

Options Ib and IIb are obtained by assuming that the masses of fermions at the ends of color bonds are non-negligible. Electro-pion mass $m(\pi_L) = 1.062$ MeV is a good candidate for the mass of the color bond. Option Ia allow 3 per cent accuracy for the predicted binding energies. Option IIb works satisfactorily but the errors are below 22 per cent only.

5.1.2 Ordinary nucleons and massless color bonds

It turns out that for the option Ia), ordinary nucleons and massless color bonds, is the most plausible candidate for $A < 4$ QCD is the secondary p-adic length scale $L_e(2,59)$ associated with prime $p \simeq 2^k$, $k = 59$ with $k_{eff} = 2 \times 59 = 118$. The proper scaling of the electromagnetic p-adic length scale corresponds to a scaling factor 2^3 meaning that one has $k_{eff} = 122 \rightarrow k_{eff} - 6 = 116 = 4 \times 29$ corresponding to $L_e(4,29)$.

1. Direct p-adic scaling of the parameters

E_s would be scaled up p-adically by a factor $2^{(127-118)/2} = 2^{9/2}$. E_c would be scaled up by a factor $2^{(122-116)/2} = 2^3$. There is also a scaling of E_c by a factor 1/4 due to the reduction of charge unit and scaling of both E_c and E_s by a factor 1/4 since the basic units are now nucleons. This gives

$$\hat{E}_s = 2^{5/2}E_s = 1.1056 \ MeV \ , \ \hat{E}_c = 2^{-1}E_c = .8056 \ MeV \ . \tag{5.1}$$

The value of electromagnetic energy unit is quite reasonable.

Table 2: Predictions for the binding energy of the lightest nuclei

nucleus	^2H	^3H	^3He
$E_B(exp)/MeV$	1.111	2.826	2.572
$E_B(pred_1)/MeV$	1.106	3.317	3.138
$E_B(pred_2)/MeV$	.942	2.826	2.647

The basic formula for the binding energy reads now

$$E_B = -\frac{(n(p)(n(p)-1))}{A^2}\hat{E}_c + n\hat{E}_s \ , \tag{5.2}$$

where $n(p)$ is the number of protons $n = A$ holds true for $A > 2$. For deuteron one has $n = 1$ since deuteron has only single color bond. This delicacy is a crucial prediction and the model fails to work without it.

This gives

$$E_B(^2H) = \hat{E}_s \ , \ E_B(^3H) = 3\hat{E}_s \ , \ E_B(^3He) = -\frac{2}{9}\hat{E}_c + 3\hat{E}_s \ . \tag{5.3}$$

The predictions are given by the third row of **Table 2** The predicted values given are too large by about 15 per cent in the worst case.

The reduction of the value of α_s in the p-adic scaling would improve the situation. The requirement that $E_B(^3H)$ comes out correctly predicts a reduction factor.8520 for α_s. The predictions are given in the fourth row of **Table 2**. Errors are below 15 per cent.
The discrepancy is 15 per cent for ^2H. By a small scaling of E_c the fit for ^3He can be made perfect. Agreement is rather good but requires that conventional strong force transmitted along nuclear space-time sheet is present and makes *nn* and *pp* states unstable. Isospin dependent strong interaction energy would be only .17 MeV in isospin singlet state which suggests that a large cancelation between scalar and vector contributions occurs. *pnn* and *ppn* could be regarded as Dn and Dp states with no strong force between D and nucleon. The contribution of isospin dependent strong force to E_B is scaled down by a factor 2/3 in $A = 3$ states from that for deuteron and is almost negligible. This option seems to allow an almost perfect fit of the binding energies. Note that one cannot exclude exotic nn-state obtained from deuteron by giving color bond negative em charge.

5.1.3 Other options

Consider next other options.

1. *Option IIb*

For option IIb) the basic building bricks are protons and $m(\pi) = 1.062$ is assumed. The basic objection against this option is that for protons as constituents *real* binding energies satisfy $E_B(^3He) < E_B(^3H)$ whereas Coulombic repulsion would suggest $E_B(^3He) > E_B(^3H)$ unless magnetic spin-spin interaction effects affect the situation. One can however look how good a fit one can obtain in this manner.

As found, the predictions of direct scaling are too large for $E_B(^3H)$ and $E_B(^3He)$ (slight reduction of α_s cures the situation). Since the actual binding energy increases by $m(\pi_L)-(2/3)(m_n-m_p)$ for ^3H and by $m(\pi_L)-(1/3)(m_n-m_p)$ for ^3He, it is clear that the assumption that lepto-pion mass is of order 1 MeV improves the fit. The results are given by **Table 3**.
Here $E_B(pred)$ corresponds to the effective value of binding energy assuming that nuclei effectively consist of ordinary protons and neutrons. The discrepancies are below 22 percent.

What is troublesome that neither the scaling of α_s nor modification of E_c improves the situation for ^2H and ^3H. Moreover, magnetic spin-spin interaction energy for deuteron is expected to reduce $E_B(pred)$ further in triplet state. Thus option IIb) does not look promising.

Table 3: Predictions for the binding energy of lightest nuclei: Option IIb

nucleus	^2H	^3H	^3He
$E_B(exp)/MeV$	1.111	2.826	2.572
$E_B(pred)/MeV$	.875	3.117	2.507

Table 4: Binding energies of the lightest nuclei: Option Ib.

nucleus	^2H	^3H	^3He
$E_B(act)/MeV$	1.642	3.880	3.634
$E_B(pred)/MeV$	1.3322	3.997	3.743

2. Option Ib)

For option Ib) with $m(\pi) = 1.062$ MeV and ordinary nucleons the actual binding $E_B(act)$ energy increases by $m(\pi)$ for $A = 3$ nuclei and by $m(\pi)/2$ for deuteron. Direct scaling gives a reasonably good fit for the p-adic length scale $L_e(9, 13)$ with $k_{eff} = 117$ meaning $\sqrt{2}$ scaling of E_s. For deuteron the predicted E_B is too low by 30 per cent. One might argue that isospin dependent strong force between nucleons becomes important in this p-adic length scale and reduces deuteron binding energy by 30 per cent. This option is not un-necessary complex as compared to the option Ia).

For option IIa) with $m(\pi) = 0$ and protons as building blocks the fit gets worse for $A = 3$ nuclei.

5.2 The QCE Associated With ^4He

^4He must somehow differ from $A \leq 3$ nucleons. If one takes the argument based on isospin dependence strong force seriously, the reasonable looking conclusion would be that ^4He is at the space-time sheet of nucleons a bound state of two deuterons which induce no isospin dependent strong nuclear force. One could regard the system also as a closed string of four nucleons such that neighboring p and n form strong iso-spin singlets. The previous treatment applies as such.

For ^4He option Ia) with a direct scaling would predict $E_B(^4He) < 4 \times \hat{E}_s = 3.720$ MeV which is by a factor of order 2 too small. The natural explanation would be that for ^4He both color and em field body correspond to the p-adic length scale $L_e(4, 29)$ ($k_{eff} = 116$) so that E_s would increase by a factor of 2 to 1.860 MeV. Somewhat surprisingly, $A \leq 3$ nuclei would have “color field bodies” by a factor 2 larger than ^4He.

1. For option Ia) this would predict $E_B(^4He) = 7.32867$ MeV to be compared with the real value 7.0720 MeV. A reduction of α_s by 3.5 per cent would explain the discrepancy. That α_s decreases in the transition sequence $k_{eff} = 127 \rightarrow 118 \rightarrow 116$ which is consistent with the general vision about evolution of color coupling strength.

2. If one assumes option Ib) with $m(\pi) = 1.062$ MeV the actual binding energy increases to 8.13 MeV. The strong binding energy of deuteron units would give an additional.15 MeV binding energy per nucleon so that one would have $E_B(^4He) = 7.47$ MeV so that 10 per cent accuracy is achieved. Obviously this option does not work so well as Ia).

3. If one assumes option IIb), the actual binding energy would increase by .415 MeV to 7.4827 MeV which would make fit somewhat poorer. A small reduction of E_c could allow to achieve a perfect fit.

5.3 What About Tetra-Neutron?

One can estimate the value of $E_B(^4n)$ from binding energies of nuclei (Z, N) and $(Z, N + 4)$ $(A = Z + N)$ as

Table 5: Estimate for the binding energy of tetraneutron

(Z,N)	(26, 26)(^{52}Fe)	(50, 70)(^{120}Sn)	(82, 124) (^{206}Pb)
$E_B(^4n)/MeV$	6.280	7.3916	5.8031

Table 6: Another estimate for the binding energy of tetraneutron

k_{eff}	2×59	4×29
$E_B(act)(^4n)/MeV$	3.7680	
$E_{B,app}(4n)/MeV$	4.4135	8.1825

$$E_B(^4n) = \frac{A+4}{4}[E_B(A+4) - \frac{A}{A+4}E_B(A)] \ .$$

In **Table 5** there are some estimate for $E_B(^4n)$.

The prediction of the above model would be $E(^4n) = 4\hat{E}_s = 3.760$ MeV for $\hat{E}_s = .940$ MeV associated with $A<4$ nuclei and $k_{eff} = 118 = 2\times 59$ associated with $A<4$ nuclei. For $k_{eff} = 116$ associated with ^4He $E_s(^4n) = E_s(^4He) = 1.82$ MeV the prediction would be 7.28 MeV. 14 percent reduction of α_s would give the estimated value for of E_s for ^{52}Fe.

If tetra-neutron is ppnn bound state with two negatively charged color bonds, this estimate is not quite correct since the actual binding energy per nucleon is $E_B(^4He) - (m_n - m_p)/2$. This implies a small correction $E_B(A+4) \rightarrow E_B(A+4) - 2(m_n - m_p)/(A+4)$. The correction is negligible.

One can make also a direct estimate of ^4n binding energy assuming tetra-neutron to be ppnn bound state. If the masses of charged color bonds do not differ appreciably from those of neutral bonds (as the p-adic scaling of $\pi + -\pi^0$ mass difference of about 4.9 MeV strongly suggests) then model Ia) with $E_s = E_B(^3H)/3$ implies that the actual binding energy $E_B(^4n) = 4E_s = E_B(^3H)/3$ (see **Table 6**). The apparent binding energy is $E_{B,app} = E_B(^4n) + (m_n - m_p)/2$. Binding energy differs dramatically from what one can imagine in more conventional models of strong interactions in which even the existence of tetra-neutron is highly questionable.
The higher binding energy per nucleon for tetra-neutron might directly relate to the neutron richness of heavy nuclei in accordance with the vision that Coulomb energy is what disfavors proton rich nuclei.

According to [C37], tetra-neutron might have been observed in the decay $^8He \rightarrow ^4He + ^4n$ and the accepted value for the mass of ^8He isotope gives the upper bound of $E(^4n) < 3.1$ MeV, which is one half of the the estimate. One can of course consider the possibility that free tetra-neutron corresponds to $L_e(2,59)$ and nuclear tetra-neutron corresponds to the length scale $L_e(4,29)$ of ^4He. Also light quarks appear as several p-adically scaled up variants in the TGD based model for low-lying hadrons and there is also evidence that neutrinos appear in several scales.

5.4 What Could Be The General Mass Formula?

In the proposed model nucleus consists of $A \leq 4$ nuclei. Concerning the details of the model there are several questions to be answered. Do $A \leq 3$ nuclei and $A = 4$ nuclei ^4He and tetra-neutron form separate nuclear strings carrying their own color magnetic fields as the different p-adic length scale for the corresponding "color magnetic bodies" would suggest? Or do they combine by a connected sum operation to single closed string? Is there single Bose-Einstein condensate or several ones.

Certainly the Bose-Einstein condensates associated with nucleons forming $A < 4$ nuclei are separate from those for $A = 4$ nuclei. The behavior of E_B in turn can be understood if ^4He nuclei and tetra-neutrons form separate Bose-Einstein condensates. For $Z > N$ nuclei poly-protons constructed as exotic charge states of stable $A \leq 4$ nuclei could give rise to the proton excess.

Before continuing it is appropriate to list the apparent binding energies for poly-neutrons and poly-protons.

Table 7: Apparent binding energies for poly-neutrons and poly-protons

poly-neutron	n	^2n	^3n	^4n
$E_{B,app}/MeV$	0	$E_B(^2H) + \frac{\Delta}{2}$	$E_B(^3H) + \frac{2\Delta}{3}$	$E_B(^4He) + \frac{\Delta}{2}$
poly-proton	p	^2p	^3p	^4p
$E_{B,app}/MeV$	0	$E_B(^2H) - \frac{\Delta}{2}$	$E_B(^3He) - \frac{\Delta}{3}$	$E_B(^4He) - \frac{\Delta}{2}$

For heavier nuclei $E_{B,app}(^4n)$ is smaller than $E_B(^4He) + (m_p - m_n)/2$.

The first guess for the general formula for the binding energy for nucleus (Z,N) is obtained by assuming that for maximum number of ^4He nuclei and tetra-neutrons/tetra-protons identified as ^4H nuclei with 2 negatively/positively charged color bonds are present.

1. $N \geq Z$ nuclei

Even-Z nuclei with $N \geq Z$ can be expressed as $(Z = 2n, N = 2(n+k)+m)$, $m = 0,1,2$ or 3. For $Z \leq 26$ (only single Bose-Einstein condensate) this gives for the apparent binding energy per nucleon (assuming that all neutrons are indeed neutrons) the formula

$$\begin{aligned} E_B(2n, 2(n+k)+m) &= \frac{n}{A}E_B(^4He) + \frac{k}{A}E_{B,app}(^4n) + \frac{1}{A}E_{B,app}(^mn) \\ &+ \frac{n^2+k^2}{n+k}E_s - \frac{Z(Z-1)}{A^2}E_c \ . \end{aligned} \tag{5.4}$$

The situation for the odd-Z nuclei $(Z,N) = (2n+1, 2(n+k)+m)$ can be reduced to that for even-Z nuclei if one can assume that the $(2n+1)^{th}$ proton combines with 2 neutrons to form ^3He nucleus so that one has still $2(k-1)+m$ neutrons combining to $A \leq 4$ poly-neutrons in above described manner.

2. $Z \geq N$ nuclei

For the nuclei having $Z > N$ the formation of a maximal number of ^4He nuclei leaves k excess protons. For long-lived nuclei $k \leq 2$ is satisfied. One could think of decomposing the excess protons to exotic variants of $A \leq 4$ nuclei by assuming that some charged bonds carry positive charge with an obvious generalization of the above formula.

The only differences with respect to a nucleus with neutron excess would be that the apparent binding energy is smaller than the actual one and positive charge would give rise to Coulomb interaction energy reducing the binding energy (but only very slightly). The change of the binding energy in the subtraction of single neutron from $Z = N = 2n$ nucleus is predicted to be approximately $\Delta E_B = -E_B(^4He)/A$. In the case of ^{32}S this predicts $\Delta E_B = .2209$ MeV. The real value is .2110 MeV. The fact that the general order of magnitude for the change of the binding energy as Z or N changes by one unit supports the proposed picture.

5.5 Nuclear Strings And Cold Fusion

To summarize, option Ia) assuming that strong isospin dependent force acts on the nuclear space-time sheet and binds pn pairs to singlets such that the strong binding energy is very nearly zero in singlet state by the cancelation of scalar and vector contributions, is the most promising one. It predicts the existence of exotic di-, tri-, and tetra-neutron like particles and even negatively charged exotics obtained from $^2H, ^3H, ^3He$, and ^4He by adding negatively charged color bond. For instance, ^3H extends to a multiplet with em charges $1, 0, -1, -2$. Of course, heavy nuclei with proton neutron excess could actually be such nuclei.

The exotic states are stable under beta decay for $m(\pi) < m_e$. The simplest neutral exotic nucleus corresponds to exotic deuteron with single negatively charged color bond. Using this as target it would be possible to achieve cold fusion since Coulomb wall would be absent. The empirical evidence for cold fusion thus supports the prediction of exotic charged states.

5.5.1 Signatures of cold fusion

In the following the consideration is restricted to cold fusion in which two deuterium nuclei react strongly since this is the basic reaction type studied.

In hot fusion there are three reaction types:

1. $D + D \rightarrow^4 He + \gamma$ $(23.8MeV)$
2. $D + D \rightarrow^3 He + n$
3. $D + D \rightarrow^3 H + p$.

The rate for the process 1) predicted by standard nuclear physics is more than 10^{-3} times lower than for the processes 2) and 3) [C16]. The reason is that the emission of the gamma ray involves the relatively weak electromagnetic interaction whereas the latter two processes are strong.

The most obvious objection against cold fusion is that the Coulomb wall between the nuclei makes the mentioned processes extremely improbable at room temperature. Of course, this alone implies that one should not apply the rules of hot fusion to cold fusion. Cold fusion indeed differs from hot fusion in several other aspects.

1. No gamma rays are seen.
2. The flux of energetic neutrons is much lower than expected on basis of the heat production rate an by interpolating hot fusion physics to the recent case.

These signatures can also be (and have been!) used to claim that no real fusion process occurs. It has however become clear that the isotopes of Helium and also some tritium accumulate to the Pd target during the reaction and already now prototype reactors for which the output energy exceeds input energy have been built and commercial applications are under development. Therefore the situation has turned around. The rules of standard physics do not apply so that some new nuclear physics must be involved and it has become an exciting intellectual challenge to understand what is happening. A representative example of this attitude and an enjoyable analysis of the counter arguments against fold fusion is provided by the article "Energy transfer in cold fusion and sono-luminescence" of Julian Schwinger [C36]. This article should be contrasted with the ultra-skeptical article "ESP and Cold Fusion: parallels in pseudoscience" of V. J. [C45] [C45].

Cold fusion has also other features, which serve as valuable constraints for the model building.

1. Cold fusion is not a bulk phenomenon. It seems that fusion occurs most effectively in nano-particles of Pd and the development of the required nano-technology has made possible to produce fusion energy in controlled manner. Concerning applications this is a good news since there is no fear that the process could run out of control.
2. The ratio x of D atoms to Pd atoms in Pd particle must lie the critical range $[.85, .90]$ for the production of ^4He to occur [D7]. This explains the poor repeatability of the earlier experiments and also the fact that fusion occurred sporadically.
3. Also the transmutations of Pd nuclei are observed [C35].

Below a list of questions that any theory of cold fusion should be able to answer.

1. Why cold fusion is not a bulk phenomenon?
2. Why cold fusion of the light nuclei seems to occur only above the critical value $x \simeq .85$ of D concentration?
3. How fusing nuclei are able to effectively circumvent the Coulomb wall?
4. How the energy is transferred from nuclear degrees of freedom to much longer condensed matter degrees of freedom?
5. Why gamma rays are not produced, why the flux of high energy neutrons is so low and why the production of ^4He dominates (also some tritium is produced)?
6. How nuclear transmutations are possible?

5.5.2 Could exotic deuterium make cold fusion possible?

One model of cold fusion has been already discussed in [K18] and the recent model is very similar to that. The basic idea is that only the neutrons of incoming and target nuclei can interact strongly, that is their space-time sheets can fuse. One might hope that neutral deuterium having single negatively charged color bond could allow to realize this mechanism.

1. Suppose that part of the deuterium in Pd catalyst corresponds to exotic deuterium with neutral nuclei so that cold fusion would occur between neutral exotic D nuclei in the target and charged incoming D nuclei and Coulomb wall in the nuclear scale would be absent.

2. The exotic variant of the ordinary $D + D$ reaction yields final states in which ^4He, ^3He and ^3H are replaced with their exotic counterparts with charge lowered by one unit. In particular, exotic ^3H is neutral and there is no Coulomb wall hindering its fusion with Pd nuclei so that nuclear transmutations can occur.

Why the neutron and gamma fluxes are low might be understood if for some reason only exotic ^3H is produced, that is the production of charged final state nuclei is suppressed. The explanation relies on Coulomb wall at the nucleon level.

1. Initial state contains one charged and one neutral color bond and final state $A = 3$ or $A = 4$ color bonds. Additional neutral color bonds must be created in the reaction (one for the production $A = 3$ final states and two for $A = 4$ final state). The process involves the creation of neural fermion pairs. The emission of one exotic gluon per bond decaying to a neutral pair is necessary to achieve this. This requires that nucleon space-time sheets fuse together. Exotic D certainly belongs to the final state nucleus since charged color bond is not expected to be split in the process.

2. The process necessarily involves a temporary fusion of nucleon space-time sheets. One can understand the selection rules if only neutron space-time sheets can fuse appreciably so that only ^3H would be produced. Here Coulomb wall at nucleon level should enter into the game.

3. Protonic space-time sheets have the same positive sign of charge always so that there is a Coulomb wall between them. This explains why the reactions producing exotic ^4He do not occur appreciably. If the quark/antiquark at the neutron end of the color bond of ordinary D has positive charge, there is Coulomb attraction between proton and corresponding negatively charged quark. Thus energy minimization implies that the neutron space-time sheet of ordinary D has positive net charge and Coulomb repulsion prevents it from fusing with the proton space-time sheet of target D. The desired selection rules would thus be due to Coulomb wall at the nucleon level.

5.5.3 About the phase transition transforming ordinary deuterium to exotic deuterium

The exotic deuterium at the surface of Pd target seems to form patches (for a detailed summary see [K18]). This suggests that a condensed matter phase transition involving also nuclei is involved. A possible mechanism giving rise to this kind of phase would be a local phase transition in the Pd target involving both D and Pd. In [K18] it was suggested that deuterium nuclei transform in this phase transition to "ordinary" di-neutrons connected by a charged color bond to Pd nuclei. In the recent case di-neutron could be replaced by neutral D.

The phase transition transforming neutral color bond to a negatively charged one would certainly involve the emission of W^+ boson, which must be exotic in the sense that its Compton length is of order atomic size so that it could be treated as a massless particle and the rate for the process would be of the same order of magnitude as for electro-magnetic processes. One can imagine two options.

1. Exotic W^+ boson emission generates a positively charged color bond between Pd nucleus and exotic deuteron as in the previous model.

2. The exchange of exotic W^+ bosons between ordinary D nuclei and Pd induces the transformation $Z \rightarrow Z+1$ inducing an alchemic phase transition $Pd \rightarrow Ag$. The most abundant Pd isotopes with $A = 105$ and 106 would transform to a state of same mass but chemically equivalent with the two lightest long-lived Ag isotopes. ^{106}Ag is unstable against β^+ decay to Pd and ^{105}Ag transforms to Pd via electron capture. For ^{106}Ag (^{105}Ag) the rest energy is 4 MeV (2.2 MeV) higher than for ^{106}Pd (^{105}Pd), which suggests that the resulting silver cannot be genuine.

This phase transition need not be favored energetically since the energy loaded into electrolyte could induce it. The energies should (and could in the recent scenario) correspond to energies typical for condensed matter physics. The densities of Ag and Pd are 10.49 gcm^{-3} and 12.023 gcm^{-3} so that the phase transition would expand the volume by a factor 1.0465. The porous character of Pd would allow this. The needed critical packing fraction for Pd would guarantee one D nucleus per one Pd nucleus with a sufficient accuracy.

5.5.4 Exotic weak bosons seem to be necessary

The proposed phase transition cannot proceed via the exchange of the ordinary W bosons. Rather, W bosons having Compton length of order atomic size are needed. These W bosons could correspond to a scaled up variant of ordinary W bosons having smaller mass, perhaps even of the order of electron mass. They could be also dark in the sense that Planck constant for them would have the value $\hbar = n\hbar_0$ implying scaling up of their Compton size by n. For $n \sim 2^{48}$ the Compton length of ordinary W boson would be of the order of atomic size so that for interactions below this length scale weak bosons would be effectively massless. p-Adically scaled up copy of weak physics with a large value of Planck constant could be in question. For instance, W bosons could correspond to the nuclear p-adic length scale $L_e(k = 113)$ and $n = 2^{11}$.

Few weeks after having written this chapter I learned that cold fusion is in news again: both Nature and New Scientists commented the latest results [C1]. It seems that the emission of highly energetic charged particles which cannot be due to chemical reactions and could emerge from cold fusion has been demonstrated beyond doubt by Frank Cordon's team [C3] using detectors known as CR-39 plastics of size scale of coin used already earlier in hot fusion research. The method is both cheap and simple. The idea is that travelling charged particles shatter the bonds of the plastic's polymers leaving pits or tracks in the plastic. Under the conditions claimed to make cold fusion possible (1 deuterium per 1 Pd nucleus making in TGD based model possible the phase transition of D to its neutral variant by the emission of exotic dark W boson with interaction range of order atomic radius) tracks and pits appear during short period of time to the detector.

5.6 Strong Force As A Scaled And Dark Electro-Weak Force?

The fiddling with the nuclear string model has led to following conclusions.

1. Strong isospin dependent nuclear force, which does not reduce to color force, is necessary in order to eliminate polyneutron and polyproton states. This force contributes practically nothing to the energies of bound states. This can be understood as being due to the cancelation of isospin scalar and vector parts of this force for them. Only strong isospin singlets and their composites with isospin doublet (n, p) are allowed for $A \leq 4$ nuclei serving as building bricks of the nuclear strings. Only *effective* polyneutron states are allowed and they are strong isospin singlets or doublets containing charged color bonds.

2. The force could act in the length scalar of nuclear space-time sheets: $k = 113$ nuclear p-adic length scale is a good candidate for this length scale. One must be however cautious: the contribution to the energy of nuclei is so small that length scale could be much longer and perhaps same as in case of exotic color bonds. Color bonds connecting nuclei correspond to much longer p-adic length scale and appear in three p-adically scaled up variants corresponding to $A < 4$ nuclei, $A = 4$ nuclei and $A > 4$ nuclei.

3. The prediction of exotic deuterons with vanishing nuclear em charge leads to a simplification of the earlier model of cold fusion explaining its basic selection rules elegantly but requires a scaled variant of electro-weak force in the length scale of atom.

What is then this mysterious strong force? And how abundant these copies of color and electro-weak force actually are? Is there some unifying principle telling which of them are realized?

From foregoing plus TGD inspired model for quantum biology involving also dark and scaled variants of electro-weak and color forces it is becoming more and more obvious that the scaled up variants of both QCD and electro-weak physics appear in various space-time sheets of TGD Universe. This raises the following questions.

1. Could the isospin dependent strong force between nucleons be nothing but a p-adically scaled up (with respect to length scale) version of the electro-weak interactions in the p-adic length scale defined by Mersenne prime M_{89} with new length scale assigned with gluons and characterized by Mersenne prime M_{107}? Strong force would be electro-weak force but in the length scale of hadron! Or possibly in length scale of nucleus ($k_{eff} = 107 + 6 = 113$) if a dark variant of strong force with $h = nh_0 = 2^3h_0$ is in question.

2. Why shouldn't there be a scaled up variant of electro-weak force also in the p-adic length scale of the nuclear color flux tubes?

3. Could it be that all Mersenne primes and also other preferred p-adic primes correspond to entire standard model physics including also gravitation? Could be be kind of natural selection which selects the p-adic survivors as proposed long time ago?

Positive answers to the last questions would clean the air and have quite a strong unifying power in the rather speculative and very-many-sheeted TGD Universe.

1. The prediction for new QCD type physics at M_{89} would get additional support. Perhaps also LHC provides it within the next half decade.

2. Electro-weak physics for Mersenne prime M_{127} assigned to electron and exotic quarks and color excited leptons would be predicted. This would predict the exotic quarks appearing in nuclear string model and conform with the 15 year old lepto-hadron hypothesis [K22]. M_{127} dark weak physics would also make possible the phase transition transforming ordinary deuterium in Pd target to exotic deuterium with vanishing nuclear charge.

The most obvious objection against this unifying vision is that hadrons decay only according to the electro-weak physics corresponding to M_{89}. If they would decay according to M_{107} weak physics, the decay rates would be much much faster since the mass scale of electro-weak bosons would be reduced by a factor 2^{-9} (this would give increase of decay rates by a factor 2^{36} from the propagator of weak boson). This is however not a problem if strong force is a dark with say $n = 8$ giving corresponding to nuclear length scale. This crazy conjecture might work if one accepts the dark Bohr rules!

6 Giant Dipole Resonance As A Dynamical Signature For the xistence Of Bose-Einstein Condensates?

The basic characteristic of the Bose-Einstein condensate model is the non-linearity of the color contribution to the binding energy. The implication is that the the de-coherence of the Bose-Einstein condensate of the nuclear string consisting of ^4He nuclei costs energy. This de-coherence need not involve a splitting of nuclear strings although also this is possible. Similar de-coherence can occur for ^4He $A < 4$ nuclei. It turns out that these three de-coherence mechanisms explain quite nicely the basic aspects of giant dipole resonance (GDR) and its variants both qualitatively and quantitatively and that precise predictions for the fine structure of GDR emerge.

6.1 De-Coherence At The Level Of ^4He Nuclear String

The de-coherence of a nucleus having n ^4He nuclei to a nucleus containing two Bose-Einstein condensates having $n-k$ and $k > 2$ ^4He nuclei requires energy given by

Table 8: The resonance energies for four manners of ^{16}O nucleus ($n = 4$) to lose its coherence.

final state	3+1	2+2	2+1+1	1+1+1+1
$\Delta E/MeV$	1.3685	2.7370	2.9325	3.1280

Table 9: Resonance energies for the four options $n \rightarrow \sum_i n_i$ for the loss of coherence.

final state	3+1	2+2	2+1+1	1+1+1+1
$\Delta E/MeV$	12.74	25.48	27.30	29.12

$$\begin{aligned} \Delta E &= (n^2 - (n-k)^2 - k^2)E_s = 2k(n-k)E_s \ , \ \ k > 2 \ , \\ \Delta E &= (n^2 - (n-2)^2 - 1)E_s = (4n-5)E_s \ , \ \ k = 2 \ , \\ E_s &\simeq .1955 \ \ MeV \ . \end{aligned} \tag{6.1}$$

Bose-Einstein condensate could also split into several pieces with some of them consisting of single ^4He nucleus in which case there is no contribution to the color binding energy. A more general formula for the resonance energy reads as

$$\begin{aligned} \Delta E &= (n^2 - \sum_i k^2(n_i))E_s \ , \ \ \sum_i n_i = n \ , \\ k(n_i) &= \begin{cases} n_i \ \text{for} \ n_i > 2 \ , \\ 1 \ \text{for} \ n_i = 2 \ , \\ 0 \ \text{for} \ n_i = 1 \ . \end{cases} \end{aligned} \tag{6.2}$$

Table 8 lists the resonance energies for four manners of ^{16}O nucleus ($n = 4$) to lose its coherence. Rather small energies are involved. More generally, the minimum and maximum resonance energy would vary as $\Delta E_{min} = (2n-1)E_s$ and $\Delta E_{max} = n^2 E_s$ (total de-coherence). For $n = n_{max} = 13$ one would have $\Delta E_{min} = 2.3640$ MeV and $\Delta E_{max} = 33.099$ MeV.

Clearly, the loss of coherence at this level is a low energy collective phenomenon but certainly testable. For nuclei with $A > 60$ one can imagine also double resonance when both coherent Bose-Einstein condensates possibly present split into pieces. For $A \geq 120$ also triple resonance is possible.

6.2 De-Coherence Inside ^4He Nuclei

One can consider also the loss of coherence occurring at the level ^4He nuclei. Predictions for resonances energies and for the dependence of GR cross sections on mass number follow.

6.2.1 Resonance energies

For ^4He nuclei one has $E_s = 1.820$ MeV. In this case de-coherence would mean the decomposition of Bose-Einstein condensate to $n = 4 \rightarrow \sum n_i = n$ with $\Delta E = n^2 - \sum_{n_i} k^1(n_i) = 16 - \sum_{n_i} k^2(n_i)$. **Table 9** gives the resonance energies for the four options $n \rightarrow \sum_i n_i$ for the loss of coherence.

These energies span the range at which the cross section for $^{16}O(\gamma, xn)$ reaction has giant dipole resonances [C4]. Quite generally, GDR is a broad bump with substructure beginning around 10 MeV and ranging to 30 MeV. The average position of the bump as a function of atomic number can be parameterized by the following formula

$$E(A)/MeV = 31.2A^{-1/3} + 20.6A^{-1/6} \tag{6.3}$$

given in [C18]. The energy varies from 36.6 MeV for $A = 4$ (the fit is probably not good for very low values of A) to 13.75 MeV for $A = 206$. The width of GDR ranges from 4-5 MeV for closed shell nuclei up to 8 MeV for nuclei between closed shells.

The observation raises the question whether the de-coherence of Bose-Einstein condensates associated with ^4He and nuclear string could relate to GDR and its variants. If so, GR proper would be a collective phenomenon both at the level of single ^4He nucleus (main contribution to the resonance energy) and entire nucleus (width of the resonance). The killer prediction is that even ^4He should exhibit giant dipole resonance and its variants: GDR in ^4He has been reported [C30].

6.2.2 Some tests

This hypothesis seems to survive the basic qualitative and quantitative tests.

1. The basic prediction of the model peak at 12.74 MeV and at triplet of closely located peaks at $(25.48, 27.30, 29.12)$ MeV spanning a range of about 4 MeV, which is slightly smaller than the width of GDR. According to [C29] there are two peaks identified as iso-scalar GMR at $13.7 \pm .3$ MeV and iso-vector GMR at 26 ± 3 MeV. The 6 MeV uncertainty related to the position of iso-vector peak suggests that it corresponds to the triplet $(25.48, 27.30, 29.12)$ MeV whereas singlet would correspond to the iso-scalar peak. According to the interpretation represented in [C29] iso-scalar *resp.* iso-vector peak would correspond to oscillations of proton and neutron densities in same *resp.* opposite phase. This interpretation can make sense in TGD framework only inside single ^4He nucleus and would apply to the transverse oscillations of ^4He string rather than radial oscillations of entire nucleus.

2. The presence of triplet structure seems to explain most of the width of iso-vector GR. The combination of GDR internal to ^4He with GDR for the entire nucleus (for which resonance energies vary from $\Delta E_{min} = (2n-1)E_s$ to $\Delta E_{max} = n^2 E_s$ $(n = A/4)$) predicts that also latter contributes to the width of GDR and give it additional fine structure. The order of magnitude for ΔE_{min} is in the range [1.3685, 2.3640] MeV which is consistent with the with of GDR and predicts a band of width 1 MeV located 1.4 MeV above the basic peak.

3. The de-coherence of $A < 4$ nuclei could increase the width of the peaks for nuclei with partially filled shells: maximum and minimum values of resonance energy are $9E_s(^4He)/2 = 8.19$ MeV and $4E_s(^4He) = 7.28$ MeV for ^3He and ^3H which conforms with the upper bound 8 MeV for the width.

4. It is also possible that n ^4He nuclei simultaneously lose their coherence. If multiplet de-coherence occurs coherently it gives rise to harmonics of GDR. For de-coherent de-coherence so that the emitted photons should correspond to those associated with single ^4He GDR combined with nuclear GDR. If absorption occurs for $n \leq 13$ nuclei simultaneously, one obtains a convoluted spectrum for resonant absorption energy

$$\Delta E = [16n - \sum_{j=1}^{n} \sum_{i_j} k^2(n_{i_j})] E_s \ . \quad (6.4)$$

   The maximum value of ΔE given by $\Delta E_{max} = n \times 29.12$ MeV. For $n = 13$ this would give $\Delta E_{max} = 378.56$ MeV for the upper bound for the range of excitation energies for GDR. For heavy nuclei [C18] GDR occurs in the range 30-130 MeV of excitation energies so that the order of magnitude is correct. Lower bound in turn corresponds to a total loss of coherence for single ^4He nucleus.

5. That the width of GDR increases with the excitation energy [C18] is consistent with the excitation of higher GDR resonances associated with the entire nuclear string. $n \leq n_{max}$ for GDR at the level of the entire nucleus means saturation of the GDR peak with excitation energy which has been indeed observed [C4] (see **Fig. 1**).

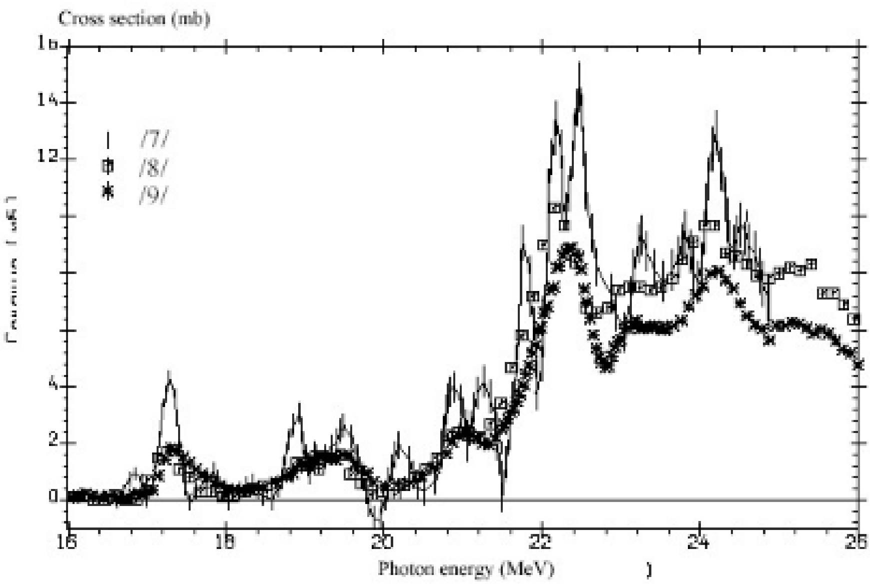

Figure 1: The comparison of photoneutron cross sections $^{16}O(\gamma, xn)$ obtained in one BR-experiment (Moscow State University) and two QMA experiments carried out at Saclay (France) Livermoore (USA). Figure is taken from [C4] where also references to experiments can be found.

One can look whether the model might work even at the level of details. Figure 3 of [C4] compares total photoneutron reaction cross sections for $^{16}O(\gamma, xn)$ in the range 16-26 MeV from some experiments so that the possible structure at 12.74 MeV is not visible in it. It is obvious that the resonance structure is more complex than predicted by the simplest model. It seems however possible to explain this.

1. The main part of the resonance is a high bump above 22 MeV spanning an interval of about 4 MeV just as the triplet at (25.48, 27.30, 29.12) MeV does. This suggest a shift of the predicted 3-peak structure in the range 25-30 MeV range downwards by about 3 MeV. This happens if the photo excitation inducing the de-coherence involves a dropping from a state with excitation energy of 3 MeV to the ground state. The peak structure has peaks roughly at the shifted energies but there is also an additional structure which might be understood in terms of the bands of width 1 MeV located 1.4 MeV above the basic line.

2. There are three smaller bumps below the main bump which also span a range of 4 MeV which suggests that also they correspond to a shifted variant of the basic three-peak structure. This can be understood if the photo excitation inducing de-coherence leads from an excited state with excitation energy 8.3 MeV to ground state shifting the resonance triplet (25.48, 27.30, 29.12) MeV to resonance triplet at (17.2, 19.00, 20.82) MeV.

On basis of these arguments it seems that the proposed mechanism might explain GR and its variants. The basic prediction would be the presence of singlet and triplet resonance peaks corresponding to the four manners to lose the coherence. Second signature is the precise prediction for the fine structure of resonance peaks.

6.2.3 Predictions for cross sections

The estimation of collision cross sections in nuclear string model would require detailed numerical models. One approach to modelling would be to treat the colliding nuclear strings as random coils with finite thickness defined by the size of $A \leq 4$ strings. The intersections of colliding strings would induce fusion reactions and self intersections fissions. Simple statistical models for the intersections based on geometric probability are possible and allow to estimate branching ratios to various channels.

In the case of GR the reduction to ^4He level means strong testable predictions for the dependence of GR cross sections on the mass number. GR involves formation of eye-glass type configuration at level of single ^4He and in the collision of nuclei with mass numbers A_1 and A_2 GR means formation of these configurations for some $A = 4$ unit associated with either nucleus. Hence the GR cross section should be in a reasonable approximation proportional to $n_1 + n_2$ where n_i are the numbers of $A = 4$ sub-units, which can be either ^4He, tetra-neutron, or possible other variants of ^4He having charged color bonds. For $Z_i = 2m_i$, $N = 2n_i$, $A_i = 4(m_i + n_i)$ nuclei one has $n_1 + n_2 = (A_1 + A_2)/4$. Also a characteristic oscillatory behavior as a function of A is expected if the number of $A = 4$ units is maximal. If GR reactions are induced by the touching of ^4He units of nuclear string implying transfer of kinetic energy between units then the GR cross sections should depend only on the energy per ^4He nucleus in cm system, which is also a strong prediction.

6.3 De-Coherence Inside $A = 3$ Nuclei And Pygmy Resonances

For neutron rich nuclei the loss of coherence is expected to occur inside ^4He, tetra-neutron, ^3He and possibly also ^3n which might be stable in the nuclear environment. The de-coherence of tetra-neutron gives in the first approximation the same resonance energy spectrum as that for ^4He since $E_B(^4n) \sim E_B(^4He)$ roughly consistent with the previous estimates for $E_B(^4n)$ implies $E_s(^4n) \sim E_s(^4He)$.

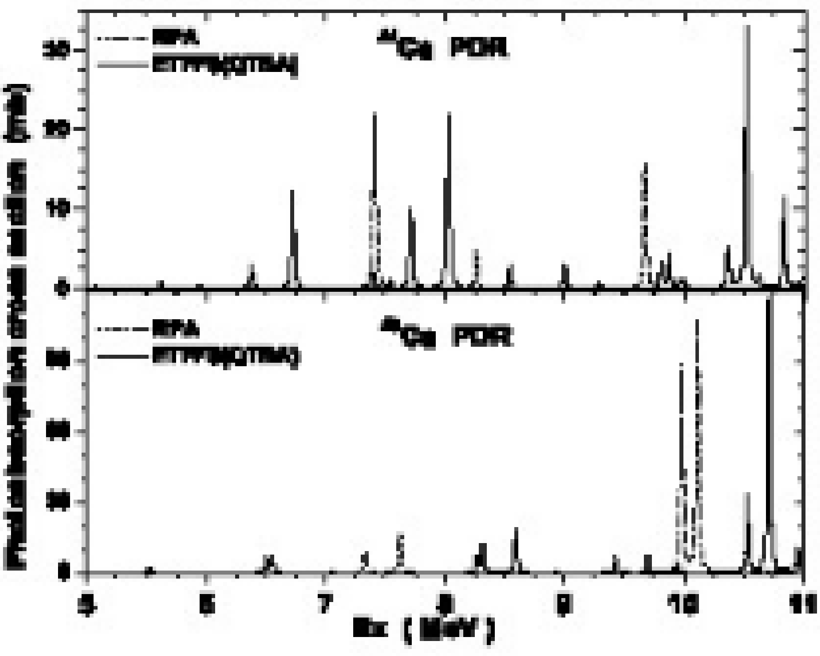

Figure 2: Pygmy resonances in ^{44}Ca and ^{48}Ca up to 11 MeV. Figure is taken from [C28].

The de-coherence inside $A = 3$ nuclei might explain the so called pygmy resonance appearing in neutron rich nuclei, which according to [C39] is wide bump around $E \sim 8$ MeV. For $A = 3$ nuclei only two de-coherence transitions are possible: $3 \rightarrow 2{+}1$ and $3 \rightarrow 1{+}1{+}1$ and $E_s = E_B(^3H) = .940$ MeV the corresponding energies are $8E_s = 7.520$ MeV and $9 * Es = 8.4600$ MeV. Mean energy is indeed ~ 8 MeV and the separation of peaks about 1 MeV. The de-coherence at level of ^4He string might add to this 1 MeV wide bands about 1.4 MeV above the basic lines.

The figure of [C28] (see **Fig. ??**) illustrating photo-absorption cross section in ^{44}Ca and ^{48}Ca shows three peaks at 6.8, 7.3, 7.8 and 8 MeV in ^{44}Ca. The additional two peaks might be assigned with the excitation of initial or final states. This suggests also the presence of also $A = 3$ nuclear strings in ^{44}Ca besides $^{H}4$ and ^{4}n strings. Perhaps neutron halo wave function contains $^{3}n + n$ component besides ^{4}n. For ^{48}Ca these peaks are much weaker suggesting the dominance of $2{\times}^{4}n$ component.

6.4 De-Coherence And The Differential Topology Of Nuclear Reactions

Nuclear string model allows a topological description of nuclear decays in terms of closed string diagrams and it is interesting to look what characteristic predictions follow without going to detailed quantitative modelling of stringy collisions possibly using some variant of string models.

In the de-coherence eye-glass type singularities of the closed nuclear string appear and make possible nuclear decays.

1. At the level of ^{4}He sub-strings the simplest singularities correspond to $4 \rightarrow 3 + 1$ and $4 \rightarrow 2 + 2$ eye-glass singularities. The first one corresponds to low energy GR and second to one of higher energy GRs. They can naturally lead to decays in which nucleon or deuteron is emitted in decay process. The singularities $4 \rightarrow 2{+}1{+}1$ *resp.* $4 \rightarrow 1{+}1{+}1{+}1$ correspond to eye-glasses with 3 *resp.* four lenses and mean the decay of ^{4}He to deuteron and two nucleons *resp.* 4 nucleons. The prediction is that the emission of deuteron requires a considerably larger excitation energy than the emission of single nucleon. For GR at level of $A = 3$ nuclei analogous considerations apply. Taking into account the possible tunnelling of the nuclear strings from the nuclear space-time sheet modifies this simple picture.

2. For GR in the scale of entire nuclei the corresponding singular configurations typically make possible the emission of alpha particle. Considerably smaller collision energies should be able to induce the emission of alpha particles than the emission of nucleons if only stringy excitations matter. The excitation energy needed for the emission of α particle is predicted to increase with A since the number n of ^{4}He nuclei increases with A. For instance, for $Z = N = 2n$ nuclei $n \rightarrow n{-}1{+}1$ would require the excitation energy $(2n{-}1)E_c = (A/2{-}1)E_c$, $E_c \simeq .2$ MeV. The tunnelling of the alpha particle from the nuclear space-time sheet can modify the situation.

The decay process allows a differential topological description. Quite generally, in the de-coherence process $n \rightarrow (n - k) + k$ the color magnetic flux through the closed string must be reduced from n to $n-k$ units through the first closed string and to k units through the second one. The reduction of the color color magnetic fluxes means the reduction of the total color binding energy from n^2E_c $((n-k)^2 + k^2)E_c$ and the kinetic energy of the colliding nucleons should provide this energy.

Faraday's law, which is essentially a differential topological statement, requires the presence of a time dependent color electric field making possible the reduction of the color magnetic fluxes. The holonomy group of the classical color gauge field $G^{A}_{\alpha\beta}$ is always Abelian in TGD framework being proportional to $H^{A}J_{\alpha\beta}$, where H^{A} are color Hamiltonians and $J_{\alpha\beta}$ is the induced Kähler form. Hence it should be possible to treat the situation in terms of the induced Kähler field alone. Obviously, the change of the Kähler (color) electric flux in the reaction corresponds to the change of (color) Kähler (color) magnetic flux. The change of color electric flux occurs naturally in a collision situation involving changing induced gauge fields.

7 Nuclear anomalies

7.1 Individual Nucleons Inside Nuclei Do Not Behave According To Predictions

Individual nucleons do not behave in nuclei as the existing theory predicts (see the popular article). This is a conclusion reached by an international team of scientists which has published their findings as article article in Phys. Rev. Letters).

I am not a nuclear physicists but have proposed what I call nuclear string model [K11]. Therefore I have good motivations for trying to understand what has been found and what nuclear string model can say about the findings.

7.1.1 Background And Results

There are many models of atomic nuclei and each of them explains some aspects of nucleus. Nucleus can be modelled rigid body or as a kind of quantum liquid. In the prevailing average field approach the presence of other nucleons is described in terms of a potential function and calculates the states of individual nucleons in this potential using Schrödinger equation. It is essential that nucleons are assumed to be independent.

The model taking potential function to be that of harmonic oscillator is surprisingly successful but one must introduce corrections such as spin-orbit coupling in order to understand the energy spectrum. In this approach the notion of nuclear shell emerges. In atomic physics and chemistry the closed shells do not participate to the interaction and the outermost shell characterized by valence dictates to a higher degree the chemical properties of atom. Valence is positive if outer shell contains particles. Valence if negative if some of them are lacking. Something similar is to be expected also now. In this case full shells correspond to magic numbers for protons and neutrons separately (note that protons and neutrons seem to behave rather independently, something highly non-trivial!). The nuclei with valence +1 or -1 would correspond to almost magic nuclei.

One generally accepted correction to the harmonic oscillator model is inspired by the assumption that heavier nuclei can be described as a kind of blob of condensed matter obeying equation of state allowing to introduce notions like acoustic waves and surface waves. The nucleon at the unfilled shell would reside at the surface of this blob. The blob has vibrational excitations characterized by multipolarity (spherical harmonic characterized by angular momentum quantum numbers and the radial part of the oscillation amplitude. These excitations give rise to analogs of surface waves in water. Valence nucleons interact with the oscillations and affect the energy levels of the valence nucleons. The predictions of this model are calculable.

The team has studied almost doubly magic nuclei with valence equal to plus or -1 and calculated the effects on the energy levels of the nucleon and found that the observed effects are significantly smaller than the predicted ones. This finding challenges both the mean field approach or the idea that nucleus can be idealized as a condensed matter like system or both.

7.1.2 Nuclear String Model

In TGD framework ordinary model of nucleus is replaced with what I call nuclear string model [K11].

Core ideas of nuclear string model

The core idea of nuclear string model is that the nucleons are ordered to a string like structure.

1. Nuclei consist of string like objects: protons and neutrons connected by color magnetic flux tubes form string like objects, perhaps separately. The color magnetic flux tubes would would be meson-like objects and could even carry net color. They are either neutral (quark and antiquark at the ends of flux tube have opposite charges) or carry em charge. What "meson-like" does mean is not completely trivial. Quark anti-quark pair connected by a flux tube is what comes in mind.

   Quarks correspond in TGD to closed flux tubes with length of order Compton length of quark traversing through two wormhole contacts and connecting them by monopole flux tubes at parallel space-time sheets. The first wormhole contact has quark quantum numbers and the second one those of a neutrino pair compensating for weak axial isospin of the quark. The compensating weak axial isospin for quark and antiquark would have opposite sign so that they are not necessary in the meson-like state. Does flux tube connect these flux tube structures or is there only single closed flux tube so that quarks would lose half of their identity.

   This predicts a large number of exotic states. The exotic states cannot be distinguished chemically from the isotopes of the nucleus. The hypothesis is that the energy scale of the excitations is in keV range and their existence explains the annual variation of nuclear decay rates which seems to be caused by X rays from Sun [C22].

This would be new nuclear physics and perhaps relevant also to the cold fusion. The energy scale would derive from the string tension of the color magnetic flux tube. The lengths of the color magnetic flux tubes corresponding to keV scale would be rather long and correspond color magnetic bodies of the nucleons. If this is the case then the color magnetic energy of the system would depend only weakly on the positions of the nucleons of string inside nuclear volume. This assumption might allow to understand the anomalous finding that the charge radius of proton is smaller than predicted [K10].

The presence of long flux tubes might allow to understand the anomalous finding that the charge radius of proton is smaller than predicted. u and d quarks are known to be light and have masses in the range 5-20 MeV. The TGD based model for elementary particles [K10] suggests that quarks correspond to closed flux tubes consisting of two portions at parallel space-time sheets with ends connected by wormhole contacts and with monopole magnetic flux rotating in the tube. Uncertainty principle suggests that the length of the flux tube structure is of the order of Compton length of the quark. The constituents of proton would be larger than proton itself! The paradox disappears if the Compton length is assigned with the magnetic flux tube connecting the two wormhole contacts associated with quark and rather near to each other and much shorter than the flux tube.

Flux tubes with Compton lengths corresponding to 10 keV photon energy would be however 3 orders of magnitude longer (10 nm). This could be due to the scaling by $h_{eff}/h \sim 10^3$. These flux tubes could also correspond to the flux tubes connecting neighboring nucleons of nuclear strings. The dark magnetic flux tubes of this length associated with neighboring nuclei could reconnect and bind nuclei to form lattice like structures. This process and thus dark nuclear physics could play a key role in in the formation of condensed matter phases as it is proposed to play also in living matter.

2. These strings of nucleons could topologically condense at larger magnetic flux tubes but could still touch also the nuclear spacetime sheet as suggested by the success of harmonic oscillator model. In biological length scales the assumption that effective Planck constant characterizing dark matter phase equals $h_{eff} = n \times h$ equals to gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where v_0 is a parameter with dimensions of velocity, implies that cyclotron frequencies are universal (no dependence on particle mass m) but also implies that particles with different masses correspond to different value of effective Planck constant so that living system would perform spectroscopy putting particles (elementary particles, atoms, ions, molecules, ..) neatly at different dark space-time sheets! If the nucleons inside nuclei are dark in this sense protons and neutrons would be at different flux tubes since their masses are slightly different.

3. Nucleus could consist of several - possibly knotted - closed flux tubes containing some number of nucleons each. An attractive hypothesis is that these flux tubes correspond to nuclear shells so that full flux tubes would correspond to full shells and define separate units. In semiclassical approximation this would mean that nuclear string is localized at the surface of sphere.

   Could one regard nuclear string at sphere as Hamiltonian cycle?

   Nuclear string means the introduction of additional structure to the many-nucleon state. One can consider the addition of even further additional structure, which is purely topological. This addition has not been considered in the earlier variant of the model and might well be un-necessary.

   (a) If the vertices of nuclear string at sphere define in a natural manner polyhedron, then nuclear string defines a closed non-intersecting curve going through the with n vertices of this polyhedron known as Hamilton cycle. If color magnetic flux tubes are long, it is convenient to consider a curve defined by line segments connecting the neighboring nucleons of the nuclear string.

The notion of Hamilton cycle is well-defined for any graph so that it makes sense for any polyhedron. It is enough that the cycle is consistent with the underlying graph structure allowing to say which vertices are nearest neighbours (they need not be neighbours in the metric sense but only in the sense of homology that is ends of the same edge).

(b) Graph structure however requires that one assumes graph structure involving not only vertices and edges connecting them but also faces which in homology theory are most naturally triangles (2-simplices). Faces are clearly an additional structure as also nuclear string in the framework of standard nuclear physics. If the state of nucleus is analogous to that of molecule with nucleons having almost fixed positions homology emerges in natural manner but for independent particle model situation is far from clear. Could one identify the 2-simplexes of the homology associated with a non-intersecting curve consisting of segments uniquely from the condition that the additional edges do not intersect at sphere? Already the example of square in plane shows that the additional edge can be either diagonal.

(c) In the case of Platonic solids the rotational symmetries preserving Platonic solid generate finite number of Hamilton cycles of same shape from a given one and it is natural to define Hamilton cycles as equivalence classes of cycles with same shape. For instance, for icosahedron one has 17 Hamilton cycles and for 11 cycles one has symmetry group Z_n, $n \in 6, 4, 2$ and the cycles obtained from them by rotations. In this case one can however say that independent particle approximation is given up and one considers equilibrium configurations analogous to those of molecules. Nuclear string however orders the nucleons and brings in additional information. Hamilton cycles make sense also for the deformations of icosahedron since it is only the homological nearness that matters. Note however that the allowed deformations of metric Hamilton cycle must be such that the edges do not intersect: in other words the deformation of nuclear string is not self intersecting.

(d) If the nucleons can perform only small oscillations around the vertices of a polyhedron, independent particle assumption fails badly. One would however have collective wave function for orientations of the polyhedron. In this case Platonic solids or their homological generalization define good candidates for full shells.

7.1.3 How Does Nuclear String Model Relate To The Shell Model?

In the mean field approximation particles move independently in a potential describing the effects of the other nucleons. The basis for N-nucleon wave functions can be constructed as products of those associated with individual nucleons. The natural question is under what conditions nuclear string model is consistent with independent particle model.

What does the consistency of nuclear string model with independent particle model imply?

Quite generally, the consistency with independent particle approach requires that the nuclear string property does not contribute much to the energy of the states.

(a) At classical level the independent motion of nucleons (along elliptic orbits in harmonic oscillator approximation) of the nuclear string would give rise to a rather complex motion of nuclear string leading to self intersections unless the flux tubes have much longer length scale than the nucleus. In this case nucleus would be like seed from which flux tubes would emerge like a plant and self intersections could be avoided but the motion of nucleons could induce local braiding of the strands emanating from nucleons. This is indeed what has been assumed. Note that the U shaped flux tubes connecting neighboring nucleons could reconnect with the similar tubes associated with other nuclei so that the motions of nucleons would give rise to genuine global braiding.

(b) Harmonic oscillator states would induce wave function in the space of string configurations having interpretation as Hamilton cycles associated with polyhedron with N vertices whose positions can vary, also in the radial direction although semiclassical shell model would force particles at the same radius. TGD allows to consider a collective localization at spherical shells: this would be rather long range correlation but consistent with the spirit of shell model. A more general approximation would be the localization to a union of spherical shells associated with the maxima of modulus of the radial wave function.

(c) In independent particle model basis wave functions are products. This is not consistent with the assumption that nucleons arrange to form a string unless the nearest neighbour nucleons at string can have arbitrary angular distance along the sphere: this would hold true exactly at the limit of vanishing string tension.

The longer the angular distance, the higher the color magnetic energy of the string. This energy would give rise to correlations inducing the mixing of harmonic oscillator wave functions. This would be the minimal breaking of independent particle approximation and would describe possibly new kind of nuclear forces between neighboring nucleons of the nuclear string as color magnetic forces.

If the color magnetic interaction corresponds to MeV scale, the length scale of the flux tubes is electron's Compton length and even in this case considerably longer than nuclear radius and independent particle approximation would not be badly broken. In this case the interpretation in terms of strong force might make sense. Even for the flux tubes which length of order Compton length for u and d quarks the flux tubes are much longer than the distance between nucleons.

If the energy scale of exotic nuclei is 1-10 keV as the variation of the nuclear decay rates seemingly induced by the variations of X ray flux from Sun suggests, the color magnetic energy would be rather small and independent particle approximation would even better than in previous case. This is expected to be the case if the color magnetic flux tubes correspond to the length scale assignable to 1-10 keV scale and thus long so that the positions of nucleons inside nucleus do not matter. 10 keV scale would in fact correspond to photon wavelength about 1 Angstrom - size of atom - so that a new interaction between nuclear and atomic physics is predicted. Note that classical and quantal pictures are consistent with each other.

(d) Independent particle model allows the nucleons with same quantum numbers to be in same position. This means self-intersection for nuclear string. Two-nucleon configuration space is $S^2 \times S^2$ and self-intersections occur in diagonal S^2 so that they are very rare and one could perhaps allow them when quantum numbers are different. Fermi statistics takes care that self-intersections do not take for nucleons with identical quantum numbers and also that the probability density for almost self-intersections is small. What is nice that Fermi statistics have geometric correlate int hat it would guarantee the absence of self-intersections in this strong sense if nucleons of given kind with given spin arrange on nuclear string so that one would have the analog of spontaneous magnetization. One would have four-kinds of strings corresponding to different directions of spin and strong isospin.

Semiclassical considerations

One can consider the situation also semi-classically.

(a) Nuclear shells correspond in the Bohr model based on harmonic oscillator potential to spheres with radii fixed by Bohr's quantization rules. Wave functions are indeed concentrated also around the classical radius but for principal quantum number n one obtains $n + 1$ local maxima (see this). The wave function at given shell would be localized at $n + 1$ surfaces rather than single surface, which is definitely a non-classical aspect. The probability density however concentrates mostly to the shell with the largest radius so that for large values of n the semiclassical approximation becomes better.

One can of course ask, whether this picture contains deeper seed of truth expressible in terms of space-time topology. This would conform with the TGD based idea that matter resides on geometric shells: this idea is suggested already by the model for a final state of star [K1] predicting that mass is concentrated on shell. In many-sheeted space-time one expects an onion-like structure made of these shells.

The TGD based proposal is that in solar system planets would be accompanied by this kind of dark matter shells with radii predicted approximately by Bohr rules. TGD based explanation for Pioneer and Flyby anomalies [K17] predicts the same surface density of dark matter at these shells as deduced for the effective surface density of dark matter in the case of galactic nucleus. Of course, nucleons inside nuclei cannot correspond to dark matter unless the value of $h_{eff}/n = n$ is small. Otherwise the size of nucleus would be too large.

(b) In the semiclassical approximation the radii of the sphere at which the vertices of polyhedron are located would correspond to the radii of nuclear shells. An approximation in which one treats the angular degrees of freedom quantally using independent particle model and radial degree of freedom collectively looks reasonable and would allow to keep the rotational symmetries but would mean giving up the additional symmetries making if possible to solve harmonic oscillator model exactly. With this assumption nuclear strings would reside at spheres.

Could magic numbers be understood in terms of Platonic solids?

Harmonic oscillator model predicts the numbers of nucleons for magic nuclei as sums of numbers of nucleons for the full shells involved but the predictions are not quite correct. One can however modify the model to get the observed magic numbers. This explanation is based on dynamics and slightly broken symmetries and arguably more convincing than explanations relying on elementary geometry.

Still one can ask whether these numbers could be consistent with the idea that a full shell corresponds to a Platonic solid such that closed nuclear string, which can connect only neighboring vertices goes through its vertices without intersecting itself?

(a) Icosahedral and tetrahedral Platonic cycles are in a key role in TGD inspired vision about bio-harmony predicting that DNA sequences have interpretation as sequences of 3-chords of what I call bio-harmony realizing genetic code [K15].

One can also consider replacing metric Platonic solid with combinatorial objects in which neighboring vertices are defined to be ends of the same edge which can be rather long. This option is consistent with independent particle model in angular degrees of freedom. In this case however the addition of 2-simplexes (triangles) is not unique so that it seems that the Platonic cycles are expected to be natural only for molecule like states.

(b) If the polyhedron defined by the positions of nucleons can be interpreted as Platonic solid (cube, octahedron, tetrahedron, icosahedron, dodecahedron) the number of nucleons at given shell would be equal the number of vertices of the Platonic solid. One can of course consider more complex scenarios. One could consider adding nucleons also to the centers of edges and faces and even superpose different Platonic solids associated with the same sphere. Same Platonic solid could also appear as scaled variants.

(c) One could consider building the nuclei by adding new spherical layers gradually and assuming that the nucleons are at the vertices (one could consider also putting them in the centers of the faces). The lowest magic numbers are 2, 8, 20, 28, 50, 82, 126, 184 and are reproduced if shells have $n = 2, 6, 12, 8, 22, 32, 44, 58$. In the standard approach one can say that each oscillator wave function corresponds to two spin directions so that the proper number to consider would be $m = n/2$. The values of m would be be $m = 1, 3, 6, 4, 11, 16, 22, 29$.

If nuclear string contains only nucleons with given spin direction, the integers m are the numbers that one should explain: this option is strictly speaking the more convincing one. If nuclear string contains nucleons with both spin directions, one must explain the integers $n = 2 \times m$.

Note that protons and neutrons can be assumed to belong to different nuclear strings.

Could one understand the integers m or n in terms of Platonic solids?

(a) $m = 1$ would correspond to the nucleon at origin, where modulus of wave function has maximum. $m = 3$ would correspond to triangle. $m = 6$ could be interpreted in terms of octahedron, and $m = 4$ in terms of tetrahedron. The larger values of m would require constructions which look artificial.

(b) $n = 2$ would correspond to line segment with 2-vertices. n=6 would correspond to octahedron. n=12 would correspond to icosahedron. $n = 8$ would correspond to cube. Note that tetrahedron, the only self-dual Platonic solid, predicting $n = 4$ is missing fron the list. Also dodecahedron with $n = 20$ is missing. $n = 22$ would require articial looking constructions.

These findings would suggest that the independent particle model is not a good approximation for light nuclei for which a model as a molecule like entity with rather rigid position of nucleons might be considered if Platonic solids are taken as metric objects. If one is not willing to give up so easily, one could argue that the exotic states in which some color bonds between nucleons are charged change the apparent numbers of neutrons and protons: one would have only apparently $n = 22$ rather than $n = 20$. For double magic nuclei the sum of the anomalous looking magic numbers would be however 20+20: say 22 protons and 18 neutrons.

7.1.4 The Experimental Findings From TGD Point Of View?

On basis of the experimental findings it is far from clear whether one can model nuclei as objects characterized by continuous nucleon densities and obeying some thermodynamical equation of state from which the dynamics describing the oscillations of nucleon densities can be deduced.

(a) Suppose that nuclear shells make in TGD framework sense also as geometric objects, that is as (say) spherical space-time sheets containing the nuclear string for which the nucleons at vertices behave independently in angular degrees of freedom. In this kind of model the approximation as condensed matter blob is not the thing that comes first into mind. It would be like modelling of solar system by replacing planets by introducing planet density and oscillations of this density.

(b) If the shell contains only single particle, the collective wave function for the radius of the sphere associated with shell co-incides with single particle wave function. In this case one cannot say that the particle is at the surface of nucleus.

(c) There is no direct interaction with the oscillations of the full shell in the lowest order since the shells correspond to different space-time sheets. The interaction is only in terms of potential functions assignable to the large space-time sheet.

7.2 GSI Anomaly

"Jester" wrote a nice blog posting titled *Hitchhikers-guide-to-ghosts-and-spooks in particle physics* summarizing quite a bundle of anomalies of particle physics and also one of nuclear physics- known as GSI anomaly. The abstract of the article *Observation of Non-Exponential Orbital Electron Capture Decays of Hydrogen-Like* ^{140}*Pr and* ^{142}*Pm Ions* [C14] describing the anomaly is here.

We report on time-modulated two-body weak decays observed in the orbital electron capture of hydrogen-like ^{140}*Pr¡sup¿59+¡/sup¿ and* ^{142}*Pm¡sup¿60+¡/sup¿ ions coasting in an ion storage ring. Using non-destructive single ion, time-resolved Schottky mass spectrometry we found that the expected exponential decay is modulated in time with a modulation period of about 7 seconds for both systems. Tentatively this observation is attributed to the coherent superposition of finite mass eigenstates of the electron neutrinos from the weak decay into a two-body final state.*

This brings in mind the nuclear decay rate anomalies which I discussed earlier in the blog posting *Tritium beta decay anomaly and variations in the rates of radioactive processes* and in [K18]. These variations in decay rates are in the scale of year and decay rate variation correlates with the distance from Sun. Also solar flares seem to induce decay rate variations.

The TGD based explanation [K18] relies on nuclear string model in which nuclei are connected by color flux tubes having exotic variant quark and antiquark at their ends (TGD predicts fractal hierarchy of QCD like physics). These flux tubes can be also charged: the possible charges $\pm 1, 0$. This means a rich spectrum of exotic states and a lot of new low energy nuclear physics. The energy scale corresponds to Coulomb interaction energy $\alpha_{em}m$, where m is mass scale of the exotic quark. This means energy scale of 10 keV for MeV mass scale. The well-known poorly understood X-ray bursts from Sun during solar flares in the wavelength range 1-8 A correspond to energies in the range 1.6-12.4 keV -3 octaves in good approximation- might relate to this new nuclear physics and in turn might excite nuclei from the ground state to these excited states and the small mixture of exotic nuclei with slightly different nuclear decay rates could cause the effective variation of the decay rate. The mass scale $m \sim 1$ MeV for exotic quarks would predict Coulomb energy of order $\alpha_{em}m$ which is of order 10 keV.

The question is whether there could be a flux of X rays in time scale of 7 seconds causing the rate fluctuation by the same mechanism also in GSI experiment. For instance, could this flux relate to synchrotron radiation. I could no identify any candidate for this periodicity from the article. In any case, the prediction is what might be called X ray nuclear physics and artificial X ray irradiation of nuclei would be an easy manner to kill or prove the general hypothesis.

One can imagine also another possibility.

(a) The first guess is that the transitions between ordinary and exotic states of the ion are induced by the emission of exotic W boson between nucleon and exotic quark so that the charge of the color bond is changed. In standard model the objection would be that classical W fields do not make sense in the length scale in question. The basic prediction deriving from induced field concept (classical ew gauge fields correspond to the projection of CP_2 spinor curvature to the space-time surface) is however the existence of classical long range gauge fields- both ew and color. Classical W field can induce charge entanglement in all length scales and one of the control mechanisms of TGD inspired quantum biology relies on remote control of charge densities in this manner. Also the model of cold fusion could involve similar oscillating time like entanglement allowing the bombarding nucleus to penetrate to the nucleus when proton has transformed to neuron in good approximation and charge is de-localized to the color bond having much larger size.

(b) In the approximation that one has two-state system, this interaction can be modelled by using as interaction Hamiltonian hermitian non-diagonal matrix V, which can be written as $V\sigma_x$, where σ_x is Pauli sigma matrix. If this process occurs coherently in time scales longer than $\hbar/V$, an oscillation with frequency $\omega = V/\hbar$ results. Since weak interactions are in question 7 second modulation period might make sense.

The hypothesis can be tested quantitatively.

(a) The weak interaction Coulomb potential energy is of form

$$\frac{V(r)}{\hbar} = \alpha_W \frac{exp(-m_W r)}{r} \ , \tag{7.1}$$

where r is the distance between nucleon center of mass and the end of color flux tube and therefore of order proton Compton length r_p so that one can write

$$r = x \times r_p \ .$$

where x should be of order unity but below it.

(b) The frequency $\omega = 2\pi/\tau = V/\hbar$ must correspond to 14 seconds, twice the oscillation period of the varying reaction rate. By taking W boson Compton time t_W as time unit this condition can be written as

$$\frac{\alpha_W exp(-y)}{y} = \frac{t_W}{\tau} \ ,$$
$$y = x\frac{r_p}{r_W} = x\frac{m_W}{m_p} \simeq 80 \times x \ ,$$
$$\alpha_W = \alpha_{em}/sin^2\theta_W \ .$$

(c) This gives the condition

$$\frac{exp(-y)}{y} = \frac{t_p}{\tau} \times \frac{sin^2\theta_W}{80 \times \alpha_{em}} \ . \quad (7.2)$$

This allows to solve y since the left hand side is known. Feeding in proton Compton length $r_p = 1.321 \times 10^{-15}$ m and $sin^2\theta_W = .23$ one obtains that the distance between flux tube end and proton cm is $x = .6446$ times proton Compton length, which compares favorably with the guess $x \simeq 1$ but smaller than 1. One must however notice that the oscillation period is exponentially sensitive to the value of x. For instance, if the charge entanglement were between nucleons, $x > 1$ would hold true and the time scale would be enormous. Hence the simple model requires new physics and predicts correctly the period of the oscillation under very reasonable assumptions.

(d) One could criticize this by saying that the masses of two states differ by amount which is of order 10 keV or so. This does not however affect the argument since the mass corresponds to the diagonal non-interaction part of the Hamiltonian contributing only rapidly oscillating phases whereas interaction potential induces oscillating mixing as is easy to see in interaction picture.

(e) If one believes in the hierarchy of Planck constants and p-adically scaled variants of weak interaction physics, charge entanglement would be possible in much longer length scales and the time scale of it raises the question whether qubits could be realized using proton and neutron in quantum computation purposes. I have also proposed that charge entanglement could serve as a mechanism of bio-control allowing to induce charge density gradients from distance in turn acting as switches inducing biological functions.

So: it happened again! Again I have given a good reason for my learned critics to argue that TGD explains everything so that I am a crackpot and so on and so on. Well... after a first feeling of deep shame I dare to defend myself. In the case of standard model explanatory power has not been regarded as an argument against the theory but my case is of course different since I do not have any academic position since my fate is to live in the arctic scientific environment of Finland. And if my name were Feynman, this little argument would be an instant classic. But most theoreticians are just little opportunists building their career and this does not leave much room for intellectual honesty.

7.3 New Evidence For Anomalies Of Radio-Active Decay Rates

Lubos Motl told about new evidence for periodic variations of nuclear decay rates reported by Sturrock et al in their article *Analysis of Gamma Radiation from a Radon Source: Indications of a Solar Influence* [C27]. The abstract of the article summarizes the results.

This article presents an analysis of about 29, 000 measurements of gamma radiation associated with the decay of radon in a sealed container at the Geological Survey of Israel (GSI) Laboratory in Jerusalem between 28 January 2007 and 10 May 2010. These measurements exhibit strong variations in time of year and time of day, which may be due in part to environmental influences. However, time-series analysis reveals a number of periodicities, including two at approximately 11.2 year^{-1} and 12.5 year^{-1}. We have previously found these oscillations in nuclear-decay data acquired at the Brookhaven National Laboratory (BNL) and at the Physikalisch-Technische Bundesanstalt (PTB), and we have suggested that these oscillations are attributable to some form of solar radiation that has its origin in the deep solar interior. A curious property of the GSI data is that the annual oscillation is much stronger in daytime data than in nighttime data, but the opposite is true for all other oscillations. This may be a systematic effect but, if it is not, this property should help narrow the theoretical options for the mechanism responsible for decay-rate variability.

7.3.1 Quantitative summary of findings

The following gives a brief quantitative summary of the findings. Radioactive decays of nuclei have been analyzed in three earlier studies and also in the recent study.

(a) BNL data are about ^{36}Cl and ^{32}Si nuclei. Strong day-time variation in month time scale was observed. Two frequency bands ranging from 11.0 to 11.2 year^{-1} and from 12.6 to 12.9 year^{-1} were observed.

(b) PTB data are about ^{226}Ra nuclei. Also now strong day-time variation was observed with frequency bands ranging from 11.0 to 11.3 year^{-1} and from 12.3 to 12.5 year^{-1}.

(c) GIS data are about ^{222}Ra nuclei. Instead of strong day-time variation a strong night-time variation was observed. Annual oscillation was centered on mid-day. 2 year^{-1} is the next strongest feature. Also a night time feature with a peak at 17 hours was observed. There are also features at 12.5 year^{-1} and 11.2 year^{-1} and 11.9 year^{-1}. All these three data sets lead to oscillations in frequency bands ranging from 11.0 to 11.4 year^{-1} and from 12.1 to 12.9 year^{-1}.

(d) Bellotti et al studied ^{137}Cl nuclei deep underground in Gran Sasso. No variations were detected.

7.3.2 Could exotic nuclear states explain the findings?

The TGD based new physics involved with the effect could relate to the excitations of exotic nuclear states induced by em radiation arriving from Sun. This would change the portions of various excited nuclei with nearly the same ground state energy and affect the average radio-active decay rates.

(a) The exotic nuclei emerge in the model of nucleus as a nuclear string with nucleons connected by color flux tubes having quark and antiquark at ends [K11]. The excitations could be also involved with cold fusion. For the normal nuclei color flux tubes would be neutral but one can consider also excitations for which quark pair carries a net change $\pm e$. This would give rise to a large number of nuclei with same em charge and mass number but having actually abnormal proton and neutron numbers. If the energy differences for these excitations are in keV range they might represent a fine structure of nuclear levels not detected earlier.

    Could these exchanges take place also between different nuclei? For instance, could it be that in the collision of deuterium nuclei the second nucleus can be neutralized by the exchange of scaled down W boson leading to neutralization of second deuterium nucleus so that Coulomb wall could disappear and make possible cold nuclear reaction. It seems that the range of this scaled variant of weak interaction is quite too short. M_{127} variant of weak interactions with W boson mass very near to electron mass could make possible this mechanism.

(b) The exchange of weak bosons could be responsible for generating these excitations: in this case two neutral color bonds would become charged with opposite charges. If one takes seriously the indications for 38 MeV new particle [C17], one can even consider a scaled variant of weak interaction physics with weak interaction length scale given by a length scale near hadronic length scale [K23]. E(38) could be scaled down Z boson with mass of about 38 MeV.

Em radiation from Sun inducing transitions of ordinary nuclei to their exotic counterparts could be responsible for the variation of the radio-active decay rates. If course, exotic nuclei in the above sense are only one option and the following argument below applies quite generally.

7.3.3 Kinetic model for the evolution for the number of excited nuclei

A simple model for the evolution of the number of excited nuclei is as follows:

$$\begin{aligned} \frac{dN}{dt} &= kJ - k_1 N \ \text{ for } \ t \in [t_0, t_1] \ , \\ \frac{dN}{dt} &= -k_1 N \ \text{ for } \ t \in [t_1, t_0 + T] \ . \end{aligned} \tag{7.3}$$

J denotes the flux of incoming radiation and N the number of excited nuclei. t_0 corresponds to the time of sunrise and t_1 to the time of sunset and T is 24 hours in the approximation that sun rises at the same time every morning. The time evolution of $N(t)$ is given by

$$\begin{aligned} N(t) &= \frac{k}{k_1}J + (N(t_0) - \frac{k}{k_1}J) exp[-k_1(t - t_0] \ \text{ for } \ t \in [t_0, t_1] \ , \\ N(t) &= N(t_1) exp[-k_1(t - t_1)] \quad \text{for } \ t \in [t_1, t_0 + T] \ . \end{aligned} \tag{7.4}$$

7.3.4 Explanation for the basic features of the data

The model can explain the qualitative features of the data rather naturally.

(a) The period of 1 year obviously correlates with the distance from Sun..5 year period correlates with the fact that the distance from Sun is minimal twice during a year. Day-time night-time difference can be explained with the fact that em radiation at night-time does not penetrate Earth. This explains also why Gran Sasso in deep underground observes nothing.

(b) The large long time scale variation for the day-time data for BNL and PTB seems to be in apparent contrast with that for the night-dime data at GIS. It is however possible to understand the difference.

   i. If the rate parameter k_1 is large, one can understand why variations are strong at day-time in BNL and BTB. For large value of k_1 $N(t)$ increases rapidly to its asymptotic value $N_{max} = kJ/k_1$ and stays in it during day so that day-time variations due to solar distance are large. At night-time $N(t)$ rapidly decreases to zero so that night-time variation due to the variation of the solar distance is small.

   ii. For GIS the strong variation is associated with the night-dime data. This can be understood in terms of small value of k_1 which can be indeed smaller for ^{226}Ra than for the nuclei used in the other studies. During daytime $N(t)$ slowly increases to its maximum at $N(t_1)$ and decreases slowly during night-time. Since $N(t_1)$ depends on the time of the year, the night-time variation is large.

   iii. The variations in time scales of roughly the time scale of month should be due to the variations in the intensity of the incoming radiation. The explanation suggested in [C27] is that the dynamics of solar core has these periodicities manifested also as the periodicities of the emission of radiation at the frequencies involved. These photons would naturally correspond to the photons emitted in the transitions between excited states of nuclei in the solar core or possibly in solar corona having temperature of about 300 eV. One could in fact think that the mysterious heating of solar corona [E1] to a temperature of 3 million K could be due to the exotic excitations of the nuclei by radiation coming from Sun. At this temperature the maximum of black body distribution with respect to frequency corresponds to energy of.85 keV consistent with the proposal that the energy scale for excitations is keV.

   iv. The difference of frequencies 12.49 year^{-1} and 11.39 year^{-1} is in good approximation 1 year^{-1}, which suggests modulation of the average frequencies with a period of year being due to the rotation of Earth around Sun. The average frequency is 11.89 year^{-1} that is 1/month. The explanation proposed in the article is in terms of rotation velocity of the inner core which would be smaller but same order of magnitude as that of outer core (frequency range from 13.7 to 14.7 year^{-1}). It is however not plausible that the keV photons could propagate from the inner core of Sun unless they are dark in TGD sense. In TGD framework it would be natural to assign the frequency band to solar Corona.

7.3.5 Can one assign the observed frequency band to the rotation of solar corona?

The rotation frequency band assignable to photosphere is too high by about $\Delta f = 3$ year^{-1} as compared to that appearing in decay rate variation. Could one understand this discrepancy?

(a) One must distinguish between the synodic rotation frequency f_S measured in the rest system of Sun and the rotation frequency observed in Earth rotating with frequency $f = 1$ year^{-1} around Sun: these frequencies relate by $f_E = f_S - f$ giving frequency range 12.7 to 13.7 year^{-1}. This is still too high by about $\Delta f = 2$ year^{-1}.

(b) Could corona rotate slower than photosphere? The measurements by Mehta [E6] give the value range 22 - 26.5 days meaning that the the coronal synodic frequency f_C would be in the range 14.0-16.6 year^{-1}. The range of frequencies observed at Earth would be 13-15.6 year^{-1} and too high by about $\Delta = 2$ year^{-1}.

If I have understood correctly, the coronal rotational velocity is determined by using solar spots as markers and therefore refers to the magnetic field rather than the gas in the corona. Could the rotation frequency of the gas in corona be about $\Delta f = 2$ year^{-1} lower than that for the magnetic spots?

One can develop a theoretical argument in order to understand the rotational periods of photosphere and corona and why they could differ by about $\Delta f = 2$ year^{-1}.

(a) Suppose that one can distinguish between the rotation frequencies of magnetic fields (magnetic body in many-sheeted space-time) and gas. Suppose that photosphere (briefly "P") and corona (briefly "C") can be treated in the first approximation as rigid spherical shells having thus moment of inertia $I = (2/3)mR^2$ around the rotational axis. The angular momentum per unit mass is $dL/dm = (2/3)R^2\omega$. Suppose that the value of dL/dm is same for the photosphere and Corona. If the rotation velocity magnetic fields determined from magnetic spots is same as the rotation velocity of gas in corona, this implies $f_C/f_P = (R_S/R_C)^2$, where R_S is solar radius identifiable as the radius of photosphere. The scaling of 13 year^{-1} down to 11 year^{-1} would require $R_C/R_S \simeq 1.09$. This radius should correspond to the hottest part of the corona at temperature about 1-2 million K.

The inner solar corona extends up to $(4/3)R_S$. This would give average radius of the inner coronal shell about $1.15R_S$. The constancy of $dL/dm(R)$ would give a differential rotation with frequency varying as $1/R^2$. If the frequency band reflects the presence of differential rotation, one has $R_{max}/R_{min} \simeq (f_{max}/f_{min})^{1/2} \simeq (15/13)^{1/2} \simeq 1.07$.

(b) One can understand why angular momentum density per mass is constant if one accepts a generalization of the Bohr quantization of planetary orbits originally proposed by Nottale and based on the notion of gravitational Planck constant $\hbar_{gr}$ [K17, K12]. One has $\hbar_{gr} = GMm/v_0$ and is assigned with the flux sheets mediating gravitational interaction between Sun and the planet or some other astrophysical object near Sun. The dependence on solar mass and planetary mass is is fixed by Equivalence Principle. v_0 has dimensions of velocity and therefore naturally satisfies $v_0 < c$. For the three inner planets one has $v_0/c \simeq 2^{-11}$. Angular momentum quantization gives $mR^2\omega = n\hbar_{gr}$ giving $R^2\omega = nGM/v_0$ so that the angular momentum per mass is integer valued. For the inner planets n has values 3, 4, 5.

(c) One could argue that for the photosphere and corona regarded as rigid bodies a similar quantization holds true but with the same vale of n since the radii are so near to each other. Also v_0 should be larger. Consider first photosphere. One can apply the angular momentum quantization condition to photosphere approximate as a spherical shell and rigid body. $I\omega_P = nGmM/v_{0P}$ for $n = 1$ gives $(2/3)R^2\omega = GM/v_{0P}$. For $v_{0P} = c$ one would obtain $\omega_P/\omega_E = (3/2)(R_E/R)^2(v_0/v_{0P}$. For $R_P = .0046491R_E$ (solar radius) this gives $\omega_P/\omega_E \simeq 12.466$ for the $v_0/c = 4.6 \times 10^{-4}$ used by Nottale [K17]: I have often used the approximate nominal value $v_0/c = 2^{-11}$ but now it this approximation is too rough. Taking into account the frequency shift due to Earth's orbital motion one obtains $\omega_P/\omega_E \simeq 11.466$ which is consistent with the lower bound of the observed frequency band and would correspond to R_{max}. The value $v_{0P} = v_{0C} = c$ looks unrealistic if interpreted as a physical velocity of some kind the increase of R_C allows however to reduce the value of v_{0C} so that it seems possible to understand the situation quantitatively.

If one wants to generalize this argument to differential rotation, one must decompose the system spherical shells or more general elements rotating at different velocities and having different value of $\hbar_{gr}$ assignable to the flux tubes connecting them to Sun and mediating gravitational interaction. This decomposition must be physical.

7.4 Reactor antineutrino anomaly as indication for new nuclear physics predicted by TGD

A highly interesting new neutrino anomaly has emerged recently. The anomaly appears in two experiments and is referred to as reactor antineutrino anomaly. There is a popular article Symmetry Magazine (see `http://tinyurl.com/jaqrmdx`) about the discovery of the anomaly in Daya Bay experiment [C31] (see `http://tinyurl.com/z7b63ua`). Bee mentioned in Backreaction blog (see `http://arxiv.org/pdf/1511.05849v2.pdf`) Reno expriment [C19] exhibiting the same anomaly. What happens that more antineutrinos with energies around 5 MeV are produced as should: the anomaly seems to extened to antineutrino energy about 6.3 MeV.

What makes me happy is that this anomaly might provide a new evidence for TGD based model of atomic nuclei.

(a) In nuclear string model [K11]) nucleons are assumed to be bonded to nuclear strings by color magnetic flux tubes with quarks at ends. These nuclear quarks are different from hadronic quarks and can have different p-adic mass scales. Nuclear d quark is expected to be heavier than nuclear d quark and can decay to nuclear u quark by emission of a virtual$W$ boson decaying to electron antineutrino pair. These decays are anomalous from the point of view of standard nuclear physics.

(b) The virtual W boson decaying to electron antineutrino pair in the anomalous region around 5 MeV should have energy which is two times neutrino energy since electron is relativistic. Since the upper boundary of anomalous region corresponds to about 6.3 MeV antineutrino energy, W energy should be below d-u mass difference, which must be therefore around 12.6 MeV . This is a highly valuable bit of information.

To proceed one can use p-adic mass calculations.

(a) The topological mixing of quark generations (characterized by handle number for partonic two surfaces) must make u and d quark masses almost but quite not identical in the lowest p-adic order. In the model for CKM mixing of hadronic quarks they would be identical in this order.

(b) p-Adic mass squared can be expressed as $m^2(q)/m(e)^2 = 2^{(k-127)/2}(s(q)+X(q))/(s(e)+X(e))$, where s is positive integer and and $X < 1$ is a parameter characterizing the poorly known second order contribution in p-adic mass calculations. For topologically unmixed u and d quarks one has $s(d) = 8$ and $s(u) = 5 = s(e)$. $p =\simeq 2^k$ characterizes the p-adic scale of quark (for p-adic mass calculations see [K9]).

Assume first that there is no breaking of isospin symmetry so that the p-adic mass scales of u and d type nuclear quarks are same.

(a) By using the information about the mass difference $m(d) - m(u) \leq 12.3$ MeV and the above p-adic mass squared formula one can estimate the common p-adic mass scale of the nuclear quarks to be k=113. This is nothing but the p-adic mass scale assigned with nuclei and corresponds to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$. Looks very natural!

(b) The maximal value 6.3 MeV for mass difference would be obtained for $s(d) = 8$ and $s(u) = 7$ and $X(e) = X(u) = X(d) = 0$ one obtains mass $m(d) - m(u) = 5.49$ MeV. Interestingly, figure 2 of the Reno article(see http://arxiv.org/pdf/1511.05849v2.pdf) shows a sharp downwards shoulder at 5.5 MeV.

$m(d) - m(u) = 6.3$ MeV can be reproduced accurately for $X(d)/8^{1/2} - X(u)/7^{1/2} \simeq .01$. There are several manners to reproduce the estimate for d-u mass difference by varying second order contributions. Mixing with higher quark generations would occur for both u quark. The mass of nuclear u (d) quark would be $(s(q)/5)^{1/2} \times 64$ MeV, $s(u) = 7$ ($s(d) = 8$) for $m(d) - m(u) = 5.5$ MeV. This mass is assumed to include the color magnetic energy of the color magnetic body of quark and would correspond to constituent quark mass rather than current quark mass, which is rather small.

What is interesting that the sum of the u and d quark masses $m(d) + m(u) = 144.95$ MeV in absence of topological mixing is about 4 per cent larger than the charged pion mass $m(\pi^+) = 139.57$ MeV. In any case, it is difficult to see how this large additional mass could be compensated.

In an alternative scenario, which is in accordance with the original picture, the isospin symmetry would be broken in the sense that p-adic mass scales of u and d would be different so that the mass difference would corresponds to the mass scale of (say) d quark and could be much smaller.

(a) For $k(d) = 119$, $s(d) = 10$ (small topological mixing) and $s(u) = 5$, $k(u) = 127$ (say) one would have $m(d) - m(u) = 10.8$ MeV so that neutrino energy would be below 5.4 MeV, which is near to the steep shoulder. One would have $m(d) = 11.3$ MeV and $m(u) = .5$ MeV (electron mass) in absence of topological mixing. Now $k(d) = 119$ is however not prime as the strongest form of p-adic length scale hypothesis would demands. $k(u) = 127$ is only the first guess. Also $k(u) = 137$corresponding to atomic length scale can be considered.

(b) The accepted values for hadronic current quark masses deduced from lattice calculations are about m(u)=2 MeV for m(d)=5 MeV and smaller than the values deduced above suggesting the interpretation of the masses estimate above as nuclear constituent quark masses.

(c) Beta stable configurations would correspond to $u\overline{u}$ bonds with total energy about $2m(e) = 1$ MeV, which is consistent with the general view about nuclear binding energy scale. Also exotic nuclear excitations containing charged color bonds with quark or antiquark or both transformed to d type state are predicted. The first guess for the excitation energy of charged color bond is $m(d) - m(u) \simeq 10.8$ MeV. Each charged color bond increases the nuclear charge by one unit but proton and neutron numbers remain the same as for the original nucleus: I have called these states exotic nuclei [K11].

(d) The so called leptohadron hypothesis [K22] postulates color excitations of leptons having as bound states leptopions with mass equal to $2m(e)$ in good approximation. An alternative option would replace colored leptons with quarks and assumes that unmixed u quark has electron mass and their production in heavy ion collisions would be natural if they appear as color bonds between nucleons. This would fix $s(u)$ to $s(u) = 5$ (no topological mixing).

(e) X rays from Sun have anomalous effects on the observed nuclear decay rate with a periodicity of year and with magnitude varying like inverse of the distance from the Sun with which also solar X ray intensity varies [C14](see http://tinyurl.com/y8ponx6): this is known as GSI anomaly. I have proposed earlier that the energy scale of the excitations of nuclear color bonds is 1-10 keV on basis of these findings [K11]. Nuclei could be in exited states with excitation energies in 1-10 keV range and the X ray radiation would affect the fraction of excited states thus changing also the average decay rates.

One can try to understand the keV energy scale to the 1 MeV energy scale of beta stable color bonds in terms of fractal scaling. Above it was found that for $k = 113$ charged color bond would have energy $m(d) + m(u) = 144.95$ MeV if quarks are free.

Since the actual charged pion mass is $m(\pi^+) = 139.57$ MeV, the pionic binding energy would be 5.38 MeV which makes about 3.7 per cent of the total mass. If one applies same fractal logic to the $k = 127$ color bond with $2m(u) = 1$ MeV, one obtains 37 keV, which has somewhat too high value. The Coulombic interaction is attractive between u and $\overline{u}$ in $k = 127$ pion with broken isospin symmetry. The naive perturbative estimate is as $\alpha/m_e \simeq 3.6$ keV reducing the estimate to 34.4 keV. The fact that π^+ has positive Coulombic interaction energy reduces the estimate further but this need not be enough. For $k(u) = 137$ (atomic length scale) one would obtain binding energy scale which is by factor 1/32 lower and about 1.2 keV. The simplest model for color bond would be as harmonic oscillator predicting multiples of 1.2 keV as excitation energies. This would conform with the earlier suggestion that color magnetic flux tubes are loops with size of even atom. This cold also explain the finding that the charge radius of proton is not quite what it is expected to be.

7.5 Pear-shaped Barium nucleus as evidence for large parity breaking effects in nuclear scales?

Nuclear physics anomalies continue to accumulate. Now there was a popular article (see `http://tinyurl.com/z8ocjfj`) telling about the discovery of large parity breaking in nuclear physics scale. What have been observed is pear-shaped ^{144}Ba nucleus not invariant under spatial reflection. The arXiv article [C26] (see `http://arxiv.org/pdf/1602.01485v1.pdf`) speaks only about octupole moment of ^{144}Ba nucleus difficult to explain using the existing models. Therefore one must take the popular article managing to associate the impossibility of time travel to the unexpectedly large octupole moment with some caution. As a matter fact, pear-shapedness has been reported earlier for Radon-220 and Radium-224 nuclei by ISOLDE collaboration working at CERN [C21] (see `http://tinyurl.com/zmau4zd` an¿ and `http://tinyurl.com/jn6k2pk`).

The popular article could have been formulated without any reference to time travel: the finding could be spectacular even without mentioning the time travel. There are three basic discrete symmetries: C,P, T and their combinations. CPT is belived to be unbroken but C,P, CP and T are known to be broken in particle physics. In hadron and nuclear physics scales the breaking of parity symmetry P should be very small since weak bosons break it and define so short scaled interaction: this breaking has been observed.

The possible big news is following: pear-shaped state of heavy nucleus suggests that the breaking of P in nuclear physics is (much?) stronger than expected. With parity breaking one would expect ellipsoid with vanishing octupole moment but with non-vanishing quadrupole moment. This suggests parity breaking in unexpectedly long length scale. This is not possible in standard model, where parity breaking is larger only in weak scale which is roughly 1/1000 of nuclear scale and fourth power of this factor reduces the weak parity breaking effects in nuclear scale.

Does this finding force to forget the plans for the next summer's time travel? If parity breaking is large, one expect s from the conservation of CPT also large compensating breaking of CT breaking. This might relate to the matter-antimatter asymmetry of the observed Universe but I cannot relate it to time travel since the very idea of time travel in its standard form does not make much much sense to me.

In TGD framework one can imagine two explanations involving large parity breaking in unexpectedly long scales. In fact, in living matter chiral selection represents mysteriously large parity breaking effect and the proposed mechanisms could be behind it.

(a) In terms of p-adically scaled down variants of weak bosons having much smaller masses and thus longer Compton length - of the order of nuclear size scale - than the ordinary weak bosons have. After this phase transition weak interaction in nuclear scale would not be weak anymore.

(b) In terms of dark state of nucleus involving magnetic flux tubes with large hbar carrying ordinary weak bosons but with scaled up Compton length (proportional to $h_{eff}/h = n$)

of order nuclear size. Also this phase transition would make weak interactions in nuclear scale much stronger.

There is a connection with X boson anomaly [L16] (see http://tgdtheory.fi/public_html/articles/Xboson.pdf). The model for the recently reported X boson involves both options but 1) is perhaps more elegant and suggests that weak bosons have scaled down variants even in hadronic scales: the prediction is unexpectedly large parity breaking. This is amusing: large parity breaking in nuclear scales for three decades ago one of the big problems of TGD and now it might have been verified!

8 X boson as evidence for nuclear string model

Anomalies seem to be popping up everywhere, also in nuclear physics and I have been busily explaining them in the framework provided by TGD. The latest nuclear physics anomaly that I have encountered (see http://tinyurl.com/zlvngnv) was discovered in Hungarian physics laboratory in the decays of the excited state ^{8}Be* of an unstable isotope of ^{8}Be (4 protons and 4 neutrons) to ground state ^{8}Be [L16, C20] (see http://arxiv.org/abs/1604.07411). For the theoretical interpretation of the finding in terms of fifth force see [C20] (see http://arxiv.org/abs/1604.07411) mediated by spin 1 X boson.

The anomaly manifests itself as a bump in the distribution of e^+e^- pairs in the transitions ^{8}Be*→ ^{8}Be at certain angle (140 degrees) between electrons. The interpretation is in terms of a production of spin 1 boson - christened as X - identified as a carrier of fifth force with range about 12 fm, nuclear length scale. The attribute 6.8σ - if taken seriously - tells that the probably that the finding is statistical fluctuation is about 10^{-12}: already 5 sigma is regarded as a criterion for discovery.

The assumption about vector boson character looks at first well-motivated: the experimental constraints for the rate to gamma pairs are believed to eliminate the interpretation as pseudo-scalar boson whereas spin 1 bosons do not have these decays. In the standard reductionistic spirit it is assumed that X couples to p and n and the coupling is sum for direct couplings to u and d quarks making proton and neutron. The comparison with the experimental constraints forces the coupling to proton to be very small: this is called protophoby. Perhaps it signifies something that many of the exotic particles introduced to explain some bump during last years are assumed to suffer various kinds of phobies. The assumption that X couples directly to quarks and therefore to nucleons is of course well-motivated in standard nuclear physics framework relying on reductionism.

TGD inspired interpretation based on nuclear string model [K11] is different. The mass of the state is within .7 accuracy pion mass scaled down to nuclear p-adic scale characterized by p-adic prime $p \simeq 2^k$, $k = 113$. Scaled down pion in $l = 1$ state is possible and allows to p-adically scale the decay rates to gamma pair and e^+e^- pair from those of pion. The pleasant surprise was that the scaled $\Gamma(\pi, \gamma\gamma)$ turned out to be consistent with the experimental bounds reported in [C20].

There is however a problem: the estimate for $\Gamma(\pi, e^+e^-)$ obtained by p-adically scaling the model based on decay virtual gamma pair decaying to e^+e^- pair [C15] is by a factor 1/88 too low. One can consider the possibility that the dependence of f_π on p-adic length scale is not the naively expected one but this is not an attractive option. The increase of Planck constant seems to worsen the situation.

The dark variants of weak bosons appear in important role in both cold fusion and TGD inspired model for chiral selection. They are effectively massless below the scaled up Compton scale of weak bosons so that weak interactions become strong. Since pion couples to axial current, the decay to e^+e^- could proceed via annihilation to Z^0 boson decay to e^+e^- pair. The estimate for $\Gamma(\pi(113), e^+e^-)$ is in the middle of the allowed range. The same model explains also the decay width of the ordinary pion and a generalization of the model to all semileptonic decays of hadrons is highly suggestive and would explain the somewhat mysterious origin of CVC and PCAC [B1].

The model is also formulated in terms of nuclear string model. In particular, the mechanism for the decay as snipping of closed pionic flux loop from a colored flux tube connecting nucleus is discussed briefly. A possible manner to measure the value of h_{eff} emerges as a by-product. By measuring lifetime and decay width independently, one can deduce the value of h_{eff}/h predicted to be integer valued as $h_{eff}/h = \tau\Gamma/\hbar$. This essentially verifying of scaled up variant of Uncertainty Principle.

8.1 Two observations and a possible puzzle generated by them

What could TGD say about the situation? First two observations and the puzzle created by them.

(a) The first observation is that 12 fm range corresponds rather precisely to p-adic length scale for prime $p \simeq 2^k$, $k = 113$ assigned to the space-time sheets of atomic nuclei in TGD framework. The estimate comes from $L(k) = 2^{(k-151)/2}L(151)$, $L(151) \simeq 10$ nm. To be precise, this scale is actually the p-adic Compton length of electron if it where characterized by k instead of $k_0 = 127$ labelling the largest not super-astrophysical Mersenne prime. $k = 113$ is very special: it labels Gaussian Mersenne prime $(1+i)^k - 1$ and also muonic space-time sheet.

(b) A related observation made few days later is that the p-adic scaling of the ordinary neutral pion mass 135 MeV from $k = 107$ to $k = 113$ by $2^{-(113-107)/2} = 1/8$ gives 16.88 MeV! That p-adic length scale hypothesis would predict the mass of X with .7 per cent accuracy for nominal value $m(X) = 17$ MeV is hardly an accident. Note that the measured value is $16.7 \pm .35(stat) \pm .5(sys)$ MeV. This would strongly suggest that X boson is $k = 113$ pion.

(c) There is however a potential problem. The decays to photon pairs producing pion in $l = 1$ partial wave have not been observed. Authors conclude that spin 1 particle is in question. If X is ρ meson like state with spin 1, why it should have same mass as pionic X? This is not plausible.

It turns out that I was too easily gullible! The decay width $\Gamma(\pi(113), \gamma\gamma)$ estimated by scaling from the decay width for ordinary pion is actually consistent with the experimental bound! The decay width $\Gamma(\pi(113), \gamma\gamma)$ is however problematic and suggests that non-standard value of h_{eff} is involved.

8.2 The estimate for $\Gamma(\pi(113), \gamma\gamma)$ is consistent with the limits on $\Gamma(X, \gamma\gamma)$

The estimate for the decay rate $\Gamma(\pi(113), \gamma\gamma)$ is easy to obtain by using effective action determined by PCAC hypothesis.

(a) The effective action defined by the "instanton density" for Maxwell field is given by

$$g_{X\gamma\gamma}F^{\mu\nu}\tilde{F}_{\mu\nu} \quad , \tag{8.1}$$

where $\tilde{F}$ is the dual of F. $g_{\pi\gamma\gamma}$ is given by

$$g_{\pi\gamma\gamma} = \frac{\alpha}{\pi f_\pi} \quad . \tag{8.2}$$

$f_\pi = 93$ MeV characterizes the matrix elements of SU(2) axial currents between vacuum and 1 pion state and it scales like pion mass.

The direct dependence of $g_{\pi\gamma\gamma}$ and implicit dependence of f_π on α and α_s determines the value of $\Gamma(\pi, \gamma\gamma)$. All vertices of tree diagrams containing coupling constant give rise to a coefficient g^2/m having identification as charge radius not affected in the scaling $h \rightarrow h_{eff}$.

(a) One motivation for the introduction of hierarchy of Planck constants is that the scaled up h_{eff} allows perturbative approach since one has $\alpha_k \rightarrow \alpha_k/n$. This argument makes sense in QFT context. If one can approximate the amplitude as box diagram with fermionic exchange with photons at the upper vertices and gluon exchange associated with the lower vertices, the dependence on $1/h_{eff}$ would come from α_s. α proportionality would boil down to the proportionality from the square of charge radius $r_s = e^2/4\pi m_\pi$ or of its analog $r_s = e^2/4\pi f_\pi$.

(b) An objection emerges from the vision that all scattering diagrams in TGD framework for given p-adic length scale and given value of h_{eff} can be transformed to tree diagrams at topological level [K25]: scattering diagrams would be analogous to computations and could be always reduced to those involving no loops. Coupling constant evolution would reduce to p-adic coupling constant evolution. Also the functional integral using exponent of Kähler as weighting would reduce to tree diagrams. This picture is strongly favoured by number theoretical vision. If this is the case, there are no topological loops in the minimal representation for diagrams and the there is no dependence on coupling strengths $\alpha_k = g_k^2/4\pi h_{eff}$ but only on classical charge radii $r_s m$, $r_s = g_k^2/4\pi m$ of particles appearing in the vertices of tree diagrams.

If loops are not present, the quark pair wave function of pion state should give rise to dependence on α_k and thus on h_{eff}. Radiative corrections would be localizable to the positive and negative energy parts of zero energy states at the boundaries of causal diamond (CD). Pion decay could be seen as $q\overline{q} \rightarrow \gamma\gamma$ scattering by quark exchange for quarks in bound state determined by color force. The dependence on $1/h_{eff}$ would come from the dependence of quark-antiquark wave function on α_s and would be analogous to $|\Psi(0)|^2$ proportionality in the case of positronium. In $\Gamma(\pi, \gamma\gamma)$ h_{eff} dependence could be localized to the dependence of $1/f_\pi^2$ on α_k and should increase/reduce the rate by reducing/increasing f_π^2. It must be emphasized that also the dependent on p-adic scale could be of from $f_\pi \propto 1/L(k)^n$, $n \neq 1$ as expected, and for $n > 1$ increase the scattering rate.

Consider now the detailed formula for the decay width $\Gamma(\pi, \gamma\gamma)$ [B1].

(a) The formula for the gamma decay width of ordinary pion can be written as

$$\Gamma(\pi, \gamma\gamma) = \frac{1}{2^6\pi^3}\frac{m_\pi^2}{f_\pi^2}(r_\pi m_\pi)^2 m_\pi \quad , \quad r_\pi = \frac{e^2}{4\pi m_\pi} \quad . \tag{8.3}$$

In this expression the only h_{eff}-dependence is contained by f_π. Using units $\hbar = 1, c = 1$ one would have apparent α^2 $(1/\hbar^2)$ dependence. One has $\Gamma(\pi) = 7.63$ eV whereas the experimental value is $\Gamma^{exp} = (7.37 \pm 1.5)$ eV. The radiative corrections are assumed to be possible only for the initial and final state wave functions in the case of bound states.

(b) According to [C20] all values of $1/g_{\pi\gamma\gamma}$ outside the range [.1 GeV,10^{18} GeV] have been excluded. This translates to the allowed range [.2 MeV, 2.3×10^{15} GeV] implying $f_\pi \geq .2$ MeV. The p-adically scaled down value of $f_{\pi(113)} = f_\pi/8 = f_\pi/8 = 11$ MeV is inside the allowed range.

(c) f_π depends on non-perturbative aspects of QCD and therefore on α_s and n in non-trivial manner. One might of course hope that the large value of h_{eff} makes the situation perturbative and that the dependence is simple. This could mean that f_π scales like m_π. In absence of h_{eff} dependence the scaling from the pion decay width would give $\Gamma(\pi(113)) = \Gamma(\pi)/8 = .95$ eV. Scaling down of f_π by a factor 55 is allowed by the experimental limits and there is no limit on scaling up. Contrary to the expectations inspired by [C20] $\Gamma(\pi, \gamma\gamma)$ does not exclude the identification of X as pion like state.

8.3 Model for $\Gamma(\pi(113), e^+e^-)$

The following considerations show that the generalization of the standard model for $\Gamma(\pi, e^+e^-)$ predicts too small production rate for $\Gamma(\pi(113), e^+e^-)$. The modification based on the assumption that either p-adically scaled down weak bosons or their dark variants are possible and color magnetic flux tubes allows to understand $\Gamma(\pi(113), e^+e^-)$ and leads to a radical proposal that dark or p-adically scaled up variants of weak physics are involved also with the semileptonic decays of hadrons so that the prevailing picture would be wrong.

8.3.1 The standard model prediction for $\Gamma(\pi(113), e^+e^-)$ is not consistent with the experimental limits

The estimate of [C20] for the decay width of $\Gamma(X, e^+e^-)$ (Eq. (6) of the article) of *spin* 1 X boson is of the form

$$\Gamma(X, e^+e^-) = \epsilon_e^2 \frac{\alpha}{3}(1 + 2\frac{m_e^2}{m_X^2}) \times m_X \quad . \tag{8.4}$$

The estimate of the authors for the range of allowed values of ϵ is $[2 \times 10^{-4}, 1.4 \times 10^{-3}]$. The rate would vary in the range $[2.3 \times 10^{-3}, 0.1]$ eV. A weaker lower bound for ϵ is 1.3×10^{-5} giving lower bound for decay width as 1.5×10^{-4} eV. The optimistic guess is that these bounds apply to pseudoscalar X.

The observed e^+e^- branching fraction for the ordinary pion is about $B(\pi, e^+e^-) = 7.5 \times 10^{-8}$ (see `http://arxiv.org/pdf/0704.3498.pdf`) giving the estimate $\Gamma(\pi, e^+e^-) \simeq 5.6 \times 10^{-7}$ eV. The challenge is to scale up this rate for $\pi(113)$. This requires a model for $\Gamma(\pi, e^+e^-)$.

In [C15] $\Gamma(\pi, e^+e^-)$ (see `http://arxiv.org/pdf/0704.3498.pdf`) is estimated as a loop correction by assuming that the decay proceeds via annihilation to virtual gamma pair decaying to electron pair by electron exchange. The reason is that there is no spinless current coupling to quarks and leptons directly (leptoquarks as carriers of this current have been considered). The estimate involves uncertainties since the form factor $F_{\pi\gamma*\gamma*}$ is not well-known off-mass-shell and must be modelled.

(a) The general expression for the ratio of branching ratios to $B(\pi, e^+e^-)$ and $B(\pi, \gamma\gamma)$ reads as

$$\begin{aligned} R(\pi, e^+e^-) &\equiv \frac{B(\pi, e^+e^-)}{B(\pi, \gamma\gamma)} = 2(\frac{\alpha}{\pi}\frac{m_e}{m_\pi})^2 \beta_e(q^2)|A(m_\pi^2)|^2 \quad , \\ \beta_e(q^2) &= \sqrt{1 - \frac{4m_e^2}{q^2}} \quad . \end{aligned} \tag{8.5}$$

$\beta_e(m_\pi^2)$ is the relativistic velocity of electron. The strongest dependence of the branching ratio on pion mass is contained by the suppression factor $x = (\alpha/\pi)^2(m_e/m_\pi)^2$ coming from approximate helicity conservation (the helicities of electron and positron are parallel at massless limit where as the spin of pion vanishes). The dependence of A on mass ratios is logarithmic.

(b) The general expression for A is as a loop integral with pion form factor defining the vertex.

$$\begin{aligned} A(q^2) &= \frac{2i}{q^2}\int \frac{d^4k}{\pi^2} \frac{q^2k^2 - (q \cdot k)^2}{D(k^2)D((k-q)^2)D_e((k-p)^2)} F_{\pi\gamma*\gamma*}(-k^2 - (k-q)^2) \quad , \\ D(k^2) &= k^2 + i\epsilon \quad , D_e(k^2) = k^2 - m_e^2 + i\epsilon \quad . \end{aligned} \tag{8.6}$$

To calculate the integral one must continue $F_{\pi\gamma*\gamma*}$ for all values of its arguments and this requires modelling.

(c) The approximate outcome of the calculations of [C15] is

$$\begin{aligned} Im(A(q^2)) &= \frac{\pi}{2\beta_e(q^2)} log(y_e(q^2)) \ , \ y_e = \frac{1-\beta_e}{1+\beta_e} \ , \\ Re(A(q^2)) &= A(q^2=0) + \frac{a^2}{\pi}\int_0^\infty ds \frac{Im(A)(s)}{s(s-q^2)} \ . \end{aligned} \tag{8.7}$$

The real part of the loop integral diverges logarithmically and $A(m\pi^2)$ is obtained from a once subtracted dispersion relation. $A(q^2=0)$ contains the unkown dynamics and is outcome of the regularization procedure. One obtains approximate expression for $Re(A)$ as

$$Re(A(q^2)) = A(q^2=0) + \frac{1}{\beta(q^2)}\left[\frac{1}{4}\log^2(y_e(q^2)) + \frac{\pi^2}{2} + Li_2(-y_e(q^2))\right] \tag{8.8}$$

Here $Li_2(z) = \int_0^z (dt/t) log(1-t)$ is dilogarith function. In good approximation one has

$$Re(A(m_{pi}^2)) = A(q^2=0) + log^2(\frac{m_e}{m_\pi}) + \frac{\pi^2}{2} \ . \tag{8.9}$$

(d) For $A(q^2=0)$ containing the dynamics authors consider the parameterization

$$\begin{aligned} A(q^2=0) &= -\frac{3}{2} log(\frac{s^1}{m_e^2} = -23.2 \pm 1 \ . \\ s^1 &= (776 \pm 22 \ \ MeV)^2 \ . \end{aligned} \tag{8.10}$$

s^1 is essentially ρ meson mass squared. The value of the dispersion integral depends on the choice of cutoff fixing the value of the loop amplitude for zero momentum transer $q^2=0$ and ρ meson mass plays the role of the cutoff - this has also physical motivation coming from vector meson dominance.

(e) The prediction is $B(\pi, e^+e^-) = (6.23 \pm .09) \times 10^{-8}$ whereas the experimental value is $B(\pi, e^+e^-) = (7.49 \pm 0.29 \pm 0.25) \times 10^{-8}$. The result is rather satisfactory. Authors can reproduce the observed branching ratio by replacement $m(\rho), m(\rho/2$ but this leads to other problems.

What happens when ordinary pion is replaced with $\pi(113)$?

(a) The suppression factor $x = (\alpha/\pi)^2(m_e/m_\pi)^2$ is scaled up by 64 if h_{eff} is not changed. A depends logarithmically on mass ratios and is not affected much as one finds by checking what happens to the terms contributing the expression of $|A|^2$: one obtains scaling down by a factor .35. If the pion decay rate scales as p-adic mass scale, one has in reasonable approximation $64 \times 7.5/8$-fold scaling giving $\Gamma(\pi(113), e^+e^-) \simeq 60 \times \times .35 \times \Gamma(\pi, e^+e^-) \simeq .17 \times 10^{-5}$ eV. The experimental lower bound is 1.5×10^{-4}, which is 88 times higher than the estimate.

(b) This is a real problem and unless one is ready to consider exotic particles such as lepto-quark like states, the only solution seems to be that $F^2_{\pi\gamma*\gamma*}$ is scaled up by factor of order 30. This requires a reduction of f_π^2 by factor 1/88. As found, the limit on $\Gamma(X, \gamma\gamma)$ allows downwards scaling of f_π^2 by a factor about 1/55 so that it is marginally possible to satisfy the experimental bounds on both decay widths. Scaling by factor $n^2 = 64$ might save the situation.

(c) What the increase of $F^2_{\pi\gamma*\gamma*}$ means is not quite clear. The analogy with positronium decay would suggest that the of $|\Psi(0)|^2$ at the origin of quark-antiquark relative coordinate is enhanced by a factor order 30. The scaling up of the size of the color flux tube does not support this view.

The increase of $F^2_{\pi\gamma*\gamma*}$ could also come from the reduction of axial coupling strength f_π allowing interpretation in terms of the reduction of $|\Psi(0)|^2$ at the origin of the relative coordinate: quarks tend to be father away since p-adic length scale is longer. This might bring additional power of 8.

(d) It would seem that the scaling of Planck constant does not work for the model based virtual gamma pair. The presence of α^2 in loop correction would in fact imply scaling down of $\Gamma(\pi, e^+e^-)$ by factor $1/n^2$ so that the scaling up of $1/f_\pi^2$ should compensate also this reduction: scaling by n^4 coming from α_s^4 proportionality of f_π^2 could do the job.

8.3.2 Could dark or p-adically scaled down weak bosons help?

In TGD framework one can criticize the model involving loop integral. If loops can be eliminated both topologically and at the level of Kähler action, they can be present only in QFT description, and one might argue that loopless description should be possible if the problem reduces to the level of single space-time sheet [K25]. If loops and radiative corrections appear at all, they do so only in the positive and negative parts of zero energy states but not in diagrams ad pion could contain also gamma pairs and electron pairs as contributions. This would end up with the virtual particle cloud picture. The most elegant description of course involves no loops at all and it seems that it is possible to achieve this by introducing dark or p-adically scaled down weak bosons.

If one does not accept loops then one must consider a loopless mechanism.

(a) I have proposed dark weak bosons to be involved with both cold fusion and chiral selection in living matter [L11, L10, L12]. Since pion couples to axial current, it is natural ask whether dark weak boson Z^0 coupling to axial current could be involved.

For ordinary weak boson the amplitude would be of course extremely small since it is proportional to $1/m_Z^2$. If weak bosons are dark at $k = 113$ color magnetic flux tubes, the range of weak interactions is scaled up and weak boson becomes effectively massless within dark Compton scale. This would make weak interaction long ranged and make possible the decay of pion via Z^0 annihilation of quark pair to dark Z^0 annihilating to electron pair. Z^0 propagator would be replaced with massless propagator at virtual mass squared given by the mass of dark pion and the rate would be scaled up by factor $m_Z^4/m^4_{\pi(113)} \simeq 0.7 \times 10^{15}$.

(b) $\pi(113) - Z$ coupling $f_{\pi(113)Z}$ is analogous to vector-boson-photon coupling $f_{V\gamma}$ of vector boson dominance model. $f_{\pi(113)Z}$ can be identified as the the coupling $f_{\pi(113)Z} = f_\pi m_\pi$ of $\pi(113)$ to axial current [B1]. The order of magnitude for $\Gamma(\pi(113), e^+e^-)$ is given by the usual Feynman rules giving single particle decay rate, and one obtains (I hope that the numerical factors are correct!)

$$\Gamma(\pi, e^+e^-) = \frac{1}{8\pi}\frac{m_e^2}{m_\pi^2}\frac{f_\pi^2}{m_\pi^2}(1 - \frac{4m_e^2}{m_\pi^2} \times m_\pi) \ . \quad (8.11)$$

The estimate gives $\Gamma(\pi, e^+e^-) = .93$ eV, which is reasonably near to the experimental upper bound .1 eV.

One must of course be very cautious here. It could also be that p-adically scaled up variant of weak physics with standard value of Planck constant is involved and the weak bosons involved have p-adically scaled down mass scale. I have also proposed [K13] that in living matter a kind of resonant coupling between dark physics ($h_{eff} = n \times h$) and p-adically scaled up non-dark physics exists for $L(k, h_{eff}) = nL(k) = L(k_1)$ requiring $2^{(k-k_1)/2} = n$. Scaled dark particles would transform to ordinary p-adically scaled particles and vice versa.

8.3.3 Could dark electro-weak physics manifest itself in ordinary hadron physics?

Could also ordinary pion decay be understood in terms of the same mechanism? Now the p-adic length scale of pion would be $k = 107$. One would have $\Gamma(\pi(113), e^+e^-) = 2^9\Gamma(\pi(107), e^+e^-)$: the power of two comes from $m_{\pi(113)}^{-3}$ proportionallity of the rate. Using $\Gamma(\pi(107), e^+e^-) = .55 \times 10^{-6}$ eV one obtains the prediction $\Gamma(\pi(113), e^+e^-) = 2.8 \times 10^{-4}$ eV. This is an order of magnitude below the range $[2.3 \times 10^{-3}, 0.1]$ eV of the allowed values deduced in [C20]. The estimate is however above the general experimental lower bound 1.5×10^{-4} eV.

Could the p-adic scaling down with ordinary value of Planck constant work better? The propagator factor would be $1/(m_Z^2(k) - m_{\pi(113)}^2)^2$ and if the two masses are near to each other, could increase the rate by resonance factor

$$r = \frac{m_{\pi(113)}^4}{\left[m_Z^2(k) - m_{\pi(113)}^2\right]^2} = \left[\frac{1}{(\frac{m_Z(k)}{m_{\pi(113)}})^2 - 1}\right]^2 . \tag{8.12}$$

From $m_Z/m_Z(k) = 2^{(k-89)/2} \sim (91/17) \times 10^3$ one obtains the estimate $k - 89 \in \{24, 25\}$ giving $k \in \{113, 114\}$.

(a) For $k = 113$ - nuclear scale (!) - the value of the resonance factor would be $r = 1.6$ giving $\Gamma(\pi(113), e^+e^-) = 4.5 \times 10^{-4}$ eV still by factor .16 smaller than the lower bound of authors. The improvement would not be large.

(b) For $k = 114$ the resonance factor would be 91.5 giving the estimate $\Gamma(\pi(113), e^+e^-) = .04$ eV belonging to the middle of the range of allowed values. Assuming that there are no numerical errors involved, the best option is $k = 114$ p-adically scaled up Z^0 boson.

This amazing finding forces to ask whether the prevailing picture about leptonic pion decays of hadrons is really correct.

(a) The basic motivation for large $h_{eff} = n \times h$ hypothesis was that it makes perturbation theory possible. Strong interactions at low energies provide a key example of the situation in which this hypothesis could be useful.

(b) The number theoretic vision that all scattering processes are describable using only tree diagrams in TGD framework [K25] suggests that the descriptions involving loops should have duals involving no loops and be based on couplings of mesons to dark weak bosons. A possible test is provided by the box diagrams associated with CP breaking for kaons and B mesons.

(c) Could it be that dark weak interactions at length scale $k = 107$ are responsible for hadronic decays to leptons? Could also vector meson dominance be formulated in terms of dark weak currents? This would explain why the symmetries group $SU(2)_L \times SU(2)_R$ of low energy hadron physics is very much like weak gauge group and conserved vector current (CVC) hypothesis and partially conserved vector current (PCAC) hypothesis.

(d) This picture would be also consistent with the $M^8 - H$ duality [K19] explaining why $SU(2)_L \times SU(2)_R$ for hadrons and SU(3) for partons provide dual descriptions. The identification of mesons as string like objects conforms with the description of hadronic reactions provided by hadronic string model and the couplings of various mesons to electroweak currents would allow to describe the hadronic weak decays. The scaled down variant of this description would apply to nuclear reactions. What is nice that this proposal is testable.

8.4 Model based on nuclear strings

One should construct a model for color bonds connecting nucleons to form nuclear strings.

(a) In nuclear string model [K11] nuclei are identified as nuclear strings with nucleons connected by color flux tubes, which can be neutral or charged and can have net color so that color confinement would be in question in nuclear length scale. The possibility of charged color flux tubes predicts the existence of exotic nuclei with some neutrons replaced by proton plus negatively charged color flux tube looking like neuron from the point of view of chemistry or some protons replaced with neutron plus positively charged flux tube. Nuclear excitation with energy determined buy the difference of initial and final color bond energies is in question.

(b) The color magnetic flux tubes are analogous to mesons of hadron physics except that they can be colored and are naturally pseudo-scalars in the ground state. These pion like colored flux tube can be excited to a colored state analogous to ρ meson with spin 1 and net color. Color bonds would be rather long flux loops with size scale determined by the mass scale of color bond: 17 MeV gives estimate which as electron Compton length divided by 34 and would correspond to p-adic length scale $k = 121 > 113$ so that length would be about $2^{(121-113)/2} = 16$ times longer than nuclear length scale.

(c) If the color bonds (cb) are indeed colored, the mass ratio $m(\rho, cb)/m(\pi, cb)$ need not be equal to $m(\rho, 107)/m(\pi, 107) = 5.74$. If the ρ and π type closed string states are closed string like objects in the sense as elementary particles are so that there is a closed magnetic monopole flux tube along first sheet going through wormhole contact to another space-time sheet and returning back, the scaling $m(\rho/\pi, 107)/m(\rho/\pi, 113) = 8$ should hold true.

With these ingredients one can construct a model for the decay ^{8}Be* $\rightarrow$ ^{8}Be $+X$.

(a) ^{8}Be* could correspond to a state for which pionic color(ed) bond is excited to ρ type color(ed) bond. The decay of ^{8}Be* $\rightarrow$ ^{8}Be $+X$ would mean a snipping of a color singlet π meson type *closed* flux tube from the color bond and leaving pion type color bond. The reaction would be analogous to an emission of closed string from open string. $m(X) = 17$ MeV would be the mass of the color-singled closed string emitted equal to $m(\pi, 113) = 17$ MeV. The emitted π would be in $l = 1$ partial wave so that resonant decay to gamma pair would not occur but decay to e^+e^- pairs is possible just like for the ordinary pion.

(b) Energy conservation suggests the identification of the excitation energy of ^{8}Be* as the mass difference of ρ and π type colored bonds (cb): $E_{ex}(^8Be*) = m(\rho, cb) - m(\pi, cb) = m(\pi, 113) = 17$ MeV in the approximation that X is created at rest. If one has $m(\rho, cb)/m(\pi, cb) = m(\rho)/m(\pi)$ - this is not necessary - this gives $m(\rho, cb) \simeq 20.6$ MeV and $m(\pi, cb) \simeq 3.5$ MeV.

(c) This estimate is based on mass differences and says nothing about nuclear binding energy. If the color bonds carry positive energy, the binding energy should be localizable to the interaction of quarks at the ends of color bonds with nucleons. The model clearly assumes that the dynamics of color bonds separates from the dynamics of nuclei in the case of the anomaly.

(d) The assumption about direct coupling of X to quarks and therefore to nucleons does not makes sense in this framework. Hence protophoby does not hold true in TGD and this is due to the presence of long color bonds in nuclear strings. Also the spin 1 assignment of [C20] would be wrong. Also the vector boson character would be wrong assumption since pion property allows to obtain gamma decay rate consistent with the experimental limits.

8.5 Conclusion

To conclude, the proposed new nuclear physics is physics of the magnetic body of nucleus and involves hierarchy of Planck constants in an essential manner, and the proposed solution to the too low decay rate $\Gamma(\pi(113), e^+e^-)$ could turn out to provide a direct experimental proof for the hierarchy of Planck constants. It also suggests a new approach to the leptonic decays of hadrons based on dark or p-adically scaled down variants of weak interactions. The proposal for the explanation of the anomaly in charge radius of proton involves physics of the magnetic body of proton [K10]. TGD inspired quantum biology is to high degree quantum physics of magnetic body. Maybe the physics of magnetic body differentiates to its own branch of physics someday.

9 Cold Fusion, Plasma Electrolysis, Biological Transmutations,And Burning Salt Water

The article of Kanarev and Mizuno [D10] reports findings supporting the occurrence of cold fusion in NaOH and KOH hydrolysis. The situation is different from standard cold fusion where heavy water D_2O is used instead of H_2O.

One can understand the cold fusion reactions reported by Mizuno as nuclear reactions in which part of what I call dark proton string having negatively charged color bonds (essentially a zoomed up variant of ordinary nucleus with large Planck constant) suffers a phase transition to ordinary matter and experiences ordinary strong interactions with the nuclei at the catode. In the simplest model the final state would contain only ordinary nuclear matter. The generation of plasma in plasma electrolysis can be seen as a process analogous to the positive feedback loop in ordinary nuclear reactions.

Rather encouragingly, the model allows to understand also deuterium cold fusion and leads to a solution of several other anomalies.

(a) The so called lithium problem of cosmology (the observed abundance of lithium is by a factor 2.5 lower than predicted by standard cosmology [E4]) can be resolved if lithium nuclei transform partially to dark lithium nuclei.

(b) The so called $H_{1.5}O$ anomaly of water [D12, D9, D14, D8] can be understood if 1/4 of protons of water forms dark lithium nuclei or heavier dark nuclei formed as sequences of these just as ordinary nuclei are constructed as sequences of ^4He and lighter nuclei in nuclear string model. The results force to consider the possibility that nuclear isotopes unstable as ordinary matter can be stable dark matter.

(c) The mysterious behavior burning salt water [D1] can be also understood in the same framework.

(d) The model explains the nuclear transmutations observed in Kanarev's plasma electrolysis. Intriguingly, several biologically important ions belong to the reaction products in the case of NaOH electrolysis. This raises the question whether cold nuclear reactions occur in living matter and are responsible for generation of biologically most important ions.

9.1 The Data

9.1.1 Findings of Kanarev

Kanarev has found that the volume of produced H_2 and O_2 gases is much larger than the volume resulting in the electrolysis of the water used in the process. If one knows the values of p and T one can estimate the volumes of H_2 and O_2 using the equation of state $V = nT/p$ of ideal gas. This gives

$$V(H_2; p, T) = \frac{A(H_2)}{A(H_2O)} \times \frac{M(H_20)}{m_p} = \frac{1}{9}\frac{M(H_20)}{m_p} \times \frac{T}{p} \quad .$$

Here $M(H_20)$ is the total mass of the water (.272 kg for KOH and.445 kg for NaOH).

Table 10: The weight of water used in the electrolysis and the total volume of gas produced for KOH and NaOH electrolysis. $r(gas)$ denotes the naive prediction for the total volume of gas per water volume appearing in previous table. For KOH *resp.* NaOH the volume ratio $[V(gas)/V(H_2O)]$ is by a factor $r = 17.4$ *resp.* $r = 15.2$ higher than the naive estimate.

	$M(H_2O)/kg$	$V(gas)/m^3$	$\frac{V(gas)}{V(H_2O)}$	$\frac{[V(gas)/V(H_2O)]}{r(gas)}$
KOH	.272	8.75	3.2×10^4	17.4
NaOH	.445	12.66	2.8×10^4	15.2

Table 11: The per cent of various nuclei in catode for KOH and NaOH electrolysis.

KOH				
Element(Z, N)	Al(13, 27)	Si(14, 28)	Cl(17, 18)	K(19, 20)
		0.94		4.50
Element(Z, N)	Ca(20, 20)	Cr(24, 28))	Fe(26, 29)	Cu(29, 34)
		1.90	93.0	0.45
NaOH				
Element(Z, N)	Al(13, 27)	Si(14, 28)	Cl(17, 18)	K(19, 20)
	1.10	0.55	0.20	0.60
Element(Z, N)	Ca(20, 20)	Cr(24, 28))	Fe(26, 29)	Cu(29, 34)
	0.40	1.60	94.0	0.65

In the situation considered one should be able to produce from one liter of water 1220 liters of hydrogen and 622 liters of oxygen giving

$$V(H_2)/V(H_2O) = 1.220 \times 10^3 \ , \qquad V(O_2)/V(H_2O) = .622 \times 10^3 \ ,$$

$$r(gas) = V(H_2 + O_2)/V(H_2O) = 1.844 \times 10^3 \ , \quad V(H_2)/V(O_2)) \simeq 1.96 \ .$$

$V(H_2)/V(O_2) \simeq 1.96$ is 4 per cent smaller than the prediction $V(H_2)/V(O_2) = 2$ of the ideal gas approximation.

The volumes of O_2 and H_2 are not reported separately. The table gives the total volumes of gas produced and ratios to the volume of water used.

9.1.2 Findings of Mizuno

Mizuno in turn found that the Fe catode contains Si, K, Cr, Fe, Cu for both KOH and NaOH electrolysis and in case of NaOH also Al, Sl, Ca. The fraction of these nuclei is of order one per cent. **Table 11** gives the fractions for both KOH and NaOH.

The results supports the view that nuclear reactions involving new nuclear physics are involved and that part of H_2 and O_2 could be produced by nuclear reactions at the catode.

(a) For Si, K, Cr, Fe, and Cu the mechanism could be common for both $NaOH$ and KOH electrolysis and presumably involve fission of Fe nuclei. The percent of K in KOH is considerably larger than in $NaOH$ case and this is presumably due to the absorption of K^+ ions by the catode.

(b) For Al, Si, and Ca the reaction occurring only for Na should involve Na ions absorbed by the catode and suffering cold fusion with some particles -call them just X - to be identified.

(c) Cu is the only element heavier than Fe and is expected to be produced by fusion with X. Quite generally, the fractions are of order one per cent.

(d) The authors suggests that the extra volume of H_2 and O_2 molecules is due to nuclear reactions in the catode. A test for this hypothesis would be the ratio of H_2 and O_2 volumes. Large deviation from value 2 would support the hypothesis. The value near 2 would in turn support the hypothesis that the water produced by electrolysis is considerably denser than ordinary water.

9.2 $H_{1.5}O$ Anomaly And Nuclear String Model

It would seem that some exotic nuclei, perhaps consisting of protons, should be involved with the cold fusion. Concerning the identification of these exotic particles there are several guidelines. $H_{1.5}O$ anomaly, anomalous production of e^+e^- pairs in heavy ion collisions, and nuclear string model.

9.2.1 $H_{1.5}O$ anomaly and anomalous production of electron-positron pairs in heavy ion collisions

There exists an anomaly which could be explained in terms of long open nuclear strings. The explanation of $H_{1,5}O$ anomaly [D12, D9, D14, D8] discussed in [K2] as a manifestation of dark protons was one of the first applications of TGD based ideas about dark matter. The proposed explanation is that the fraction of 1/4 of protons is in atto-second time scale dark and invisible in electron scattering and neutron diffraction. Note that atto-second time scale corresponds to the time during which light travels a length of order atomic size.

A natural identification of the dark protons would be in terms of protonic strings behaving like nuclei having anomalously large size, which would be due to the anomalously large value of Planck constant. A partial neutralization by negatively charge color bonds would make these states stable.

The TGD based explanation of anomalous production of electron-positron pairs in the collisions of heavy nuclei just above the Coulomb wall [K22] is in terms of lepto-pions consisting of pairs of color octet electron and positron allowed by TGD and having mass slightly below $2m_e \simeq 1$ MeV. The strong electromagnetic fields created in collision create coherent state of lepto-pions decaying into electron positron pairs.

9.2.2 Nuclear string model

The nuclear string model describes nuclei as string like structures with nucleons connected by color magnetic flux tubes whose length is of order electron Compton length about 10^{-12} meters and even longer and thus much longer than the size scale of nuclei themselves which is below 10^{-14} meters. Color magnetic flux tubes define the color magnetic body of nucleus and each flux tube has colored fermion and anti-fermion at its ends. The net color of pair is non-vanishing so that color confinement binds the nucleons to the nuclear string. Nuclei can be visualized as structures analogous to plants with nucleus taking the role of seed and color magnetic body of much larger size taking the role of plant with color flux tubes however returning back to another nucleon inside nucleus.

One can imagine two basic identifications of the fermions.

(a) For the first option fermions are identified as quarks. The color flux tube can have three charge states $q = +1, 0, -1$ according to whether it corresponds to $u\overline{d}, u\overline{u} + d\overline{d}$, or $\overline{u}d$ type state for quarks. This predicts a rich spectrum of exotic nuclei in which neutrons consist actually of proton plus negatively charged flux tube. The small mass difference between neutron and proton and small mass of the quarks (of order MeV) could quite well mean that these exotic nuclei are identified as ordinary nuclei. The findings of [C12] [C12] support the identification as quarks.

(b) Lepto-hadron hypothesis [K22] encourages to consider also the possibility that color bonds have color octet electrons at their ends. This would make it easier to understand why lepto-pions are produced in the collisions of heavy nuclei.

(c) One can also consider the possibility that the color bonds are superpositions of quark-antiquark pairs and colored electron-positron pairs.

9.2.3 Two options

One can consider two options for protonic strings. Either their correspond to open strings connected by color magnetic flux tubes or protons are dark so that giant nuclei are in question.

1. Protonic strings as open strings?

Color flux tubes connecting nucleons are long and one can ask whether it might be possible also open nuclear strings with long color flux tubes connecting widely separate nucleons even at atomic distance. These kind of structures would be favored if the ends of nuclear string are charged.

Even without assumption of large values of Planck constant for the color magnetic body and quarks the net length of flux tubes could be of the order of atomic size. Large value $\hbar$ would imply an additional scaling.

The simplest giant nuclei constructible in this manner would consist of protons connected by color magnetic flux tubes to from an open string. Stability suggest that the charge per length is not too high so that some minimum fraction of the color bonds would be negatively charged. One could speak of exotic counterparts of ordinary nuclei differing from them only in the sense that size scale is much larger. A natural assumption is that the distance between charged protonic space-time sheets along string is constant.

In the sequel the notation $X(z,n)$ will be is used for the protonic string containing net charge z and n negatively charged bonds. $a = z + n$ will denote the number of protons. z, n and a are analogous to nuclear charge Z, neutron number N, and mass number A. For open strings the charge is $z \geq 1$ and for closed strings $z \geq 0$ holds true.

This option has however problem. It is difficult imagine how the nuclear reactions could take place. One can imagine ordinary stringy diagrams in which touching of strings means that proton of protonic string and ordinary nucleus interact strongly in ordinary sense of the word. It is however difficult to imagine how entire protonic string could be absorbed into the ordinary nucleus.

2. Are protons of the protonic string dark?

Second option is that protonic strings consist of dark protons so that nuclear space-time-sheet has scale up size, perhaps of order atomic size. This means that fermionic charge is distributed in much larger volume and possibly also the fermions associated with color magnetic flux tubes have scaled up sized. The value $\hbar = 2^{11}\hbar_0$ would predict Compton length of order 10^{-12} m for nucleon and upper size of order 10^{-11} for nuclei.

Cold nuclear reactions require a transformation of dark protons to ordinary ones and this requires leakage to the sector of the imbedding space in which the ordinary nuclei reside (here the book metaphor for imbedding space is very useful). This process can take place for a neutral part of protonic string and involves a reduction of proton and fermion sizes to normal ones. The phase transition could occur first only for a neutral piece of the protonic string having charges at its ends and initiate the nuclear reaction. Part of protonic string could remain dark and remaining part could be “eaten” by the ordinary nucleus or dark protonic string could “eat” part of the ordinary nuclear string. If the leakage occurs for the entire dark proton string, the nuclear reaction itself is just ordinary nuclear reaction and is expected to give out ordinary nuclei. What is important that apart from the crucial phase transition steps in the beginning and perhaps also in the end of the reaction, the model reduces to ordinary nuclear physics and is in principle testable.

The basic question is how plasma phase resulting in electrolysis leads to the formation of dark protons. The proposal [K4] that the transition takes place with perturbative description of the plasma phase fails, might be more or less correct. Later a more detailed nuclear physics picture about the situation emerges.

3. What happens to electrons in the formation of protonic strings?

One should answer two questions.

(a) What happens to the electrons of hydrogen atoms in the formation of dark protonic strings?

(b) In plasma electrolysis the increase of the input voltage implies a mysterious reduction of the electron current with the simultaneous increase of the size of the plasma region near the catode [C25]. This means reduction of conductance with voltage and thus non-linear behavior. Where does electronic charge go?

Obviously the negatively charged color bond created by adding one proton to a protonic string could take the charge of electron and transform electrons as charge carriers to color bonds of dark Li isotopes which charge $Z = 3$ by gluing to existing protons sequence proton and negatively charged color bond. If the proton comes from H_2O OH^- replaces electron as a charge carrier. This would reduced the conductivity since OH^- is much heavier than electron. This kind of process and its reversal would take place in the transformation of hydrogen atoms to dark proton strings and back in atto-second time scale.

The color bond could be either $\overline{u}d$ pair or $e_8\overline{\nu}_8$ pair or quantum superposition of these. The basic vertex would involve the exchange of color octet super-symplectic bosons and their neutrino counterparts. Lepton number conservation requires creation of color singlet states formed of color octet neutrinos which ar bosons and carrying lepton number -2. One color confined neutrino pair would be created for each electron pair consumed in the process and might escape the system: if this happens, the process is not reversible above the time scale defined by colored neutrino mass scale of order.1 eV which happens to be of order.1 atto-seconds for ordinary neutrinos. Also ordinary nuclei could consist of nucleons connected by identical neutral color bonds (mostly).

The exchange of light counterparts of charged ρ mesons having mass of order MeV could lead to the transformation of neutral color bonds to charged ones. In deuterium cold fusion the exchange of charged ρ mesons between D and Pd nuclei could transform D nuclei to states behaving like di-neutrons so that cold fusion for D could take place. In the earlier proposal exchange of W^+ boson of scaled variant of weak interactions was proposed as a mechanism.

The formation of charged color bonds binding new dark protons to existing protonic nuclear strings or giving rise to the formation of completely new protonic strings would also increase of the rates of cold nuclear reactions.

Note that this picture leaves open the question whether the fermions associated with color bonds are quarks or electrons.

9.2.4 Nuclei and their dark variants must have same binding energy scale at nuclear quantum criticality

The basic question is what happens to the scale of binding energy of nuclei in the zooming up of nuclear space-time sheet. Quantum criticality requires that the binding energies scales must be same.

(a) Consider first the binding energy of the nuclear strings. The highly non-trivial prediction of the nuclear string model is that the contributions of strong contact interactions at nuclear space-time sheet (having size $L < 10^{-14}$ m) to the binding energy vanish in good approximation for ground states with vanishing strong isospin. This means that the binding energy comes from the binding energy assignable to color bonds connecting nucleons together.

(b) Suppose that this holds true in a good approximation also for dark nuclei for which the distances of nucleons at zoomed up nuclear space-time sheet (having originally size below 10^{-14} meters) are scaled up. As a matter fact, since the scale of binding energy for contact interactions is expected to reduce, the situation is expected to improve.

Suppose that color bonds with length of order 10^{-12} m preserve their lengths. Under these assumptions the nuclear binding energy scale is not affected appreciably and one can have nuclear quantum criticality. Note that the length for the color bonds poses upper limit of order 100 for the scaling of Planck constant.

It is essential that the length of color bonds is not changed and only the size of the nuclear space-time sheet changes. If also the length and thickness of color bonds is scaled up then a naive scaling argument assuming that color binding energy related to the interaction of transforms as color Coulombic binding energy would predict that the energy scales like $1/\hbar$. The binding energies of dark nuclei would be much smaller and transformation of ordinary nuclei to dark nuclei would not take place spontaneously. Quantum criticality would not hold true and the argument explaining the transformation of ordinary Li to its dark counterpart and the model for the deuterium cold fusion would be lost.

9.3 A Model For The Observations Of Mizuno

The basic objection against cold nuclear reactions is that Coulomb wall makes it impossible for the incoming nuclei to reach the range of strong interactions. In order that the particle gets to the catode from electrolyte it should be positively charged. Positive charge however implies Coulomb wall which cannot be overcome with the low energies involved.

These two contradictory conditions can be satisfied if the electrolysis produces exotic phase of water satisfying the chemical formula $H_{1.5}O$ with $1/4$ of protons in the form of almost neutral protonic strings can possess only few neutral color bonds. The neutral portions of the protonic string, which have suffered phase transition to a phase with ordinary Planck constant could get very near to the target nucleus since the charges of proton can be neutralized in the size scale of proton by the charges $\overline{u}$ and d quarks or e and $\overline{\nu}$ associated with the two bonds connecting proton to the two neighboring protons. This could make possible cold nuclear reactions.

It turns out that the model fixes protonic strings to isotopes of dark Lithium (with neutrons replaced with proton plus negatively charged color bond). What is intriguing is that the biologically most important ions (besides Na^+) Cl^-, K^+, and Ca^{++} appear at the catode in Kanarev's plasma electrolysis actually result as outcomes of cold nuclear reactions between dark Li and Na^+.

9.3.1 General assumptions of the model

The general assumptions of the model are following.

(a) Ordinary nuclei are nuclear strings, which can contain besides neutrons also "pseudo-neutrons" consisting of pairs of protons and negatively charged color bonds. The model for D cold fusion requires that the Pd nuclei contain also "pseudo-neutrons".

(b) Reaction products resulting in the fusion of exotic protonic string transforming partially to ordinary nuclear matter (if originally in dark phase) consist of the nuclei detected in the catode plus possibly also nuclei which form gases or noble gases and leak out from the catode.

(c) Si, K, Cr, and Cu are produced by the same mechanism in both KOH and NaOH electrolysis.

(d) Al, Cl, and Ca is produced by a mechanism which must involve cold nuclear reaction between protonic string and Na ions condensed on the catode.

(e) $Cu(Z,N) = Cu(29,34)$ is the only product nucleus heavier than $Fe(26,29)$. If no other nuclei are involved and Cu is produced by cold fusion

$$X(z,n) + Fe(26,29) \rightarrow Cu(29,34) \ ,$$

the anatomy of protonic string must be

$$X(z,n) = X(3,5)$$

so that dark variant $Li(3,5)$ having charge 3 and mass number 8 would be in question. $X(3,5)$ would have 2 neutral color bonds and 5 negatively charged color bonds. To minimize Coulomb interaction the neutral color bonds must reside at the ends of the string. For quark option one would have charge $1 + 2/3$ at the first end and $1 + 1/3$ at the second end and charges of all protons between them would be neutralized. For color octet lepton color bond one would have charge 2 at the other end and zero at the other end.

For quark option the net protonic charge at the ends of the string causing repulsive interaction between the ends could make protonic string unstable against transition to dark phase in which the distance between ends is much longer even if the ends are closed within scaled up variant of the nuclear volume.

Arbitrarily long strings $X(3,n)$ having neutral bonds only at their ends are possible and their fusions lead to neutron rich isotopes of Cu nucleus decaying to the stable isotope. Hence the prediction that only Cu is produced is very general.

The simplest dark protonic strings $X(3,n)$ have quantum numbers of $Li(3,n)$. One of the hard problems of Big Bang cosmology is that the measured abundance of lithium is by a factor of about 2.5 lower than the predicted abundance [E4]. The spontaneous transformation of $Li(3,n)$ isotopes to their dark variants could explain the discrepancy. Just by passign notice that Li has mood stabilizing effect [C5]: the spontaneous transformation of Li^+ to its dark variant might relate to this effect.

9.3.2 Production mechanisms for the light nuclei common to Na and K

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These nuclei must be produced by a fission of Fe nuclei.

(a) For $Si(14,14)$ production the mechanism would be cold fission of Fe nucleus to two parts in the collision with the protonic string:

$$X(3,5) + Fe(26,29) \rightarrow Si(14,14) + Al(13,14) + X(2,6) \ .$$

$X(2,6)$ represent dark or ordinary $He(2,6)$. As a noble gas He isotope would leave the catode.

Note that arbitrarily long proton strings with two neutral bonds at their ends give neutron rich isotope of Si and exotic or ordinary isotope of He so that again the prediction is very general.

(b) $K(19,20)$ is produced much more in KOH which most probably means that part of K^+ is absorbed from the electrolyte. In this case the reaction could proceed as follows:

$$X(3,5) + Fe(26,29) \rightarrow K(19,20) + Ne(7,7) + X(3,7) \ .$$

Note that the neutron number could be distributed in many manners between final states. For arbitrarily long proton string with two neutral bonds at ends higher neutron rich isotopes of K and Ne are produced. As noble gas Ne would leak out from the catode.

Ordinary $Li(3,7)$ would decay by neutron emission to stable isotopes of Li. The temperature of the system determines whether Li boils out (1615 K under normal pressure). Li is not reported to appear in the catode. In plasma electrolysis the temperature is in the interval $.5 \times 10^4$- 10^4 C and around 10^3 C in the ordinary electrolysis so that the high temperature might explain the absence of Li. Also the in-stability of Li isotopes against transition to dark Li in electrolyte would imply the absence of Li.

(c) For $Cr(24,28)$ production the simplest reaction would be

$$X(3,5) + Fe(26,29) \rightarrow Cr(24,28) + He(2,2) + X(3,4) \ .$$

Helium would leak out as noble gas. Proton string would shorten by one unit and keep its charge. $X(3,4)$ would represent the stable isotope $Li(3,4)$ or its dark counterpart and what has been said in 2) applies also now.

9.3.3 How to understand the difference between KOH and NOH?

One should understand why Al, Cl, and Ca are not detected in the case of KOH electrolysis.

Al, Cl, and Ca would be created in the fusion of protonic strings with $Na(11,12)$ nuclei absorbed by the catode. With this assumption the rates are expected to be of same order of magnitude for all these processes as suggested by the one per cent order of magnitude for all fractions.

One can imagine two reaction mechanisms.

I: One could understand the production assuming only $X(3,5)$ protonic strings if the number of $X(3,5)$ strings absorbed by single Na nucleus can be $k = 1,2,3$ and that nuclear fission can take place after each step with a rate which is slow as compared to the rate of absorptions involving also the phase transition to dark matter. This is however highly implausible since ordinary nuclear interactions are in question.

II: Second possibility is that the protonic strings appearing with the highest probability are obtained by fusing copies of the basic string $X(3,5)$ by using neutral color bond between the strings. The minimization of electrostatic energy requires that that neutral color bonds are equally spaced so that there are three completely neutralized protons between non-neutralized protons.

One would have thus at least the strings $X(3,5)$, $X(6,10)$, and $X(9,15)$, which correspond to dark $Li(3,5)$ and dark variants of the unstable isotopes $C(6,10)$ and $F(9,15)$. In nuclear string model also ordinary nuclei are constructed from $He(2,2)$ strings and lighter strings in completely analogous manner, and one could perhaps see the dark nuclei constructed from $Li(3,5)$ as the next level of hierarchy realized only at the level of dark matter.

The charge per nucleon would be 3/8 and the length of the string would be a multiple of 8. Interestingly, the numbers 3, 5, and 8 are subsequent Fibonacci numbers appearing very frequently also in biology (micro-tubules, sunflower patterns). The model predicts also the occurrence of cold fusions $X(z = 3k, n = 5k) + Fe(26,29) \rightarrow (Z,N) = (26+3k, 29+5k)$. For $k = 2$ this would give $Ge(32,39)$ which is stable isotope of Ge. For $k = 3$ one would have $(Z,N) = (35,44)$ which is stable isotope of Br [C41, C7].

Consider now detailed description of the reactions explaining the nuclei detected in the catode.

(a) $Al(13,14)$ would be produced in the reaction

$$X(3,5) + Na(11,12) \rightarrow Al(13,14) + X(1,3) \ .$$

$H(1,3)$ or its dark variant could be in question. Also the reaction $X(3,5)+Na(11,12) \rightarrow Al(13,17) + p$, where $Al(12,17)$ is an unstable isotope of Al is possible.

The full absorption of protonic string would yield $Si(14,17)$ beta-decaying to $P(15,16)$, which is stable. Either P leaks out from the catode or full absorption does not take place appreciably.

(b) $Cl(17,18)$ would be produced by the sequence

$$\begin{aligned} \mathbf{I1}: \quad 2X(3,5) + Na(11,12) &\rightarrow Cl(17,18) + X(0,4) \ , \\ \mathbf{I2}: \quad X(6,10) + Na(11,12) &\rightarrow Cl(17,18) + X(0,4) \ . \end{aligned}$$

$X(0,4)$ represents ordinary or dark tetra-neutron [C37, C24, C11]. The instability of the transformation of tetra-neutron to dark matter could explain why its existence has remained controversial.

If the protonic string were absorbed completely, the resulting $Cl(17,22)$ - if equivalent to ordinary nucleus - would transform via beta-decays to $A(18,23)$ and then to $K(19,22)$, which is stable and detected in the target.

(c) $Ca(20,20)$ would be produced in the reaction

$$\begin{array}{lll} \mathbf{I1}: & 3X(3,5)+Na(11,12) & \rightarrow & Ca(20,20)+X(0,7) \ , \\ \mathbf{I2}: & X(9,15)+Na(11,12) & \rightarrow & Ca(20,20)+X(0,7) \ . \end{array}$$

$X(0,7)$ would be dark counterpart of "septa-neutron". The complete absorption of nuclear string would produce $Ca(20,27)$, which (if ordinary nucleus) transforms via beta decays to $Sc(21,26)$ and then to $Ti(22,25)$, which is stable.

9.4 Comparison With The Model Of Deuterium Cold Fusion

It is interesting to compare the model with the model for cold fusion [C35, C1] reported using deuterium target and D_2O instead of water.

9.4.1 Earlier model

(a) The model is based on the assumption that D nuclei in the target suffer a phase transition to a state in which D nuclei become neutral so that the color bond between neutron and proton becomes negatively charged: one has effectively di-neutrons.

(b) The mechanism of charging of color bond must either involve weak interactions or exchange of lepto-ρ mesons already discussed briefly. The proposal is that the exchange of W bosons of scaled up version of weak physics is involved with the range of interactions given by atomic length scale. The exchange of W^+ bosons was assumed to take place between Pd and D nuclei. This mechanism could lead to the formation of negatively charged color bonds in also ordinary nuclei.

(c) The neutrality of exotic D nuclei allows to overcome Coulomb wall. One can understand the reported selection rules: in particular the absence of Helium isotopes (only isotopes of H are detected). The absence of gamma rays can be understood if the resulting gamma rays are dark and leak out before a transformation to ordinary gamma rays.

9.4.2 Are D nuclei in Pd target dark or not?

The question whether the exotic D nuclei are dark was left pending. The recent model suggests that the answer is affirmative.

(a) The basic difference between the two experiments would be that in Kanarev's experiments incoming nuclei are dark whereas in D fusion catode contains the dark nuclei and cold nuclear reactions occur at the "dark side" and is preceded by ordinary-to-dark phase transition for incoming D.

(b) D cold fusion occurs for a very restricted range of parameters characterizing target: the first parameter is doping ratio: essentially one D nucleus per one Pd nucleus is needed which would fit with the assumption that scaled up size is of the order of atom size. Temperature is second parameter. This and the fact that the situation is highly sensitive to perturbations conforms with the interpretation as a phase transition to dark matter occurring at quantum criticality.

(c) The model for Kanarev's findings forces to consider the possibility that dark D nuclei combine to form longer strings and can also give rise to dark $Li(3,5)$ explaining the observed nuclear transmutations in the target.

(d) In cold nuclear reactions incoming nuclei would transform to dark nuclei (the picture as a leakage between different pages of a book like structure defined by the generalized imbedding space is helpful). The reaction would take place for dark nuclei in zoomed up nuclear physics and the reaction products would be unstable against phase transition to ordinary nuclei.

(e) Is it then necessary to assume that target D nuclei are transformed to neutral ones (di-neutrons effectively) in order to have cold nuclear reactions? Nuclear space-time sheets are scaled up. If nucleon space-time sheets are not scaled up, p and n are connected by color magnetic flux tubes of same length as in the case of ordinary nuclei but located at much larger nuclear space-time sheet. The classical analog for the quantal distribution of nucleon charges is even charge distribution in a sphere or radius R defined by the charge of the scaled up nucleus. The height of the Coulomb wall is $E_c = e^2/R$. If $R = a$, a the atomic radius, one has $E_c \sim .1$ keV. The wall is by a factor 10^{-4} lower than in ordinary nuclear collision so that the incoming D nucleus might overcome the Coulomb wall.

If Coulomb wall can be overcome, all dark variants of $D + D$ reaction are possible. Helium nuclei have not been however detected, which supports the view that D in target is transformed to its neutral variant. Gamma rays would be dark and could leak out without detection which would explain the absence of gamma rays.

9.4.3 Nuclear quantum criticality is essential

A note about the energetics of cold nuclear reactions is in order. The nuclear quantum criticality deriving from the cancelation of the contact interaction energies between nucleons for isospin singlets and scaling up of *only* nuclear space-time sheet is an absolutely essential assumption. Otherwise dark D would have much smaller binding energy scale than the visible one, and ordinary D in the Pd target could not transform to dark "di-neutron" state. Also the transformation of incoming D to its dark variant D at catode could not take place.

9.5 What Happens To Oh Bonds In Plasma Electrolysis?

For an innocent novice one strange aspect of hydrolysis is how the OH bonds having energies of order 8 eV can be split in temperatures corresponding to photon energies of order.5 eV. Kanarev has suggested his own theory for how this could happen [D13]. TGD suggests that OH bonds are transformed to their dark variants with scaled down bond energy and that there might be no essential difference between OH bond and hydrogen bond.

9.5.1 The reduction of energy of OH bonds in plasma electrolysis

Kanarev has found that in plasma electrolysis the energy of OH bonds is reduced from roughly 8 eV to about.5 eV, which corresponds to the fundamental metabolic energy quantum identifiable as the zero point kinetic energy liberate as proton drops from $k = 137$ space-time sheet to much larger space-time sheet. In pyrolysis [D4] similar reduction could occur since the pyrolysis occurs above temperature about 4000 C conforming with the energy scale of hydrogen bond.

The explanation discussed in [K20] is that there is some mechanism exciting the bonds to a state with much lower bond energy. Dark matter hierarchy [K4] suggests that the excitation corresponds to the transformation of OH bond to dark bond so that the energy scale of the state is reduced.

Also in the ordinary electrolysis of water [D2] the energy of OH bonds is reduced to about 3.3 eV meaning a reduction factor of order 2. The simplest interpretation would be as a transformation of OH bonds to dark OH bond with $\hbar \rightarrow 2\hbar$ (the scaling could be also by some other integer or even rational). The energy needed to transform the bond to dark bond could come from remote metabolism via the dropping of dark protons from a dark variant of some sub-atomic space-time sheet with size not smaller than the size of the atomic space-time sheet to a larger space-time sheet.

In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

$H_{1.5}O$ anomaly suggests that 1/4 of protons of water are dark in atto-second time scale [K2] and one can imagine that both protons of water molecule can become dark under conditions defined by plasma electrolysis. Also the atomic space-time sheets and electron associated with OH bonds could become dark.

Atomic binding energies transform as $1/\hbar^2$. If the energy of hydrogen bond transforms like Coulombic interaction energy as given by the perturbative calculation, it is scaled down as $1/\hbar$ since the length of the bond scales up like $\hbar$. Effectively $\alpha_{em} \propto 1/\hbar$ is replaced by its scaled down value. For $\hbar \rightarrow 2^4\hbar_0$ the energy would scale from 8 eV to.5 eV and the standard metabolic energy quantum could induce the splitting of the dark OH bond. If 2^4 is the scale factor of $\hbar$ for dark nuclear space-time sheets, their size would be of order 10^{-3} meters. The model for cold fusion is consistent with this since what matters is different value of Planck constant for the dark nuclear space-time sheets.

There is an objection against the reduction of OH bond energy. The bonds could be split by a process in which dark nuclear reactions kick protons to $k = 133$ dark space-time sheet. In this case the maximal zero point kinetic energy liberated in the dropping back would be 8 eV and could induce breaking of OH bond. For $\hbar/\hbar_0 \geq 4$ the size of $k = 133$ dark space-time sheet would be larger than the size of $k = 137$ atomic space-time sheet.

9.5.2 Are hydrogen bonds dark OH bonds?

The fact that the energy of hydrogen bonds [D3] is typically around.5 eV forces to ask what distinguishes hydrogen bond from dark OH bond. Could it be that the two bonds are one and the same thing so that dark OH bonds would form standard part of the standard chemistry and molecular biology? In hydrogen bond same hydrogen would be shared by the oxygen atoms of the neighboring atoms. For the first O the bond would be ordinary OH bond and for the second O its dark variant with scaled down Coulomb energy. Under conditions making possible pyrolysis and plasma electrolysis both bonds would become dark. The variation of the hydrogen bond energy could reflect the variation of the scaling factor of $\hbar$.

The concentration of the spectrum of bond energies on integer multiples of fundamental energy scale - or even better, on powers of 2 - would provide support for the identification. There is evidence for two kinds of hydrogen bonds with bond energies in ratio 1: 2 [D11] : the TGD based model is discussed in [K2].

9.5.3 Mechanism transforming OH bonds to their dark counterparts

The transformation of OH bonds to dark bonds would occur both in ordinary and plasma electrolysis and only the change of Planck constant would distinguish between the two situations.

(a) Whatever the mechanism transforming OH bonds to their dark counterparts is, metabolic energy is needed to achieve this. Kanarev also claims over-unity energy production [D13]. Cold fusion researchers make the same claim about ordinary electrolysis. Cold nuclear reactions between Na^+ (K^+) and dark protons and dark Li could obviously serve as the primary energy source. This would provide the fundamental reason for why $NaOH$ or KOH must be present. Cold nuclear reactions would thus occur also in the ordinary electrolysis of water and provide the energy inducing the transition of OH bonds to dark ones by (say) $\hbar \rightarrow 2\hbar$ transition.

(b) One can imagine several metabolic mechanisms for the visible-to-dark transformation of HO bonds. The energy spectrum of cold nuclear reactions forms a continuum whereas the energies needed to transform OH bonds to their dark variants presumably are in narrow bands. Therefore the energy liberated in cold nuclear reactions is not probably used as such. It is more plausible that standard metabolic energy quanta liberated in the dropping of protons (most naturally) to larger space-time sheets are utilized. The most important metabolic energy quanta for the dropping of proton come as $E_k = 2^{k-137}kE_0$: $E_0 = .5$ eV is liberated in the dropping of proton from atomic space-time sheet ($k = 137$) to much larger space-time sheet (the discrete spectrum of increments of the vacuum energy in the dropping approaches this energy [K12]). The energy liberated in the dark nuclear reactions would "load metabolic batteries" by kicking the dark protons to the dark variants of $k < 137$ space-time sheet (the size of dark atomic space-time sheet scales like $\hbar$). Their dropping to larger space-time sheets would liberate photons with energies near to those transforming OH bonds to hydrogen bonds.

(c) A signature for the standard metabolic energy quanta would be visible light at $2eV$ and also discrete lines below it accumulating to $2eV$. Kanarev's indeed reports the presence of red light [D13] as a signature for the occurrence of process.

9.6 A Model For Plasma Electrolysis

Kanarev's experiments involve also other strange aspects which lead to the view that cold nuclear reactions and dark matter physics are essential aspects of not only plasma electrolysis of Kanarev but also of ordinary electrolysis and responsible for the claimed over unity energy production. Biologically important ions are produced in reactions of dark Li and Na^+ and there is very strong electric voltage over the cell membrane. This inspires the question whether cold nuclear reactions serve as a metabolic energy source in living cell and are also responsible for production of ions heavier than Na^+.

9.6.1 Brief description of plasma electrolysis

Electrolysis [D2], pyrolysis [D4] , and plasma electrolysis [C25], [D13] of water are methods of producing free hydrogen. In pyrolysis the temperature above 4000 C leads to hydrogen and oxygen production. Oxygen production occurs also at catode and hydrogen yield is higher than given by Faraday law for ordinary electrolysis [D2].

The article of Mizuno and collaborators [C25] about hydrogen production by plasma electrolysis contains a brief description of plasma electrolysis. A glow discharge occurs as the input voltage used in electrolysis is above a critical value and plasma is formed near catode. In the arrangement of [C25] plasma state is easily achieved above 140 V. If the values of temperature and current density are right, hydrogen generation in excess of Faraday's law as well as a production of oxygen at catode (not possible in ideal electrolysis) are observed. Above 350 V the control of the process becomes difficult.

9.6.2 What really happens in electrolysis and plasma electrolysis?

1. Ordinary electrolysis

To understand what might happen in the plasma electrolysis consider first the ordinary electrolysis of water.

(a) The arrangement involves typically the electrolyte consisting of water plus $NaOH$ or KOH without which hydrolysis is impossible for thermodynamical reasons.

(b) Electronic current flows from the anode to catode along a wire. In electrolyte there is a current of positively charged ions form anode to catode. At the catode the reaction $2H_2O+2e^- \rightarrow 2H_2+2OH^-$ yields hydrogen molecules seen as bubbles in water. At the anode the reaction $2H_2O \rightarrow O_2+4H^++4e^-$ is followed by the reaction $2H^++2e^- \rightarrow H_2$ and the flow of $2e^-$ to the catode along wire. The net outcome is hydrolysis: $H_2O \rightarrow 2H_2+2O_2$. Note that O_2 is produced only at anode and H_2 at both anode and catode.

2. What happens in plasma electrolysis?

In plasma electrolysis something different might happen.

(a) Cold nuclear reactions should take place at catode in presence of Na^+ ions plus dark Li and should be in equilibrium under ordinary conditions and contribute mainly to the formation of dark OH bonds. The rate of cold nuclear reactions increases with input voltage V since the currents of Na^+ and dark Li to the catode increase. Obviously the increased rate of energy yield from dark nuclear reactions could be the real reason for the formation of plasma phase above critical voltage.

(b) By previous considerations the reduction of electron current above critical voltage has interpretation as a transition in which electronic charge is transferred to negative charge of color bonds of dark proton strings. Existing protonic strings could grow longer and also new strings could be created from the ionized hydrogen resulting in the electrolysis of water. The increase of the size of the dark nuclei would mean increase of the cross sections for cold nuclear reactions. The liberated energy would ionized hydrogen atoms and give rise to a positive feedback loop somewhat like in ordinary nuclear reactions.

(c) The increased energy yield in cold nuclear reactions suggests that OH bonds are transformed very effectively to dark OH bonds in the plasma region. This means that the thermal radiation can split the hydrogen bonds and induce the splitting of two water molecules to $4H$ and $2O$ and therefore production of $2H_2+O_2$ everywhere in this kind of region. The temperature used by Kanarev corresponds to energy between .5-1 eV [D13] which conforms with the fact that OH bond energy is reduced to about.5 eV. Note that the presence of anode and catode is not absolutely necessary if cold nuclear reactions can take place in the entire electrolyte volume and generate plasma phase by positive feedback loop.

(d) The prediction is that Faraday's law for hydrogen production does not hold true. O/H ratio has the value $r = O/H = 0$ for the ordinary electrolysis at catode. $r = 1/2$ holds true if local dissociation of water molecules dominates. According to [C25] r increases from electrolysis value $r = .066$ above $V = 140$ V achieving the value $r = .45$ for $V = 350$ V where the system becomes unstable. Also cold nuclear reactions could contribute to hydrogen and oxygen production and affect the value of r as suggested by the large volume of gas produced in Kanarev's experiments [D10].

9.6.3 Over-unity energy production?

Over-unity energy production with output power 2- or even 3-fold as compared with input power has been reported from plasma electrolysis. The effectiveness is deduced from the heating of of the system. Note that Mizuno reports in [C25] that 10 per cent effectiveness but this is for the storage of energy to hydrogen and does not take into account the energy going to the heating of water.

The formation of higher isotopes of Li by fusing dark protons to existing dark proton strings is a good candidate for the dominant energy production mechanism. An estimate for the energy liberate in single process $Li(3,n)+m_p+e \rightarrow Li(3,n+1)+2\nu_8$ is obtained by using energy conservation. Here $2\nu_8$ denotes color singlet bound state of two color octet excitations of neutrino.

Since e_8 and ν_8 are analogous to u and d quarks one expects that their masses are very nearly the same. This gives as the first guess $m_{\nu_8} = m_e$ and since lepto-pion (color bound state of color octet electrons, [K22]) has mass $m = 2m_e$ a good guess is $m(2\nu_8) = 2m_{\nu_8} = 2m_e$. The energy conservation would give

$$m(Li(3,n)) + m_p = m(Li(3,n+1)) + m_e + T(2\nu_8) + E(\gamma) \ . \quad (9.1)$$

Here $T(2\nu_8)$ is the kinetic energy of $2\nu_8$ state and E_γ is the energy of photon possibly also emitted in the process.

The process is kinematically possible if the condition

$$\Delta m = m(Li(3,n)) + m_p - m(Li(3,n+1) \geq m_e \ . \quad (9.2)$$

is satisfied. All incoming particles are approximated to be at rest, which is a good approximation taking into account that chemical energy scales are much lower than nuclear ones. For the left hand side one obtains from the mass difference of $Li(3,n=4)$ and $Li(3,5)$ isotopes the estimate $\Delta m = 1.2312$ MeV for the liberated binding energy which is considerably larger than $m_e = .51$ MeV. Hence the process is kinematically possible and $2\nu_8$ would move with a relativistic velocity $v = .81c$ and presumably leave the system without interacting with it.

The process can involve also the emission of photons and the maximal amount of energy that photon can carry out corresponds to $E = \Delta m = 1.2312$ MeV. Let us denote by $\langle E\rangle < \Delta m$ the average photonic energy emitted in the process and express it as

$$\langle E\rangle = z\Delta m \ , \ z < 1. \quad (9.3)$$

One obtains an estimate for the production rate of photon energy (only this heats the system) from the incoming electron current I. If a fraction $x(V)$ of the current is transformed to negatively charged color bonds the rate for energy production becomes by a little manipulation

$$\frac{P/kW}{I/A} = x(V)z \times 3.5945 \ . \quad (9.4)$$

This formula allows to estimate the value of the parameter $x(V)z$ from experimental data. Since simplest Feynman graph producing also photons is obtained by adding photon line to the basic graph, one expects that z is of order fine structure constant:

$$z \sim \alpha_{em} = 1/137 \ . \quad (9.5)$$

The ratios of the excess power for a pair of (V,I) values should satisfy the condition

$$\frac{P(V_1)I(V_2)}{P(V_2)I(V_1)} = \frac{x(V_1)}{x(V_2)} \ . \quad (9.6)$$

$x(V)$ should be deducible as a function of voltage using these formulas if the model is correct.

These formulae allow to compare the predictions of the model with the experimental results of Naudin for Mizuno-Omori Cold Fusion reactor [C8]. **Table 12** gives the values of $\epsilon = x(V)z$ and ratios $x(V(n))/x(V(n_1)$ deduced from the data tabulated by Naudin [C34] for the various series of experiments using the formulae above.

(a) Most values of $x(V)z$ are in the range $.03 - .12$. $z = 1/137$ would give $x(V)z \leq 1/137$ so that order of magnitude is predicted correctly. One cannot over-emphasize this result.

(b) Apart from some exceptions the values look rather reasonable and do not vary too much. If one neglects the exceptional values, ones has $x_{max}(V)/x_{min}(V) < 4$. $n = 1,5,8,9,29$ correspond to exceptionally small values of $x(V)$. Perhaps cold fusion is not present for some reason. The output power is smaller than input power for $n = 9$ and $n = 29$.

Table 12: The values of $x(V)z$ and $x(V(n))/x(V(1))$ deduced from the data of *Cold Fusion reaction-Experimental test results on June 25, 2003 by JL Naudin* at `http://jlnlabs.online.fr/cfr/html/cfrdatas.htm`.

n	$Voltage/V$	$Current/A$	$x(V)z$	$x(V(n))/x(V(2))$
1	185	8.56	0.005	.145
2	147	2.45	0.036	1.00
3	215	2.10	0.046	1.30
4	220	9.32	0.044	1.22
5	145	1.06	0.001	.03
6	213	1.40	0.05	1.34
7	236	1.73	0.08	2.18
8	148	.83	0.01	.21
9	148	1.01	-0.00	-0.008
10	221	1.31	0.03	.87
11	279	3.03	0.05	1.46
12	200	8.58	0.03	0.89
13	199	7.03	0.07	1.91
14	215	9.78	0.04	1.07
15	207	8.34	0.03	0.74
16	247	2.19	0.06	1.69
17	260	2.20	0.02	0.55
18	257	2.08	0.03	0.71
19	195	2.95	0.06	1.59
20	198	2.62	0.07	1.98
21	182	2.40	0.05	1.26
22	212	2.27	0.06	1.74
23	259	2.13	0.12	3.22
24	260	4.83	0.04	1.05
25	209	3.53	0.04	1.16
26	230	4.99	0.10	2.79
27	231	5.46	0.09	2.53
28	233	5.16	0.10	2.85
29	155	4.60	-0.00	-0.04
30	220	4.44	0.11	2.95
31	256	5.25	0.05	1.36
32	211	3.68	0.03	.97
33	201	3.82	0.04	1.06

9.6.4 Has living matter invented cold nuclear physics?

Intriguingly, the ions Na^+, Cl^-, K^+, Ca^{++} detected by Mizuno in the catode in Kanarev's experiments [D10] correspond to the most important biological ions. There is also a considerable evidence for the occurrence of nuclear transmutations in living matter [C13, C44]. For instance, Kervran claims that it is not possible to understand where the Ca needed to form the shells of eggs comes from. A possible explanation is that dark nuclear reactions between Na^+ and dark Litium produced the needed Ca.

There is extremely strong electric field through cell membrane (resting voltage is about.06 V). The acceleration of electrons in this field could generate plasma phase and creation of dark Li nuclei via a positive feedback loop. This could mean that cold nuclear reactions serve also in living cell as a basic metabolic energy source (possibly in the dark sector) and that also biologically important ions result as products of cold nuclear reactions.

9.7 Tests And Improvements

9.7.1 Test for the hypothesis about new physics of water

The model involves hypothesis about new physics and chemistry related to water.

(a) The identification of hydrogen bond as dark OH bond could be tested. One could check whether the qualitative properties of bonds are consistent with each. One could try to find evidence for quantization of bond energies as integer multiples of same energy (possible power of two multiples).

(b) $H_{1.5}O$ formula in atto-second scale should be tested further and one could look whether similar formula holds true for heavy water so that sequences of dark protons might be replaced with sequences of dark deuterons.

(c) One could find whether plasma electrolysis takes place in heavy water.

9.7.2 Testing of the nuclear physics predictions

The model in its simplest form assumes that only dark Li, C, F, etc. are present in water. This predicts quite specific nuclear reactions in electrolyte and target and reaction product. For both target and electrolyte isotopes of nuclei with atomic number $Z + k3$ are predicted to result in cold fusion reactions if energetically possible. For a target heavier than Fe also fission reactions might take place.

The estimates for the liberated energies are obtained assuming that dark nuclei have same binding energies as ordinary ones. In some cases the liberated energy is estimated using the binding energy per nucleon for a lighter isotope. Ordinary nuclei with maximal binding energy correspond to nuclear strings having ^4He or its variants containing negatively charged color bonds as a basic structural unit. One could argue that gluing $nLi(3,5)$ or its isotope does not give rise to a ground state so that the actual energy liberated in the process is reduced so that process might be even impossible energetically. This could explain the absence of Ge from Fe catode and the absence of Ti, Mn, and Ni in KOH plasma electrolysis [D10].

catode: For catode Fe and W have been used. For Fe the fusions $Fe + Li \rightarrow Cu + 28.84\ MeV$ and $Fe + C \rightarrow Ge + 21.64\ MeV$ are possible energetically. Mizuno does not report the presence of Ge in Fe target. The reduction of the binding energy of dark $C(6,10)$ by 21.64 MeV (1.35 MeV per nucleon) would make second reaction impossible but would still allow $Li+C$ and $Na+C$ fusion. Second possibility is that Ge containing negatively charged color bonds has smaller binding energy per nucleon than ordinary Ge. $W + Li \rightarrow Ir$ would liberate 8.7 MeV if binding energy of dark Li is same as of ordinary Li.

Electrolyte: Consider electrolytes containing ions X^+ with atomic number Z. If X is lighter than Fe, the isotopes of nuclei with atomic number $Z + 3k$ might be produced in fusion reactions $nLi + X$. $X = Li, K, Na$ has one electron at s-shell whereas $B, Al, Cr, ...$ has one electron at p-shell.

Table 13: The estimates for the energies liberated in fusions of dark nuclei of water and the ion of electrolyte. Boldface refers to dark nuclei $Li(3,5), C(6,10)$, and $F(9,15)$.

Reaction	$\mathbf{Li} + Li \rightarrow C$	$\mathbf{C} + Li \rightarrow F$	$\mathbf{F} + Li \rightarrow Mg$
E/MeV	27.1	24.0	31.5
	$\mathbf{Li} + Na \rightarrow Si$	$\mathbf{C} + Na \rightarrow Cl$	$\mathbf{F} + Na \rightarrow Ca$
E/MeV	34.4	30.5	33.7
	$\mathbf{Li} + K \rightarrow Ti$	$\mathbf{C} + K \rightarrow Mn$	$\mathbf{F} + K \rightarrow Ni$
E/MeV	32.2	33.6	32.7

9.7.3 Relationship to the model of Widom and Larsen and further tests

W. Guglinski kindly informed me about the theory of cold fusion by Widom and Larsen [C46]. This theory relies on standard nuclear physics. The theory is reported to explain cold fusion reaction products nicely in terms of the transformation of electrons and protons to very low energy neutrons which can overcome the Coulomb barrier. The problem of the theory is that very high energy electrons are required since one has $Q = .78$ MeV for $e + p \rightarrow n$ and $Q = -3.0$ MeV for $e + D \rightarrow n + n$. It is difficult to understand how so energetic electrons could result in ordinary condensed matter.

Since proton plus color bond is from the point of view of nuclear physics neutron and the fusion reactions would obey ordinary nuclear physics rules, the predictions of TGD are not expected to deviate too much from those of the model of Widom and Larsen.

An important class of predictions relate to ordinary nuclear physics. Tetra-neutron could be alpha particle with two negatively charged color bonds and neutron halos could consist of protons connected to nucleus by negatively charged color bonds. This could reduce the binding energy considerably.

Cold nuclear fusion might also provide an in situ mechanism for the formation of ores. Nuclear ores in places where they should not exist but involving remnants of organic matter would be the prediction. Cold fusion has a potential for a technology allowing to generate some metals artificially.

9.7.4 How to optimize the energy production?

The proposed model for the plasma electrolysis suggests following improvements to the experimental arrangement.

The production of energy in process is due to three reactions: 1) $Li + p$ in plasma. 2) $Li+Fe/W...$ in target, and 3) $Li+Na/K...$ in plasma. The model suggests that 1) dominates so that basic process would occur in plasma rather than catode.

(a) Since W does not evaporate so easily, it is better material for catode if the production of dark Li dominates energy production.

(b) catode could be replaced with a planar electrode with fractal peaky structure generating the required strong electric fields. This could increase the effectiveness of the energy production by increasing the effective area used.

(c) Since $H_2O \rightarrow OH^- + p$ is required by the generation of dark Li sequences. The energy feed must be able to follow the rapidly growing energy needs of this reaction which seems to occur as bursts.

(d) The prediction is that the output power is proportional to electron current rather than input power. This suggests minimization of input power by minimizing voltage. This requires maximization of electron conductivity. Unfortunately, the transformation of electrons to OH^- ions as charge carriers reduces conductivity.

10 Anomalies Possible Related To Electrolysis Of Water And Cold Fusion

10.1 Comparison With The Reports About Biological Transmutations

Kervran's book "Biological Transmutations" [C13] contains a surprisingly detailed summary about his work with biological transmutations and it is interesting to find whether the proposed model could explain the findings of Kervran. TGD suggests two general mechanisms.

(a) The nuclear reactions involving dark Li, C, and F predicted to be present in living matter.

(b) Nuclear fusions made possible by a temporary transformation of ordinary nuclear space-time sheets to dark ones with much larger size so that Coulomb wall is reduced considerably. The nuclear reaction might proceed if it is energetically possible. Almost any reaction $A+B \rightarrow C$ is possible via this mechanism unless the nuclei are not too heavy.

10.1.1 Fortuitous observations

In his childhood Kervran started to wonder why hens living in a limestone poor region containing thus very little calcium in ground and receiving no calcium in their nutrition could develop the calcium required by eggs and by their own bones. He noticed that hens had the habit of eating mica, which contains silicon. Later this led to the idea that Si could somehow transmute to Ca in living matter. In the proposed model this could correspond to fusion of $Si(14,14)+\mathbf{C(6,6)} \rightarrow Ca(20,20)$ which occurs spontaneously.

Second fortuitous observation were the mysterious CO poisonings by welders working in factory. After careful studies Kervran concluded that CO must be produced endogenously and proposed that the inhaled air which had been in contact with incandescent iron induces the transformation $N_2 \rightarrow CO$ conserving both neuron and neutron number. This transformation might be understood in TGD context if the nuclear space-time sheets are part of time in dark with much larger size so that a direct contact becomes possible for nuclear space-time sheets and Coulomb wall is reduced so that the reaction can proceed with some probability if energetically possible. The thermal energy received from hot iron might help to overcome the Coulomb barrier. The mass difference $m(2N)-m(O)-m(C)=10.45$ MeV allows this reaction to occur spontaneously.

10.1.2 Examples of various anomalies

Kervran discusses several plant anomalies. The ashes of plants growing in Si rich soil contain more Ca than they should: this transmutation has been already discussed. The ashes of a plant growing on Cu fibres contain no copper but 17 per cent of iron oxides in addition to other elements which could not have come from the rain water. The reaction $Cu(58)+\mathbf{Li(3,4)} \rightarrow Fe(26,32)+\mathbf{C(6,6)}$ would liberate energy of 11.5 MeV.

There are several mineral anomalies.

(a) Dolomite rock is formed inside limestone rocks which would suggest the transmutation of $Ca(20,20)$ into $Mg(12,12)$. The nuclear reaction $Ca(20,20)+\mathbf{Li(3,4)} \rightarrow Mg(12,12)+Na(11,12)$ would liberate energy of 3.46 MeV. Ca emerges from Si in soil and in what Kervran refers to a "sickness of stone". The candidate reaction has been already discussed.

(b) Graphite is found in siliceous rocks. Kervran proposes the reaction $Si \rightarrow C+O$. $m(Si)-m(C)-M(O)=-16.798$ MeV does not allow this reaction to proceed spontaneously but the reaction $Si+\mathbf{Li} \rightarrow C+Na$ liberates the energy 2.8880 MeV.

(c) Kervran mentions the reaction $O+O \rightarrow S$ as a manner to produce sulphur from oxygen. This reaction is obviously energetically favored.

Kervran discusses the transmutations $Na \rightarrow K$ and $Na \rightarrow Ca$ occurring also in plasma electrolysis and explained by TGD based model. Further transmutations are $Na \rightarrow Mg$ and $Mg \rightarrow Ca$. $Na \rightarrow Mg$ could correspond to the reaction $Na(11,12) + \mathbf{Li(3,2)} \rightarrow Mg(12,12) + He(2,2)$ favored by the high binding energy per nucleon for ^4He (7.072 MeV). $Mg \rightarrow Ca$ would correspond to the reaction $Mg+O \rightarrow Ca$, which obviously liberates energy.

10.2 Are The Abundances Of Heavier Elements Determined By Cold Fusion In Interstellar Medium?

According to the standard model, elements not heavier than Li were created in Big Bang. Heavier elements were produced in stars by nuclear fusion and ended up to the interstellar space in super-nova explosions and were gradually enriched in this process. Lithium problem forces to take this theoretical framework with a grain of salt.

The work of Kervran [C13] suggests that cold nuclear reactions are occurring with considerable rates, not only in living matter but also in non-organic matter. Kervran indeed proposes that also the abundances of elements at Earth and planets are to high degree determined by nuclear transmutations and discusses some examples. For instance, new mechanisms for generation of O and Si would change dramatically the existing views about evolution of planets and prebiotic evolution of Earth.

10.2.1 Where did the Lithium go?

Ulla - one of the commentators in my blog - sent an interesting link concerning Lithium problem to an article by Elisabetta Caffau et al titled "An extremely primitive halo star" [E5].

What has been found is a star which is extremely poor on metallic elements: ("metallic" refers to elements heavier than Li). The mystery is that not only elements heavier than Li but also Li itself, whose average abundance is believed to be determined by cosmological rather than stellar nucleosynthesis, is very scarcely present in these stars.

This finding can be coupled with too other observations about anomalies in Li abundance.

(a) The average abundance of Li in Cosmos is lower than predicted by standard cosmology by a factor between 2 and 3 [E3].

(b) Also Sun has too low Li abundance [E2].

Authors think that some process could have created very high temperature destroying the Li in this kind of stars: maybe dark matter annihilation might have caused this. This looks rather artificial to me and would not explain too low Li abundance for other stars and for interstellar medium.

The transformation of Li to dark matter (ordinary Lithium in a phase with larger value of Planck constant) would mean its effective disappearance. This process would have occurred both in interstellar medium and in stars so that all three Li problems would be solved at once. Many question marks remain. What about the rate for the phase transition to dark matter? Also lighter elements should be able to transform to dark form. Why the cosmological abundances for them are however essentially those predicted by the standard model of primordial nucleosynthesis? Is the reason that Li their fusion to Li was much faster than transformation to dark matter during primordial nucleosynthesis whereas Li fused very slowly and had time to transform to dark Li?

Li problem would rather sharply distinguish between two very different views about dark matter: dark matter as some exotic elementary particles on one hand and dark matter as phases of ordinary matter implied by generalization of quantum theory on the other hand.

Table 14: Table gives the most abundant isotopes of stable nuclei.

H(1, 0)							He(2, 2)
Li(3, 4)	Be(4, 5)	B(5, 6)	C(6, 6)	N(7, 7)	O(8, 8)	F(9, 10)	Ne(10, 10)
Na(11, 12)	Mg(12, 12)	Al(13, 14)	Si(14, 14)	P(15, 16)	S(16, 16)	Cl(17, 18)	A(18, 22)
K(19, 20)	Ca(20, 20)						

10.2.2 Are heavier nuclei produced in the interstellar space?

TGD based model is consistent with the findings of Kervran and encourages to a consider a simple model for the generation of heavier elements in interstellar medium. The assumptions are following.

(a) Dark nuclei $X(3k,n)$, that is nuclear strings of form $Li(3,n)$, $C(6,n)$, $F(9,n)$, $Mg(12,n)$, $P(15,n)$, $A(18,n)$, etc..., form as a fusion of Li strings. $n = Z$ is the most plausible value of n. There is also ^4He present but as a noble gas it need not play an important role in condensed matter phase (say interstellar dust). The presence of water necessitates that of $Li(3,n)$ if one accepts the proposed model as such.

(b) The resulting nuclei are in general stable against spontaneous fission by energy conservation. The binding energy of $He(2,2)$ is however exceptionally high so that alpha decay can occur in dark nuclear reactions between $X(3k,n)$ allowed by the considerable reduction of the Coulomb wall. The induced fissions $X(3k,n) \rightarrow X(3k-2,n-2) + He(2,2)$ produces nuclei with atomic number $Z \mod 3 = 1$ such as $Be(4,5)$, $N(7,7)$, $Ne(10,10)$, $Al(13,14)$, $S(16,16)$, $K(19,20)$, ... Similar nuclear reactions make possible a further alpha decay of $Z \mod 3 = 1$ nuclei to give nuclei with $Z \mod 2$ such as $B(5,6)$, $O(8,8)$, $Na(11,12)$, $Si(14,14)$, $Cl(17,18)$, $Ca(20,20)$, ... so that most stable isotopes of light nuclei could result in these fissions.

(c) The dark nuclear fusions of already existing nuclei can create also heavier Fe. Only the gradual decrease of the binding energy per nucleon for nuclei heavier than Fe poses restrictions on this process.

Table 14 allows the reader to build a more concrete view about how the heavier nuclei might be generated via the proposed mechanisms.

10.2.3 The abundances of nuclei in interstellar space should not depend on time

The basic prediction of TGD inspired model is that the abundances of the nuclei in the interstellar space should not depend on time if the rates are so high that equilibrium situation is reached rapidly. The $\hbar$ increasing phase transformation of the nuclear space-time sheet determines the time scale in which equilibrium sets on. Standard model makes different prediction: the abundances of the heavier nuclei should gradually increase as the nuclei are repeatedly re-processed in stars and blown out to the interstellar space in super-nova explosion.

Amazingly, there is empirical support for this highly non-trivial prediction [E7]. Quite surprisingly, the 25 measured elemental abundances (elements up to $Sn(50,70)$ (tin) and $Pb(82,124)$ (lead)) of a 12 billion years old galaxy turned out to be very nearly the same as those for Sun. For instance, oxygen abundance was 1/3 from that from that estimated for Sun. Standard model would predict that the abundances should be.01-.1 from that for Sun as measured for stars in our galaxy. The conjecture was that there must be some unknown law guaranteeing that the distribution of stars of various masses is time independent. The alternative conclusion would be that heavier elements are created mostly in interstellar gas and dust.

10.2.4 Could also "ordinary" nuclei consist of protons and negatively charged color bonds?

The model would strongly suggest that also ordinary stable nuclei consist of protons with proton and negatively charged color bond behaving effectively like neutron. Note however that I have also consider the possibility that neutron halo consists of protons connected by negatively charged color bonds to main nucleus. The smaller mass of proton would favor it as a fundamental building block of nucleus and negatively charged color bonds would be a natural manner to minimizes Coulomb energy. The fact that neutron does not suffer a beta decay to proton in nuclear environment provided by stable nuclei would also find an explanation.

(a) Ordinary shell model of nucleus would make sense in length scales in which proton plus negatively charged color bond looks like neutron.

(b) The strictly nucleonic strong nuclear isospin is not vanishing for the ground state nuclei if all nucleons are protons. This assumption of the nuclear string model is crucial for quantum criticality since it implies that binding energies are not changed in the scaling of $\hbar$ if the length of the color bonds is not changed. The quarks of charged color bond however give rise to a compensating strong isospin and color bond plus proton behaves in a good approximation like neutron.

(c) beta decays might pose a problem for this model. The electrons resulting in beta decays of this kind nuclei consisting of protons should come from the beta decay of the d-quark neutralizing negatively charged color bond. The nuclei generated in high energy nuclear reactions would presumably contain genuine neutrons and suffer beta decay in which d quark is nucleonic quark. The question is whether how much the rates for these two kinds of beta decays differ and whether existing facts about beta decays could kill the model.

10.3 Burning Salt Water By Radio-Waves And Cold Fusion By Plasma Electrolysis

John Kanzius has made a strange discovery [D1]: salt water in the test tube radiated by radio waves at harmonics of a frequency f=13.56 MHz burns. Temperatures about 1500 C, which correspond to.17 eV energy have been reported. One can radiate also hand but nothing happens. The original discovery of Kanzius was the finding that radio waves could be used to cure cancer by destroying the cancer cells. The proposal is that this effect might provide new energy source by liberating chemical energy in an exceptionally effective manner. The power is about 200 W so that the power used could explain the effect if it is absorbed in resonance like manner by salt water. In the following it is proposed that the cold nuclear reactions are the source of the energy.

10.3.1 Do radio waves of large Planck constant transform to microwave photons or visible photons in the process?

The energies of photons involved are very small, multiples of 5.6×10^{-8} eV and their effect should be very small since it is difficult to imagine what resonant molecular transition could cause the effect. This leads to the question whether the radio wave beam could contain a considerable fraction of dark photons for which Planck constant is larger so that the energy of photons is much larger. The underlying mechanism would be phase transition of dark photons with large Planck constant to ordinary photons with shorter wavelength coupling resonantly to some molecular degrees of freedom and inducing the heating. Microwave oven of course comes in mind immediately. The fact that photosynthesis means burning of water and the fact that visible light is emitted in turn suggests that the radio wave photons are transformed to visible or nearly visible photons corresponding to the energy scale of photons involved with photosynthesis.

The original argument inspired by the analogy with microwave oven is discussed below. The generalization to the case of visible photons is rather straightforward and is discussed in [K2].

(a) The fact that the effects occur at harmonics of the fundamental frequency suggests that rotational states of molecules are in question as in microwave heating. The formula for the rotational energies [D5] is

$$E(l) = E_0 \times (l(l+1) \ , \ \ E_0 = \hbar_0^2/2\mu R^2 \ , \ \ \mu = m_1 m_2/(m_1+m_2) \ .$$

Here R is molecular radius which by definition is deduced from the rotational energy spectrum. The energy inducing the transition $l \rightarrow l+1$ is $\Delta E(l) = 2E_0 \times (l+1)$.

(b) $NaCl$ molecules crystallize to solid so that the rotational heating of $NaCl$ molecules cannot be in question.

(c) The microwave frequency used in microwave ovens is 2.45 GHz giving for the Planck constant the estimate 180.67 equal to 180 with error of.4 per cent. The values of Planck constants for $(\hat{M}^4/G_a) \times \hat{CP}_2 \hat{\times} G_b$ option (factor space of M^4 and covering space of CP_2 maximizing Planck constant for given G_a and G_b) are given by $\hbar/\hbar_0 = n_a n_b$. $n_a n_b = 4 \times 9 \times 5 = 180$ can result from the number theoretically simple values of quantum phases $exp(i2\pi/n_i)$ corresponding to polygons constructible using only ruler and compass. For instance, one could have $n_a = 2 \times 3$ and $n_b = 2 \times 3 \times 5$.

10.3.2 Connection with plasma electrolysis?

The burning of salt water involves also the production of O_2 and H_2 gases. Usually this happens in the electrolysis of water [D2]. The arrangement involves typically electrolyte consisting of water plus $NaOH$ or KOH present also now but anode, catode and electronic current absent. The proposed mechanism of electrolysis involving cold nuclear reactions however allows the splitting of water molecules to H_2 and O_2 even without these prerequisites.

The thermal radiation from the plasma created in the process has temperature about 1500 C which correspond to energy about.17 eV: this is not enough for splitting of bonds with energy.5 eV. The temperature in salt water could be however considerably higher.

The presence of visible light suggests that plasma phase is created as in plasma electrolysis. Dark nuclear reactions would provide the energy leading to ionization of hydrogen atoms and subsequent transformation of the electronic charge to that of charged color bonds in protonic strings. This in turn would increase the rate of cold nuclear reactions and the liberated energy would ionize more hydrogen atoms so that a positive feedback loop would result.

Cold nuclear reactions should provide the energy transforming hydrogen bonds to dark bonds with energy scaled down by a factor of about 2^{-6} from say 8 eV to.125 eV if $T = 1500C$ is accepted as temperature of water. If Planck constant is scaled up by the factor $r = 180$ suggested by the interpretation in terms of microwave heating, the scaling of the Planck constant would reduce the energy of OH bonds to about.04 eV, which happens to be slightly below the energy assignable to the cell membrane resting potential. The scaling of the size of nuclear space-time sheets of D by factor $r = 180$ is consistent with the length of color bonds of order 10^{-12} m. The role of microwave heating would be to preserve this temperature so that the electrolysis of water can continue. Note that the energy from cold nuclear reactions could partially escape as dark photons.

There are some questions to be answered.

(a) Are the radio wave photons dark or does water - which is a very special kind of liquid - induce the transformation of ordinary radio wave photons to dark photons by fusing 180 radio wave massless extremals (MEs) to single ME. Does this transformation occur for all frequencies? This kind of transformation might play a key role in transforming ordinary EEG photons to dark photons and partially explain the special role of water in living systems.

(b) Why the radiation does not induce a spontaneous combustion of living matter which also contains Na^+ and other ions. A possible reason is that $\hbar$ corresponds to Planck constant of dark Li which is much higher in living water. Hence the energies of dark photons do not induce microwave heating.

(c) The visible light generated in the process has yellow color. The mundane explanation is that the introduction Na or its compounds into flame yields bright yellow color due to so called sodium D-lines [D6] at 588.9950 and 589.5924 nm emitted in transition from 3p to 3s level. Visible light could result as dark photons from the dropping of dark protons from dark space-time sheets of size at least atomic size to larger dark space-time sheets or to ordinary space-time sheets of same size and de-cohere to ordinary light. In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system.

Yellow light corresponds roughly to the rather narrow energy range.96-2.1 eV ($.59 - .63\ \mu m$). The metabolic quanta correspond to jumps to space-time sheets of increasing size give rise to the fractal series $E/eV = 2\times(1-2^{-n})$ for transitions $k = 135 \rightarrow 135+n$, $n = 1, 2, ...$ [K12]. For $n = 3, 4, 5$ the lines have energies $1.74, 1.87, 1.93$ eV and are in the visible red ($\lambda/\mu m = .71, .66, .64$). For $n > 5$ the color is yellow. In Kanarev's experiments the color is red which would mean the dominance of $n < 6$ lines: this color is regarded as a signature of the plasma electrolysis. In the burning of salt water the light is yellow [D1], which allows to consider the possibility that yellow light is partially due to $n > 5$ lines. Yellow color could also result from the dropping $k = 134 \rightarrow 135$ ($n = 1$).

11 About Physical Representations of Genetic Code in Terms of Dark Nuclear Strings

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas. One can argue that genetic code is realized in several manners just like bits can be represented in very many manners. Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony involving icosahedral and tetrahedral geometries. Second model has two variants based on dark nuclear strings: the original version maps codons do dark nucleons, the more recent version maps codons to dark 3-nucleon states. Both models predict correctly the numbers of DNA codons coding for a given amino-acid but the model based on dark 3-nucleon triplets is favoured by some recent findings suggesting a pairing between DNA nucleotides and dark nucleons. Also the counterparts of RNA,tRNA, and amino-acids are predicted. In the sequel the updated nuclear string variant is summarized and also its connection with the model of harmony is discussed.

11.1 Background

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas (see chapters of [K6] and [K11, K8]). One can argue that genetic code is realized in several manners just like bits can be represented in very many manners.

Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony [L4] involving icosahedral and tetrahedral geometries. Second one having two variants is based on dark nuclear strings. Both models predict correctly the numbers of

DNA codons coding for a given amino-acid. In the sequel the nuclear string variant and also its connection with the model of harmony is discussed in detail.

It is good to start with an overall view about physical realization of genetic code that I have discussed during last twenty years.

11.1.1 Genetic code and Combinatorial Hierarchy

The first proposal [K7] was purely mathematics inspired and in terms of so called Combinatorial Hierarchy consisting of certain Mersenne primes $M_k = 2^k - 1$ via the formula $M(n+1) = M_{M(n)}$ having interpretation in terms of abstraction. The list beginning from $M(1) = 2$ is $2, M_2 = 3, M_3 = 7, M_7 = 127, M_{127} = 2^{127} - 1$: it is not known whether subsequent integers are Mersenne primes. The idea is that the $2^k - 1$ points define almost full Boolean algebra spanned by k bits- one visualization is as a polygon. The algebra defined $k - 1$ bits is maximal full Boolean sub-algebra having interpretation as maximal number of mutually independent statements, which can hold true simultaneously. For M_7 ($k = 3$) one would have 2 bits and 4 codons. For M_7 one would have $k = 7$ and 6 bits and genetic code. For M_{127} one would have 126 bits and one would have "memetic" code realizable in terms of sequences of 21 DNA codons.

11.1.2 Geometric theory of harmony and genetic code

The idea that the 12-note scale could allow mapping to a closed path going through all vertices of icosahedron having 12 vertices and not intersecting itself is attractive. Also the idea that the triangles defining the faces of the icosahedron could have interpretation as 3-chords defining the notion of harmony for a given chord deserves study. The paths in question are known as Hamiltonian cycles and there are 1024 of them [**?**]. There paths can be classified topologically by the numbers of triangles containing 0, 1, or 2 edges belonging to the cycle representing the scale. Each topology corresponds to particular notion of harmony and there are several topological equivalence classes.

In the article [L8] I introduced the notion of Hamiltonian cycle as a mathematical model for musical harmony and also proposed a connection with biology: motivations came from two observations. The number of icosahedral vertices is 12 and corresponds to the number of notes in 12-note system and the number of triangular faces of icosahedron is 20, the number of amino-acids. This led to a group theoretical model of genetic code and replacement of icosahedron with tetra-icosahedron to explain also the 21st and 22nd amino-acid and solve the problem of simplest model due to the fact that the required Hamilton's cycle does not exist. The outcome was the notion of bioharmony.

All icosahedral Hamilton cycles with symmetries(Z_6,Z_4, Z_2^{rot} and Z_2refl turned out to define harmonies consistent with the genetic code. In particular, it turned out that the symmetries of the Hamiltonian cycles allow to to predict the basic numbers of the genetic code and its extension to include also 21st and 22nd amino-acids Pyl and Sec: there are actually two alternative codes - maybe DNA and its conjugate are talking different dialects! One also ends up with a proposal for what harmony is leading to non-trivial predictions both at DNA and amino-acid level.

The conjecture is that DNA codons correspond to 3-chords perhaps realized in terms of dark photons or even ordinary sound. There are 256 different bio-harmonies and these harmonies would give additional degrees of freedom not reducing to biochemistry. Music expresses and creates emotions and a natural conjecture is that these bio-harmonies are correlates of emotions/moods at bio-molecular level serving as building bricks of more complex moods. Representations of codons as chords with frequencies realized as those of dark photons and also sound is what suggests itself naturally. This together with adelic physics involving hierarchy of algebraic extensions of rationals would explain the mysterious lookin connection between rational numbers defined by ratios of frequencies with emotions.

11.1.3 Letter-wise representations of genetic code in terms of single particle states

The model for DNA-cell membrane system as topological quantum computer with lipids and DNA nucleotide or codons connected by flux tubes led to a proposal for the correspondence of letters of genetic code with particle states.

(a) The original proposal was that the 4 letters A,T,C,G correspond to dark u and d quark and their antiparticles $\overline{u}$ and $\overline{d}$. Quarks and their antiparticles would reside at the ends of the flux tube. Spin would not matter in this model. The obvious criticism is that introducing dark antiquarks is too far fetched.

(b) One can also consider a variant for which one has u and d quarks and spin matters.

(c) TGD based model of bio-superconductivity assumes that flux tubes appear as pairs with members of Cooper pair at parallell flux tubes [K13, K14]. This suggests that electron pairs at in spin 1 and spin 0 states could realize the code. The spin of the electrons would matter and one would obtain 4 states - two qubits in correspondence with A,T,C,G.

Also the model of dark nuclear strings allows to imagine letter-wise representations of the genetic code. The model for cold fusion based on the findings of Prof. Holmlid and his group [C10, L15] leads to the idea that Pollack's EZs [L7] are accompanied by dark nuclear strings consisting of dark protons connected by color flux tubes analogous to mesons [L10, L15]. Color bonds would have quark and antiquark at their ends [K11]. This leads to non-trivial predictions and nuclear anomalies giving support for the notion of nuclear string have emerged, the latest anomaly is so called X boson with mass of 17 MeV [L16, C20] having identification as p-adically scaled analog of pion.

Dark protons could also decay to neutrons by dark weak decays rapidly since dark weak bosons are effectively massless below dark Compton length. Furthermore, proton plus negatively charged color bond could behave like neutron as far as chemistry is considered. The X boson anomaly of nuclear physics [L16] suggests that the flux tubes in the ground state correspond to pion-like states which can be colored: this could bind the nucleons to form a nucleus. The evidence for the occurence of cold fusion in living matter gives support for the role of dark nuclear strings [L11] [L15].nOne can consider several representations of the genetic code in this framework.

Consider first models for which letters are represented separately.

(a) Dark protons and neutrons have 4 spin states and could correspond to letter A,T,C,G. In this case dark color bonds would not matter. A rather convincing proposal for a pathway leading to a selection purines as DNA nucleotides has been proposed [I1]. TGD based model [L13] suggests that acidic solutions contain dark protons and purine results when the precursor amine combines with dark proton such that the proton remains dark. Could DNA nucleotide pair with dark protons and neutrons (resulting in dark beta decay from dark proton strings yielded by Pollack's mechanism)?

(b) Also the 4 states of dark color bonds between dark nucleons (3 pion-like states and one eta meson like state: spin 1 bonds would be analogous to ρ and ω mesons and have higher mass) correspond to letters A,T,C,G. Now the dark protons and neutrons would not matter. This option would require that the character of the nucleotide correlates with the color flux tube attached to the dark proton. They would have at their ends charge conjugate color bonds. The states would be of form $u\overline{u}, d\overline{d}, u\overline{d}, d\overline{u}$ with the ordering of q and $\overline{q}$ correlating with the direction in which transcription and replication take place being thus same or opposite). For conjugate strand the direction of strand would be opposite in the sense that one would have $\overline{u}u, \overline{d}u, \overline{du}, \overline{u}u$.

For this option one could consider the strands of dark DNA double strand being connected by flux tube pairs resulting when U-shaped color flux tube have reconnected. If color flux tubes are colored, color confinement could bind the dark protons to dark nucleus. Similar mechanism could be at work for the ordinary nuclei.

The basic problem of all the proposals based on letter-wise correspondence is that they do not even try to explain the numbers of DNA codons coding for a given amino-acid and are also silent about tRNA.

11.1.4 Codon-wise representations of genetic code realized in terms of dark nuclear strings

For this option entire codons rather than letters would be represented. The difference between two representations is analogous to that between spoken and written languages. In spoken languages words are not analyzed further to letters. These models are able to predict also the numbers of codons coding for a given amino-acid successfully.

(a) The geometric theory of harmony represents codons as 3-chords without assigning fixed notes to A,T,C,G and explains also DNA-amino-acid correspondence.

(b) The map of codons to the dark nucleon states of dark nucleon consisting of dark u and d type quarks does the same and also predicts the degeneracies successfully.

(c) This model can be modified by replacing u and d by dark nucleon states p and n without any change in predictions related to genetic code. The evidence that DNA codons indeed couple to dark nucleon states [L13] supports this option.

In the sequel I consider the models mapping DNA codons to dark nucleons and then generalize the model so that it applies to triplets of dark nucleons.

11.2 Models of genetic code based on dark nuclear strings

Water memory is one of the ugly words in the vocabulary of the main stream scientist. The work of pioneers is however now carrying fruit. The group led by Jean-Luc Montagnier, who received Nobel prize for discovering HIV virus, has found strong evidence for water memory and detailed information about the mechanism involved [K8, K21], [I3]. The work leading to the discovery was motivated by the following mysterious finding. When the water solution containing human cells infected by bacteria was filtered in purpose of sterilizing it, it indeed satisfied the criteria for the absence of infected cells immediately after the procedure. When one however adds human cells to the filtrate, infected cells appear within few weeks. If this is really the case and if the filter does what it is believed to do, this raises the question whether there might be a representation of genetic code based on nano-structures able to leak through the filter with pores size below 200 nm.

The question is whether dark nuclear strings might provide a representation of the genetic code. In fact, I posed this question year before the results of the experiment came with motivation coming from the attempts to understand water memory. The outcome was a totally unexpected finding: the states of dark nucleons formed from three quarks can be grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

11.2.1 Mapping DNA and amino-acids to dark nucleon states

The dark model emerged from the attempts to understand water memory [K8]. The outcome was a totally unexpected finding [K11, K8]: the states of dark nucleons formed from three quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, 20 amino-acids, and tRNA and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks -

just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η.

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino-acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would be not be anymore separable to letters but entangled states of 3 quarks.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics and maybe even in ordinary nuclear physics if the nucleons of ordinary nuclear physics are linear nucleons. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

The ability of the model to explain genetic code in terms of spin pairing is an impressive achievement, which I still find difficult to take seriously.

(a) The original model mapping codons to dark nucleon states assumed the overall charge neutrality of the dark proton strings: the idea was that the charges of color bonds cancel the total charge of dark nucleon so that all states uuu, uud, udd, ddd can be considered. The charge itself would not affect the representation of codons. Neutrality assumption is however not necessary. The interpretation as dark nucleus resulting from dark proton string could quite well lead to the formation the analog of ordinary nucleus via dark beta decays [L15] so that the dark nucleus could have charge. Isospin symmetry breaking is assumed so that neither quarks nor flux tubes are assigned to representations of strong $SU(2)$.

   There is a possible objection. For ordinary baryon the mass of Δ is much larger than that of proton. The mass splitting could be however much smaller for linear baryons if the mass scale of excitations scales as $1/h_{eff}$ as indeed assumed in the model of dark nuclear strings [L10, L15].

(b) The model assumes that the states of DNA can be described as tensor products of the four 3-quark states with spin content $2 \otimes 2 \otimes 2 = 4 \oplus 2_1 \oplus 2_2$ with the states formed with the 3 spin triplet states $3 \otimes 3 = 5 \oplus 3 \oplus 1$ with *singlet state dropped*. The means that flux tubes are spin 1 objects and only spin 2 and spin 1 objects are accepted in the tensor product. One could consider interpretation in terms of ρ meson type bonding or gluon type bonding. With these assumptions the tensor product $(2 \otimes 2 \otimes 2) \otimes (5 \oplus 3)$ contains $8 \times 8 = 64$ states identified as analags of DNA codons.

   The rejection of spin 0 pionic bonds looks strange. These would however occur as bonds connecting dark codons and could correspond to different p-adic length scale as suggested by the successful model of X boson [L16].

   One can also ask why not identify dark nucleon as as closed triangle so that there would be 3 color bonds. In this case $3 \otimes 3 \otimes 3$ would give 27 states instead of 8 ($\oplus 1$). This option does not look promising.

(c) The model assumes that amino-acids correspond to the states 4×5 with $4 \in \{4 \oplus 2 \oplus 2\}$ and $5 \in \{5 \oplus 3\}$. One could tensor product of spin 3/2 quark states and spin 2 flux tube states giving 20 states, the number of amino-acids!

(d) Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino-acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allow immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$

to the states of 4×5 with same or opposite spin projection. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1,2,3,2\}$ and $D_b \in \{1,2,2,2,1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1,2,3,4,6$ are predicted. The numbers $N(k)$ of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2,7,2,6,3] \ .$$

The correct numbers for vertebrate nuclear code are $(N(1), N(2), N(3), N(4), N(6)) = (2,9,1,5,3)$. Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2,9,1,5,3)$!

It is difficult to exaggerate the importance of this simple observation suggesting that genetic code is realized already at the level of dark or even ordinary nuclear physics and bio-chemistry is only a kind of shadow of dark matter physics.

11.2.2 Objections based on group theory and statistics

The model and its generalization replacing u, d with nucleon states p, n works amazingly nicely but is better to try to invent objections against the proposal and try to find inconsistencies. Fermi and Bose statisticsare the most obvious providers of killer arguments.

(a) The basic objection is that if the quarks are organized in linear structures, one cannot talk about representation of 3-D rotation group since symmetry breaking to SO(2) acting along common axis which could be either the local axis along dark DNA helix of the axis of the entire helix. The linear ordering of the quarks is not consistent with the full harmonics. Rather, harmonics restricted to half space $0 \leq \theta \leq \pi/2$ ($\pi \geq \theta \geq \pi/2$) should characterize the "upper" ("lower") flux tube direction at the position of quark in the middle.

If reflection along quantization axis and SO(2) generate the symmetries one still has labelling of the states by angular momentum projection and states form doublets $(m, -m)$. The representations of SO(3) split into these representation and the numbers of states with given spin projection remain the same. Therefore the predictions for the numbers of DNA codons coding given aminoacid are not changed. It is quite possible that braid statistics made possible by 1-dimensionality is needed to realize the idea about ordering and this would allow to have full DNA multiplets.

(b) In quark model one forms tensor product of tensor products of 3 quark spin states and 3 quark isospin states and by color singletness requires that the state is completely antisymmetric in quark degrees of freedom. The state is completely symmetric in the non-colored degrees of freedom. One obtains only two representations $\Delta \leftrightarrow (3/2, 3/2)$ and $N = (1/2, 1/2)$ with positive parity. In quark model context the presence of other tensor products in $(4 \oplus 2_1 \oplus 2_2)_S \otimes (4 \oplus 2_1 \oplus 2_2)_I$ is forbidden. One reason is that spatial wave function is assumed to be symmetric in ground state. This forbids 2_2 in spin degrees of freedom. Symmetrization leaves only the Δ and N (Note that the total number of these state is 20!). Now strong isospin is broken and it is natural to not include it to the tensor product.

(c) The presence of 2_2 would be forbidden in quark model since it would require antisymmetric spatial wave function to compensate for the antisymmetry of 2_2. In the recent case the situation is 1-dimensional and the ordering along nuclear string forces localization of quarks and one cannot have identical wave functions for quarks.

1-D situation also suggests strongly braid statistics. Perhaps the situation could be understood in terms of fermionic oscillator operators along nuclear string having anti-commutation relations corresponding to non-trivial braid statistics - maybe making the statistics commutative. This could naturally allow anti-symmetrization along nuclear string for 2_2 states.

(d) If one assumes ordinary statistics, one could one take care of the statistics of the 16 states in $2_2 \otimes (5 \oplus 3)$ by assuming that for 2_2 the color state is symmetric and thus 10-D representation of $SU(3)$. The state associated with color flux tubes cannot compensate this color (triality is 1) since it must correspond to triality zero representation. If the colors of DNA strand and conjugate correspond to 10 and $\overline{10}$ and color entanglement cold guarantee color singletness for the codon pairs. This would however require antiquarks for the conjugate strand.

 3 10:s associated with 3 codons contains in their tensor product a singlet (see `http://tinyurl.com/zjxxqhj`). Minimal color singlet dark DNA sequence would requite 3 color codons. One can of course wonder whether the presence of 3 decouplet codons - 2 at the beginning and 2 at end and one in the middle could define genes as basic units.

(e) The statistics problem is encountered also for the flux tubes. 5 (and 1) as symmetric representation is allowed by statistics but triplet is antisymmetric and thus not allowed. Again braid statistics might help. If one assumes that the flux tubes are colored - say color octets - and color wave function for flux tube pairs is antisymmetric, one can achieve Bose statistics for 3. Flux tube pair would correspond to $8 \in \{8 \times 8\}$ and minimum of two flux codons would be needed for color singletness in flux tube degrees of freedom.

(f) For the counterparts of amino-acids one has only $4 \otimes 5$ allowed also by statistics considerations assuming color singlets. Could distinction between DNA/RNA and amino-acids related to statistics, perhaps braid statistics. The suggested role of braid strands possibly connecting DNA double strands and DNA double strands and lipid layers of cell membrane encourages the question whether the DNA strand and its conjugate entangle via via the reconnection of the color flux tubes defining U-shaped "tentacles" to a flux tube pair connecting the strands. For amino-acids they would not be needed. Same could happen in the transcription process of DNA to mRNA and in the translation process for mRNA tentacles and those associated with tRNA.

11.2.3 It is also possible to map DNA and amino-acids to dark 3-nucleon states

The assumption that entire codon rather than letter corresponds to a state of dark proton does not conform with the model for the origin of purines as DNA nucleotides [L13] assuming that purines and in fact all nucleotides are combined with dark proton unless one assumes that 3 nucleotides combine with the same dark proton. This looks somewhat artificial but cannot be excluded.

Amazingly, the arguments of the model involve only the representations of rotation group and since p and n have same spin as u and d, the arguments generalize to 3- nucleon states (ppp, ppn, pnn, nnn) connected by two color bounds and organized to linear structures. Concerning genetic code, exactly the same predictions follow in the recent formulation of the model. In this case quark color is not present. One could however use the 1-dimensionality and the ordering of dark nucleons as already described.

This variant has several nice features. The model is consistent with the model for dark nucleon strings consisting of nucleons and color bonds between them. There is no need to introduce Δ type nucleon states and colored states are not needed in fermionic sector. Color bonds must be colored if one wants ordinary bosonic statistics for flux tubes but here braid statistics might help. Colored bonds could of course have some important function.

11.2.4 Ordinary or braid statistics?

There are four options to consider: ordinary/braid statistics (1/2) and dark nucleon/dark nucleon triplet as representation of DNA codon (a/b). One has options 1a,1b,2a,2b.

(a) Option 1a. For the ordinary statistics amino-acid like dark nucleons are color singlets. Part of DNA codons represented as dark nucleons and would be colored and 10-D representation of SU(3). Dark amino-acids need not have color bonds with dark parts of other colored biomolecules like DNA,RNA, with exception possible formed by dark tRNA. DNA double strand could realize color confinement via the reconnection of color flux tubes.

(b) Option 1b. Option 1b requires in ordinary statitics for antisymmetric doublet an antisymmetric wave function for the 3 nucleons not allowing constant valued wave function also disfavored by the linear ordering. This condition might have the same implications as braid statistics.

(c) Options 1a and 1b. DNA is the only molecule that appears as double strands. A possible explanation is that codons and anticodons are paired by U-shaped flux tubes associated with the color bonds of dark DNA to form color singlets. Nucleonic colors would sum up to zero along the strand.

(d) Option 2a. For braid statistics it could be possible to avoid colored states of nucleon and flux tubes altogether.

(e) Option 2b. The codons would have no color and amino-acids could obey braid statistics reducing to ordinary statistics. This would not be the case for DNA/RNA.

11.2.5 Objections Against the Identification of Codons as Dark Nucleon States

Consider next some particle physicist's objections against the option mapping codons to dark nucleon states.

(a) The realization of the model requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one has a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states could be scaled up.

(b) Both the absolute and relative mass differences between Δ and N *resp.* ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller - say of the same order of magnitude as fine structure constant 1/137 - so that the mass splittings could be so small as to make decays impossible.

The color magnetic spin interaction energy give rise to hyperfine splitting of quark in perturbative QCD is of form $E_c \propto \hbar g B/m$, where m is mass parameter which is of the order of baryon mass. Magnetic flux scales as $\hbar$ by flux quantization and if flux tube thickness scales as $\hbar^2$, one has $B \propto 1/\hbar$. Mass splittings would not depend on $\hbar$, which does not make sense. Mass splitting becomes small for large $\hbar$ if the area of flux quantum scales as $\hbar^{2+n}$, $n > 0$ so that color magnetic hyper-fine splitting scales as $1/\hbar^n$ from flux conservation. The magnetic energy for a flux tube of length L scaling as $\hbar$ and thickness $S \propto \hbar^{2+n}$ has order of magnitude $g^2 B^2 L S$ and does not depend on $\hbar$ for $n = 1$. Maybe this could provide first principle explanation for the desired scaling.

The size scale of DNA would suggest that single DNA triplet corresponds to 3 Angstrom length scale. Suppose this corresponds to the size of dark nucleon. If this size scales as $\sqrt{\hbar}$ as p-adic mass calculations suggest, one obtains a rough estimate $\hbar/hbar_0 = 2^{38}$. The proton-Δ mass difference due to hyper-fine splitting would be scaled down to about $2^{-38} \times 300$ MeV $\sim 10^{-9}$ eV, which is completely negligible in the metabolic energy scale .5 eV. If the size of dark nucleon scales as $\hbar$ the mass difference is about 12 eV which corresponds to the energy scale for the ionization energy of hydrogen. Even this might be acceptable.

For these reasons the option mapping codons to dark nucleon triplets is clearly favored and will be discussed in the following.

11.3 The model mapping codons to dark 3-nucleon states

The model based on dark 3-nucleon states is discussed seems more realistic and will be discussed in more detail in the sequel.

11.3.1 Could dark DNA, RNA, tRNA and amino-acids correspond to different charge states of codons?

If dark codons correspond to dark nucleon triplets as assumed in the following considerations there are 4 basic types of dark nucleon triplets: ppp, ppn, pnn, nnn. Also dark nucleons could represent codons as uuu, uud, udd, ddd: the following discussion generalizes as such also to this case. If strong isospin/em charge decouples from spin the spin content is same independently of the nucleon content. One can consider the possibility of charge neuralization by the charges assignable to color flux tubes but this is not necessarily. In any case, one would have 4 types of nucleon triplets depending on the values of total charges.

Could different dark nucleon total charges correspond to DNA,RNA, tRNA and amino-acids? Already the group representation content - perhaps correlating with quark charges - could allow to distinguish between DNA, RNA, tRNA, and amino-acids. For amino-acids one would have only 4×5 and ordinary statistics and color singlets. For DNA and RNA one would have full multiplet also color non-singlets and for tRNA one could consider $(4 \oplus 2_1 \oplus 2_2) \times 5$ containing 40 states. 31 is the minimum number of tRNAs for the realization of the genetic code. The number of tRNA molecules is known to be between 30-40 in bacterial cells. The number is larger in animal cells but this could be due to different chemical representations of dark tRNA codons.

If the net charge of dark codon distinguishes between DNA,RNA, tRNA, and amino-acid sequences, the natural hypothesis to be tested is that dark ppp, ppn, pnn, and nnn sequences are accompanied by DNA,RNA, tRNA, and amino-acid sequences. The dark beta decays of dark protons proposed to play essential role in the model of cold fusion [?]ould transform dark protons to dark neurons. Peptide backbones are neutral so that dark nnn sequence could be also absent but the dark nnn option is more natural if the general vision is accepted. There is also the chemically equivalent possibility that only dark protons are involved: dark proton + neutral color bond would represent proton and dark proton + negatively charged color bond would represent neutron. At this moment it is not possible to distinguish between these two options.

Is this picture consistent with what is known about charges of amino-acids DNA,RNA, tRNA, and amino-acids? Consider first the charges of these molecules.

(a) DNA strand has one negative charge per nucleotide. Also RNA molecule has high negative charge. This conforms with the idea that dark nucleons accompany both DNA and RNA. DNA codons could be accompanied by dark ppp implying charge neutralization in some scale and RNA codons by dark ppn. The density of negative charge for RNA would be 2/3 for that for DNA.

(b) Arg, His, and Lys have positively charged side chains and Asp,Glu negative side chains (see `https://en.wikipedia.org/wiki/Amino_acid`). The charge state of amino-acid is sensitive to the pH value of solution and its conformation is sensitive to the counter ions present. Total charge for amino-acid in peptide however vanishes unless it is associated with the side chain: as in the case of DNA and RNA it is the backbone whose charge is expected to matter.

(c) Amino-acid has central C atom to which side chain, NH_2, H and COOH are attached. For free amino-acids in solution water solution $NH_2 \rightarrow NH_3^+$ tends to occur pH=2.2 by receiving possibly dark proton whereas COOH tends to become negatively charged above pH= 9.4 by donating proton, which could become dark. In peptide OH attach to C and one H attached to N are replaced with peptide bond. In the pH range 2.2-9.4 amino-acid is zwitterion for which both COOH is negatively charged and NH_2 is replaced with NH_3^+ so that the net charge vanishes. The simplest interpretation is that the ordinary proton from negatively ionized COOH attaches to NH_2 - maybe via intermediate dark proton state.

(d) The backbones of peptide chains are neutral. This conforms with the idea that dark amino-acid sequence consists of dark neutron triplets. Also free amino-acids would be accompanied by dark neutron triplets. If the statistics is ordinary only 4 dark nnn states are possible as also 5 dark color flux tube states.

(e) tRNA could involve dark pnn triplet associated with the codon. An attractive idea is secondary genetic code assigning RNA codons to tRNA-amino-acid complex and projecting $8 \otimes (5 \oplus 3)$ containing 64 dark RNA spin states to $8 \otimes 5$ containing 40 dark tRNA spin states with same total nucleon and flux tube spins. Dark tRNA codons would in turn be attached to dark amino-acids by a tertiary genetic code projecting spin states $8 \otimes 5$ to $4 \otimes 5$ by spin projection. In the transcription dark tRNA would attach to dark mRNA inducing attachment of dark amino-acid to the growing amino-acid sequence and tRNA having only dark tRNA codon would be left. The free amino-acids in the water solution would be mostly charged zwitterions in the pH range 2.2-9.4 and the negative charge of COO^- would be help in the attachement of the free amino-acid to the dark proton of tRNA codon. Therefore also the chemistry of free amino-acids would be important.

An interesting question is why pnn triplets for tRNA would only 5 in flux tube degrees of freedom entire 8 in nucleon degrees of freedom. For RNA consisting of ppn triplets also 3 would be possible. What distinguishes between ppn and pnn?

The model should explain the widely different properties of DNA,RNA , tRNA, and amino-acids. There are two options.

(a) DNA/RNA/amino-acid codons could correspond to ppp/ppn/nnn and tRNA would correspond to pnn (order is not necessarily this). Different charge or dark codons explain why DNA (RNA) has H (OH) in $2'$ position. The repulsive Coulomb energy between dark codons would be stronger for DNA and the compensation of this forces by the magnetic tension associated with the flux tube pair connecting codon and anticodon this might have something to do with the stability of DNA double strand.

   i. The instability of RNA as compared to DNA would result from the instability of the ribose in RNA (deoxiribose in DNA) as indeed believed. The absence of RNA double strands could be due to the instability of the flux tube pair assignable to n-n. This trivially implies absence of replication and transcription if it is based on same mechanism as in the case of DNA.

   ii. pnn structure could explain why tRNA does not form sequences and allow to understand wobble pairing, which states that the third mRNA codon does not correspond to unique tRNA anticodon but one has C,A,U $\rightarrow$ I and U$\rightarrow$ I. Due to the symmetries of the third letter of the codon, this is consistent with the genetic code. The physical explanation for wobble base pairing could relate to pnn structure of tRNA. If the charge ordering is random one would have nnp,npn,pnn and C,A,U $\rightarrow$ I could correspond to these 3 situations whereas for U$\rightarrow$ I the correspondence would not depend on the ordering. Also for RNA one would have ppn,pnp, npp degeneracy but in this case one would have charge independence.
   A possible charge pairing between RNA and tRNA would be p$\leftrightarrow$n. The charge pairing between DNA and RNA could be p $\rightarrow$ n for the third least significant letter of DNA. This would minimize the coding errors possibly induced this pairing.

   iii. One can criticize the charge assignment ppn (possibly allowing permutations) for RNA codons. Could dark weak beta decays give rise to 1-D lattice like structure? Could the repetitive structure be due to energy minimization.

(b) Could the correspondence be letterwise? For DNA A,T,C,G would correspond to p, and for RNA A,C,G to p and U to n. Codons not containing U wold be ppp type codons and one can wonder why the oxiribose for them is not replaced with de-oxiribose. The possible presence of n in dark codons could explain why RNA sequences are highly unstable and why they do not replicate and transcribe.

11.3.2 Replication, transcription, translation

The formation of flux tube pairs between molecules would be central in replication and transcription and in all bio-catalysis. Dark DNA would replicate first to dark DNA or mRNA. This requires that the building bricks of dark DNA and mRNA emerge from environment perhaps by mechanism involving reconnection for the magnetic tentacles and reduction of h_{eff} bringing the molecules near each other. Flux tube pairs between dark DNA codons and and their conjugates (individual dark RNA codons) would be formed during replication (transcription). The formation of flux tube pair between mRNA and dark tRNA part of tRNA would bring tRNA to mRNA, where amino-acid would associate with the growing amino-acid sequence.

For options 1a and 1b based on ordinary statistics color singletness condition could play an important role in the replication and transcription.

(a) If the value of h_{eff} before reconnection and contraction of flux tube dictating the scale of color confinement is large enough, colored dark nucleons could float as free - possibly colored states - in the environment for option 1a). For option 1b dark nucleons could be present in environment - this could relate directly to the ionization in electrolyte. For options 1a and 1b dark codons representing dark tRNA molecules would accompany them.

(b) For options 1a) and 1b) color confinement in flux tube degrees of freedom by forming dark color flux tube pairs between dark DNA and its conjugate in codon-wise manner could give rise to DNA double strands as chemical shadows of dark double strands. The coupling between codon and anticodon would be defined by the condition that the total color bond spins of paired codons are opposite. Quark color could be compensated for option 1a along DNA strand: 3 10:s give singlet. One can of course ask whether dark DNA RNA sequences exist rather than being built during replication and transcription.

11.3.3 Are sound-like bubbles whizzing around in DNA essential to life?

I got a link to a very interesting article [I2] about sound waves in DNA (see `http://tinyurl.com/z7hod9b`). The article tells about THz de-localized modes claimed to propagate forth and back along DNA double strand somewhat like bullets. These modes involve collective motion of many atoms. These modes are interpreted as a change in the stiffness of the DNA double strand leading to the splitting of hydrogen bonds in turn leading to a splitting into single strands. The resulting gap is known as transcriptional bubble propagating along double strand is the outcome. I do not how sound the interpretation as sound wave is.

It has been proposed that sound waves along DNA give rise to the bubble. The local physical properties of DNA double strand such as helical structure and elasticity affect the propagation of the waves. Specific local sequences are proposed to favor a resonance with low frequency vibrational modes, promoting the temperary splitting of the DNA double strand. Inside the bubble the bases are exposed to the surrounding solvent, which has two effects.

Bubbles expose the nucleic acid to reactions of the bases with mutagens in the environment whereas so called molecular intercalators may insert themselves between the strands of DNA. On the other hand, bubbles allow proteins known as helicases to attach to DNA to stabilize the bubble, followed by the splitting the strands to start the transcription and replication process. The splitting would occur at certain portions of DNA double strand. For this reason, it is believed that DNA directs its own transcription.

The problem is that the strong interactions with the surrounding water are expected to damp the sound wave very rapidly. Authors study experimentally the situation and report that propagating bubbles indeed exist for frequencies in few THz region. Therefore the damping deo not seem to be effective. How this is possible? As an innocent layman I also wonder how this kind of mechanism can be selective: it would seem that the bullet like sound wave initiates transcription at many positions along DNA. The transcription should be localized to a region assignable to single gene. What could guarantee this?

Can TGD say anything interesting about the mechanism behind transcription and replication?

(a) In TGD magnetic body controls and coordinates the dynamics. The strongest hypothesis is that basic biochemical process are induced by those for dark variants of basic bio-molecules (dark variants of DNA, enzymes,...). The belief that DNA directs its own transcription translates to the statement that the dark DNA consisting most plausibly from sequences of dark proton triplets ppp at dark magnetic flux tubes controls the transcription: the transcription/replication at the level of dark DNA induces that at the level of ordinary DNA.

(b) If the dark DNA codons represented as dark proton triplets (*ppp*) are connected by 3 flux tube pairs, the reverse of the reconnection should occur and transform flux tube pairs to two U-shaped flux tubes assignable to the two dark DNA strands. Dark proton sequences have positive charge +3e per dark codon giving rise to a repulsive Coulomb force between them. There would be also an attractive force due to magnetic tension of the flux tubes. These two forces would compensate each other in equilibrium (there also the classical forces due to the negatively charged phosphates associated with nucleotides but these would not be so important).

If the flux tube pairs are split, the stabilizing magnetic force however vanishes and the dark flux tubes repel each other and force the negatively charged DNA strands to follow so that also ordinary DNA strand splits and bubble is formed. The primary wave could therefore be the splitting of the flux tube pairs: whether one can call it as a sound wave is not clear to me. Perhaps the induced propagating splitting of ordinary DNA double strand could be regarded as an analog of sound wave.

The splitting of flux tube pairs for a segment of DNA would induces a further splitting of flux tubes since repulsive Coulomb force tends to drive the flux tubes further away. The process could be restricted to DNA if the "upper" end of the split DNA region has some dark DNA codons which are not connected by flux tubes pairs. This model reason why for dark proton sequences.

(c) This model does not yet explain how the propagating splitting wave is initiated. Could a quantum phase transition increasing the value of h_{eff} associated with the flux tube pairs occur for some minimal portion of dark DNA "below" the region associated with gene and lead to the propagating wave induced by the above classical mechanism? That the wave propagates in one direction only could be due to chirality of DNA double helix.

An interesting question is how the RNA world vision (see `https://en.wikipedia.org/wiki/RNA_world`) relates to this general picture.

(a) There are strong conditions on the predecessor of DNA and RNA satisfies many of them: reverse transcription to DNA making possible transition to DNA dominated era is possible. Double stranded RNA exists `https://en.wikipedia.org/wiki/RNA#Double-stranded_RNA` in cells and makes possible RNA genome: this would however suggest that cell membrane came first. RNA is a catalyst. RNA has ability to conjugate an amino-acid to the $3'$ end of RNA and RNA catalyzes peptide bond formation essential for translation. RNA can self-replicate but only relatively short sequences are produced.

(b) TGD picture allows to understand why only short sequences of RNA are obtained in replication. If the replication occurs at the level of dark ppn sequences as it would occur for DNA in TGD framework, long RNA sequences might be difficult to produce because of the stopping of the propagation of the primary wave splitting the flux tube pairs. This could be due to the neuron pairs to which there is associated no Coulomb repulsion essential for splitting.

(c) In TGD framework RNA need not be the predecessor of DNA since the evolution would occur at the level of dark nucleon strings and DNA as the dark proton string is the simpest dark nucleon string and might have emerged first. Dark nuclear strings would have served as templates and biomolecules would have emerged naturally via the transcription of their dark counterparts to corresponding bio-polymers.

11.3.4 Is bio-catalysis a shadow of dark bio-catalysis based on generalization of genetic code?

Protein catalysis and reaction pathways look extremely complex (see http://tinyurl.com/kp3sdlm) as compared to replication, transcription, translation, and DNA repair. Could simplicity emerge if biomolecules are identified as chemical shadows of objects formed from dark nuclear strings consisting of dark nucleon triplets and their dynamics is shadow of dark stringy dynamics very much analogous to text processing?

What if bio-catalysis is induced by dark catalysis based on reconnection as recognition mechanism? What if contractions and expansions of U-shaped flux tubes by h_{eff} increasing phase transitions take that reactants find each other and change conformations as in the case of opening of DNA double strand? What if codes allowing only the dark nucleons with same dark nuclear spin and flux tubes spin to be connected by a pair of flux tubes?

This speculation might make sense! The recognition of reactants is one part of catalytic action. It has been found in vitro RNA selection experiments that RNA sequences are produced having high frequency for the codons which code for the amino-acid that these RNA molecules recognize (http://tinyurl.com/kp3sdlm. This is just what the proposal predicts!

Genetic codes DNA to RNA as $64 \rightarrow 64$ map, RNA to tRNA as $64 \rightarrow 40$, tRNA to amino-acids with $40 \rightarrow 20$ map are certainly not enough. One can however consider also additional codes allowed by projections of $(4 \oplus 2_1 \oplus 2_2) \otimes (5 \oplus 3(\oplus 1))$ to lower-dimensional sub-spaces defined by projections preserving spins. One could also visualize bio-molecules as collections of pieces of text attaching to each other along conjugate texts. The properties of catalysts and reactants would also depend by what texts are "visible" to the catalysts. Could the most important biomolecules participating biochemical reactions (proteins, nucleic acids, carbohydrates, lipids, primary and secondary metabolites, and natural products, see https://en.wikipedia.org/wiki/Biomolecule) have dark counterparts in these sub-spaces.

The selection of bio-active molecules is one of the big mysteries of biology. The model for the chemical pathway leading to the selection of purines as nucleotides [L13] assumes that the predecessor of purine molecule can bind to dark proton without transforming it to ordinary proton. A possible explanation is that the binding energy of the resulting bound state is higher for dark proton than the ordinary one. Minimization of the bound state energy could be a completely general criterion dictating which bio-active molecules can pair with dark protons. The selection of bio-active molecules would not be random after all although it looks so. The proposal for DNA-nuclear/cell membrane as topological quantum computer with quantum computations coded by the braiding of magnetic flux tubes connecting nucleotides to the lipids wlead to the idea that flux tubes being at O=-bonds [K3].

11.3.5 Comparing TGD view about quantum biology with McFadden's views

McFadden [I4] has very original view about quantum biology: I have written about his work for the first time for years ago, much before the emergence of ZEO, of the recent view about self as generalized Zeno effect, and of the understanding the role of magnetic body containing dark matter [K5]. The pleasant surprise was that I now understand McFadden's views much better from TGD viewpoint.

(a) McFadden sees decoherence as crucial in biological evolution: here TGD view is diametric opposite although decoherence is a basic phenomenon also in TGD.

(b) McFadden assumes quantum superpositions of different DNAs. To me this looks an unrealistic assumption in the framework of PEO. In ZEO it is quite possible option.

(c) McFadden emphasizes the importance of Zeno effect (in PEO). In TGD the ZEO variant of Zeno effect is central for TGD inspired theory of consciousness and quantum biology. Mc Fadden suggests that quantum effects and Zeno effect are central in bio-catalysis: the repeated measurement keeping reactants in the same position can lead to an increase of reaction rate by factors of order billion. McFadden describe enzymes as quantum mousetraps catching the reactants and forcing them to stay in same position. The above description for how catalysis catches the reactants using U-shaped flux tube conforms with mousetrap picture.

McFadden discusses the action of enzymes in a nice manner and his view conforms with TGD view. In ZEO the system formed by catalyst plus reactants could be described as a negentropically entangled sub-self, and self indeed corresponds to a generalized Zeno effect. The reactions can proceed in shorter scales although the situation is fixed in longer scales (hierarchy of CDs): this would increase the length of the period of time during which reactions can proceed and lead to catalytic effect. Zeno effect in ZEO plus hierarchies of selves and CDs would be essentially for the local aspects of enzyme action.

(d) Protons associated with hydrogen bonds and electronic Cooper pairs play a universal role in McFadden's view and the localization of proton in quantum measurement of its position to hydrogen bond is the key step of enzyme catalysis. Also TGD dark protons at magnetic flux tubes giving rise to dark nuclear strings play a key role. For instance, McFadden models enzyme catalysis as injection of proton to a very special hydrogen bond of substrate. In TGD one has dark protons at magnetic flux tubes and their injection to a properly chosen hydrogen bond and transformation to ordinary proton is crucial for the catalysis. Typical places for reactions to occur are C=O type bonds, where the transition to C-OH can occur and would involve transformation of dark proton to ordinary proton. The transformation of dark proton to ordinary one or vice versa in hydrogen bonds would serve as a biological quantum switch allowing magnetic body to control biochemistry very effectively.

What about electronic Cooper pairs assumed also by McFadden. They would flow along the flux tube pairs. Can Cooper pairs of electrons and dark protons reside at same flux tubes? In principle this is possible although I have considered the possibility that particles with different masses (cyclotron frequencies) reside at different flux tubes.

McFadden [I4] has proposed quantum superposition for ordinary codons: This does not seem to make sense in PEO since the chemistries of codons are different) but could make sense in ZEO. In TGD one could indeed imagine quantum entanglement (necessary negentropic in p-adic degrees of freedom) between dark codons. This NE could be either between additional degrees of freedom or between spin degrees of freedom determining the dark codons. In the latter case complete correlation between dark and ordinary DNA codons would imply also the superposition of their tensor products with ordinary codons.

The NE between dark codons could also have a useful function: it could determine physically gene as a union of disjoint mutually entangled portions of DNA. Genes are known to be highly dynamical units, and after pre-transcription splicing selects the portions of the transcript translated to protein. The codons in the complement of the real transcript are called introns and are spliced out from mRNA after the pre-transcription (see `https://en.wikipedia.org/wiki/RNA_splicing`).

What could be the physical criterion telling whether a given codon belongs to exonic or intronic portion of DNA? A possible criterion distinguish between exons and introns is that exons have NE between themselves and introns have no entanglement with exons (also exons could have NE between themselves). Introns would not be useless trash since the division into exonic and exonic region would be dynamical. The interpretation in terms of TGD inspired theory of consciousness is that exons correspond to single self.

11.3.6 Is there a connection between geometric model of harmony and nuclear string model of genetic code?

There should exists a connection between the geometric model of harmony and genetic code and the model of genetic code discussed.

(a) Dark DNA strands could be connected by color flux tubes to form a double strand by reconnections of U-shaped color flux tubes. What would induce a codon-wise or letter-wise pairing of DNA codons and their conjugates represented as dark quark triplets to form double DNA strand? Cyclotron resonance could accompany reconnection (magnetic field strength would be identical and reconnection could occur).

(b) One has the correspondence codon $\leftrightarrow$ state of dark nucleon or codon $\leftrightarrow$ state of dark nucleon triplet. The geometric model of harmony and genetic code [L4] represents the codons as 3-chords. The 3-chord would be represented in terms of cyclotron frequencies of dark photons assignable to the 3 dark quarks (nucleons) in the state. Each quark-color bond pair (including the pion-like bond) could be in 12 states with corresponding cyclotron frequency mappable to the basic octave. The cyclotron frequency triplets would be same for codons and conjugates. The only manner to understand the scale is in terms of spectrum of magnetic field strengths for U-shaped flux tube pairs.

This would require 3 pairs of flux tubes between the dark codons of DNA strands. If the quarks inside linear dark proton are connected by color flux tubes (like protons in the model of dark nucleus). Reconnection for U-shaped flux tube connecting quarks would give rise to the double strand formed by dark proton strings. The magnetic field strength of the 3-flux tubes would be determined by the state of dark proton and would be same for DNA and RNA codons and also for RNA codons and corresponding tRNA-amino-acid complexes. The cyclotron frequencies would define a scaled up variant of Pythagorean scale projected to the basic octave [L4]. This option does not favor the idea about separater 4-letter code.

(c) The geometric model for harmony is formulated in terms of orbits of the subgroups of the isometry groups of tetrahedral and icosahedral geometries. The DNAs coding particular amino-acid correspond correspond to the orbit of the triangle of icosahedron corresponding to the amino-acid. The decomposition $60 \rightarrow 20 + 20 + 20$ suggests strongly decomposition of I to 20 Z_3 cosets containing 3 elements each other and in correspondences with the triangular faces of icosahedron.

(d) The model of the genetic code just discussed relies on the model of dark nucleon based on group theory. The symmetric groups of Platonic solids are in turn associated with inclusion of hyper-finite factors and appear in Mc Kay correspondence, whose proof involves decompositions of SU(2) representations to the representations of the discrete subgroups of Platonic solids. A further observation is that the numbers of elements for isometries of icosahedron and tetrahedron are 60 and 4 respectively: the sum is 64. Could the action of Z_3 leaving face invariant could be posed as an additional condition on amino-acids and reduce the amino-acid representation to $4 \otimes 5$.

(e) In the geometric model of harmony genetic icosahedral 20+20+20 part of the code involves a combination of three different Hamilton's cycles mapping 60 DNAs to 20 amino-acids: in terms of icosahedral group I and its coset space I/Z_3 these maps correspond to coset projections. Could the decomposition $(4\oplus 2_1 \oplus 2_2)\otimes(5\otimes 3)$ be understood in terms of a reduction to icosahedral and tetrahedral subgroups of rotation group or of their spin coverings.

In this process finite-dimensional representation of $SO(3)$ decomposes to a direct sum of representations of the discrete subgroup if its dimension is larger than any of the dimensions of representations of the finite sub-group (for basic facts about these see `http://tinyurl.com/ho4onbs`). One might hope that the decomposition of the representations of SO(3) appearing in the above formula under icosahedral group and or tetrahedral group could allow to understand the emergence of DNA, RNA, tRNA, and amino-acids as kind of symmetry breaking.

(f) In the geometric model of harmony 64-codon code [L4] is obtained as a fusion 60-codon code assignable to icosahedron + 4 codon code assignable to tetrahedron. There are actually two codes corresponding to tetrahedron and icosahedron as disjoint entities and tetrahedron glued to icosahedron along one face. The model explains the two additional amino-acids Pyl and Sec coded for a variant of the genetic code.

How could these two successful models relate to each other? In p-adic physics of cognition Platonic solids and polygons can be seen as discrete approximation for sphere [L14] and biomolecules could be understood as cognitive representation in the intersection of real and p-adic space-time surface consisting of algebraic points. Could one assign icosahedron and tetrahedron to a codon in some concrete manner? Could the attachment of tetrahedron to icosahedron along one face have concrete meaning? The answer seems to be negative.

(a) One can about the interpretation of the 12 vertices of the icosahedron - how number 12 could be assigned with the genetic code? The vertices correspond to notes perhaps represented as magnetic field strength at the flux tubes assignable to color bonds. This field strength should be determined by the spin state of dark 3-nucleon. No concrete nuclear string counterpart seems to exist for the closed Hamiltonian cycle consisting of 12 notes and in case of tetrahedral extension of 13 notes. 12 vertices of icosahedron correspond to 12 notes and 20 faces to 3-chords so that there is not need for more concrete correspondence.

(b) The attachment of tetrahedron to icosahedron would bring in further note very near to one of the notes of Pythagorean scale and corresponding 3-chords. This has concrete interpretation and there is no need to make this more concrete at the level of geometry of DNA. If icosahedron and tetrahedron are disjoint one obtains four additional codons. It seems that all these 4 3-chords be assigned with the 3 color bonds, one note for each of them. What distinguishes at the level of dark nucleon string the situations in which tetrahedron is attached and non-attached to the color bond? In presence of attachment there would be 1 shared 3-chord corresponding to stop codon assignable with the shared face. The 13:th note appearing in 4 3-chords differs very little from one of the notes of the icosahedral scale: this corresponds to the fact that 12 perfect quints do not quite give 7 octaves as already Pythagoras realized. Crazy question: Could this small difference relate to the small relative mass difference $(m_p - m_n)/m_p \simeq .0014$ making itself possible visible in cyclotron frequency scale? The idea does not seem plausible: $[(3/2)^{12} - 2^7]/2^7 \simeq .014$ is 10 times larger than $(m_p - m_n)/m_p \simeq .0014$.

The conclusion is that genetic code can be understand as a map of stringy nucleon states induced by the projection of all states with same spin projections to a representative state with the same spin projections (total quark spin and total flux tube spin). Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin.

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