Cold fusion, low energy nuclear reactions, or dark nuclear synthesis?

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Abstract

Steven Krivit has written three books about the history of cold fusion/low energy nuclear reactions (LENR). These books provide excellent overall view about the subject and inspired to develop further the TGD inspired model of cold fusion (as I have called the phenomenon for historical reasons) at more detailed level and compare it to Widom-Larsen model (WL). WL has three questionable assumptions. The basic idea is that proton is transformed to neutron by weak interactions so that Coulomb wall disappears. Large renormalization of electron mass is required to make $e + p \rightarrow n + \nu$ kinematically possible. The extremely low $p \rightarrow n$ beta decay rate must be somehow compensated in the rate for the absorption of neutron by target nucleus. This is achieved by assuming ultraslow neutrons. This in turn requires extreme fine tuning of renormalized electron mass. One also assumes that gamma rays, which are not detected, are transformed to infrared radiation and therefore not seen.

Surprisingly, the basic prediction of Widom-Larsen model about $(A, Z) \rightarrow (A+1, Z+1) \rightarrow$ .. follows trivially from TGD inspired model in which dark nuclei with binding energy scale much lower than for ordinary nuclei are formed as sequences consisting of ordinary protons, deuterons or even heavier nuclei, which then transform to ordinary nuclei and liberate nuclear binding energy. This occurs at negatively charged surfaces (that of cathode for instance) since they attract positively charged flux tubes. The energy scale of dark variants of gamma rays is considerably smaller than that of gamma rays. The questionable assumptions of WL are not needed.

The new information provided by the first book of Krivit allows to develop a detailed model for the transformation of dark nuclei to ordinary ones. This data allows also to refine the nuclear string model giving connections with various anomalies such as X boson anomaly.

Contents

1 Introduction

Steven Krivit has written three books or one book in three parts [C11, C10, C12] - as you wish - about cold fusion (shortly CF in the sequel) - or low energy nuclear reaction (LENR) - which is the prevailing term nowadays and preferred by Krivit. The term "cold fusion" can be defended only by historical reasons: the process cannot be cold fusion. LENR relies on Widom-Larsen model (WL) trying to explain the observations using only the existing nuclear and weak interaction physics. Whether LENR is here to stay is still an open question. TGD suggests that even this interpretation is not appropriate: the nuclear physics involved would be dark and associated with $h_{eff} = n \times h$ phases of ordinary matter having identification as dark matter. Even the term "nuclear transmutation" would be challenged in TGD framework and "dark nuclear synthesis" looks a more appropriate term.

The books were a very pleasant surprise for many reasons, and I have been able to develop my own earlier overall view by adding important details and missing pieces and allowing to understand the relationship to Widom-Larsen model (WL).

1.1 What the books are about?

There are three books.

"Hacking the atom: Explorations in Nuclear Research, vol I" (see `http://tinyurl.com/yb2zxpmy`) considers the developments between 1990-2006. The first key theme is the tension between two competing interpretations. On one hand, the interpretation as CF involving necessarily new physics besides ordinary nuclear fusion and plagued by a direct contradiction with the expected signatures of fusion processes, in particular those of $D + D \rightarrow^4 He$. On the other hand, the interpretation as LENR in the framework of WL in which no new physics is assumed and neutrons and weak interactions are in a key role.

Second key theme is the tension between two competing research strategies.

(a) The first strategy tried to demonstrate convincingly that heat is produced in the process - commercial applications was the basic goal. This led to many premature declarations about solution of energy problems within few years and provided excellent weapons for the academic world opposing cold fusion on basis of textbook wisdom.

(b) Second strategy studied the reaction products and demonstrated convincingly that nuclear transmutations (isotopic shifts) took place. This aspect did not receive attention in public and the attempts to ridiculize have directed attention to the first approach and to the use of the term "cold fusion".

According to Krivit, CF era ended around 2006, when Widom and Larsen proposed their model in which LENR would be the mechanism [C15, C2, C1, C13, C14]. Widom-Larsen model (WL) can be however criticized for some un-natural looking assumptions: electron is required to have renormalized mass considerably higher than the real mass; the neutrons initiating nuclear reactions are assumed to have ultralow energies below thermal energy of target nuclei. This requires electron mass to be larger but extremely near to neutron-proton mass difference. The gamma rays produced in the process are assumed to transform to infrared radiation.

To my view, WL is not the end of the story. New physics is required. For instance, the work of professor Holmlid and his team [C3, L5] has provided new fascinating insights to what might be the mechanism of what has been called nuclear transmutations.

"Fusion Fiasco: Explorations in Nuclear Research, vol II" (see `http://tinyurl.com/ybtvwlyz`) discusses the developments during 1989 when cold fusion was discovered by Fleischman and Pons [C7] and interpreted as CF. It soon turned out that the interpretation has deep problems and CF got the label of pseudoscience.

"Lost History: Explorations in Nuclear Research, vol III" (see `http://tinyurl.com/ybxrsvqk`) tells about surprisingly similar sequence of discoveries, which has been cleaned away from history books of science because it did not fit with the emerging view about nuclear physics and condensed matter physics as completely separate disciplines. Although I had seen some remarks about this era I had not not become aware what really happened. It seems that discoveries can be accepted only when the time is mature for them, and it is far from clear whether the time is ripe even now.

What I say in the sequel necessarily reflects my limitations as a dilettante in the field of LENR/CF. My interest on the topic has lasted for about two decades and comes from different sources: LENR/CF is an attractive application for the unification of fundamental interactions that I have developed for four decades now. This unification predicts a lot of new physics - not only in Planck length scale but in all length scales - and it is of course fascinating to try to understand LENR/CF in this framework.

For instance, while reading the book, I realized that my own references to the literature have been somewhat random and not always appropriate. I do not have any systematic overall view about what has been done in the field: here the book makes wonderful service. It was a real surprise to find that first evidence for transmutation/isotope shifts emerged already for about century ago and also how soon isotope shifts were re-discovered after Pons-Fleischman discovery [C7]. The insistence on $D + D \rightarrow^4 He$ fusion model remains for an outsider as mysterious as the refusal of mainstream nuclear physicists to consider the possibility of new nuclear physics. One new valuable bit of information was the evidence that it is the cathode material that transforms to the isotope shifted nuclei: this helped to develop my own model in more detail.

Remark: A comment concerning the terminology. I agree with the author that cold fusion is not a precise or even correct term. I have myself taken CF as nothing more than a letter sequence and defended this practice to myself as a historical convention. My conviction is that the phenomenon in question is not a nuclear fusion but I am not at all convinced that it is LENR either. Dark nucleosynthesis is my won proposal.

1.2 What did I learn from the books?

Needless to say, the books are extremely interesting, for both layman and scientist - say physicist or chemist, or anyone involved in developing new energy technologies. The books provide a very thorough view about the history of the subject. There is also an extensive list of references to the literature. Since I am not an experimentalist and feel myself a dilettante in this field as a theoretician, I am unable to check the correctness and reliability of the data represented. In any case, the overall view is consistent with what I have learned about the situation during years. My opinion about WL is however different.

I have been working with ideas related to CF/LENR (or nuclear transmutations) but found books provided also completely new information and I became aware about some new critical points.

I have had a rather imbalanced view about transmutations/isotopic shifts and it was a surprise to see that they were discovered already 1989 when Fleisch and Pons published their work [C7]. Even more, the premature discovery of transmutations for century ago (1910-1930) interpreted by Darwin as a collective effect, was new to me. Articles about transmutations were published in prestigious journals like Nature and Naturwissenschaften. The written history is however history of winners and all traces of this episode disappeared from the history books of physics after the standard model of nuclear physics assuming that nuclear physics and condensed matter physics are totally isolated disciplines. The developments after the establishment of standard model relying on GUT paradigm looks to me surprisingly similar.

Sternglass - still a graduate student - wrote around 1947 to Einstein about his preliminary ideas concerning the possibility to transform protons to neutrons in strong electric fields. It became as a surprise to Sternglass that Einstein supported his ideas. I must say that this increased my respect of Einstein even further. Einstein's physical intuition was marvellous. In 1951 Sternglass found that in strong voltages in keV range protons could be transformed to neutrons with unexpectedly high rate. This is strange since the process is kinematically impossible for free protons: it however can be seen as support for WL model.

Also scientists are humans with their human weaknesses and strengths and the history of CF/LENR is full of examples of both light and dark sides of human nature. Researchers are fighting for funding and the successful production of energy was also the dream of many people involved. There were also people, who saw CF/LENR as a quick manner to become millionaire. Getting a glimpse about this dark side was rewarding. The author knows most of the influential people, who have worked in the field and this gives special authenticity to the books.

It was a great service for the reader the basic view about what happened was stated clearly in the introduction. I noticed also that with some background one can pick up any section and start to read: this is a service for a reader like me. I would have perhaps divided the material into separate parts but probably your less bureaucratic choice leaving room for surprise is better after all.

Who should read these books? The books would be a treasure for any physicist ready to challenge the prevailing prejudices and learn about what science is as seen from the kitchen side. Probably this period will be seen in future as very much analogous to the period leading to the birth of atomic physics and quantum theory. Also layman could enjoy reading the books, especially the stories about the people involved - both scientists and those funding the research and academic power holders - are fascinating. The history of cold fusion is a drama in which one can see as fight between Good and Evil and eventually realize that also Good can divide into Good and Evil. This story teaches about a lot about the role of egos in all branches of sciences and in all human activities. Highly rationally behaving science professionals can suddenly start to behave completely irrationally when their egos feel being under threat.

My hope is that the books could wake up the mainstream colleague to finally realize that CF/LENR or - whatever you wish to call it - is not pseudoscience. Most workers in the field are highly competent, intellectually honest, an have had so deep passion for understanding Nature that they have been ready to suffer all the humiliations that the academic hegemony can offer for dissidents. The results about nuclear transmutations are genuine and pose a strong challenge for the existing physics, and to my opinion force to give up the naive reductionistic paradigm. People building unified theories of physics should be keenly aware of these phenomena challenging the reductionistic paradigm even at the level of nuclear and condensed matter physics.

1.3 The problems of WL

For me the first book representing the state of CF/LENR as it was around 2004 was the most interesting. In his first book Krivit sees 1990-2004 period as a gradual transition from the cold fusion paradigm to the realization that nuclear transmutations occur and the fusion model does not explain this process.

The basic assumption of the simplest fusion model was that the fusion $D + D \rightarrow^4 He$ explains the production of heat. This excluded the possibility that the phenomenon could take place also in light water with deuterium replaced with hydrogen. It however turned out that also ordinary water allows the process. The basic difficulty is of course Coulomb wall but the model has also difficulties with the reaction signatures and the production rate of ^4He is too low to explain heat production. Furthermore, gamma rays accompanying ^4He production were not observed. The occurrence of transmutations is a further problem. Production of Li was observed already in 1989, and later russia trio Kucherov, Savvatinova, Karabut detected tritium, ^4He, and of heavy elements [C8]. They also observed modifications at the surface of the cathode down to depth of .1-1 micrometers.

Krivit sees LENR as a more realistic approach to the phenomena involved. In LENR Widom-Larsen model (WL) is the starting point [C15, C2, C1, C13, C14]. This would involve no new nuclear physics. I also see WL as a natural starting point but I am skeptic about understanding

CF/LENR in term of existing physics. Some new physics seems to be required and I have been doing intense propaganda for a particular kind of new physics [K4].

WL assumes that weak process proton (p)$\rightarrow$ neutron (n) occurring via $e+p \rightarrow n+\nu$ (e denotes electron and ν for neutrino) is the key step in cold fusion. After this step neutron finds its way to nucleus easily and the process continues in conventional sense as analog of r-process assumed to give rise to elements heavier than iron in supernova explosions and leads to the observed nuclear transmutations. Essentially one proton is added in each step decomposing to four sub-steps involving beta decay $n \rightarrow p$ and its reversal.

There are however problems.

1. Already the observations of Sternglass suggest that $e+p \rightarrow n+\nu$ occurs. $e+p \rightarrow n+\nu$ is however kinematically impossible for free particles. e should have considerably higher effective mass perhaps caused by collective many-body effects. $e+p \rightarrow n+\nu$ could occur in the negatively charged surface layer of cathode provided the sum of the rest masses of e and p is larger than that of n. This requires rather large renormalization of electron mass claimed to be due to the presence of strong electric fields. Whether there really exists a mechanism increasing the effective mass of electron, is far from obvious and strong nuclear electric fields are proposed to cause this.

2. Second problematic aspect of WL is the extreme slowness of the rate of beta decay transforming proton to neutron. For ultraslow neutrons the cross section for the absorption of neutron to nucleus increases as $1/v_{rel}$, v_{rel} the relative velocity, and in principle could compensate the extreme slowness of the weak decays. The proposal is that neutrons are ultraslow. This is satisfied if the sum of rest masses is only slightly larger than proton mass. One would have $m_E \simeq m_n - m_p \Delta E_n$, where ΔE_n is the kinetic of neutron. To obtain correct order of magnitude for the rate of neutron absorptions ΔE_n should be indeed extremely small. One should have $\Delta E = 10^{-12}$ eV and one has $\Delta E/m_p = 10^{-21}$! This requires fine tuning and it is difficult to believe that the electric field causing the renormalization could be so precisely fine-tuned.

   ΔE corresponds to extremely low temperature about 10^{-8} K hard to imagine this at room temperature. Thermal energy of the target nucleus at room temperature is of the order $10^{-11} A m_p$, A mass number. Hence it would seem that the thermal motion of the target nuclei mask the effect.

3. One should also understand why gamma rays emitted in the ordinary nuclear interactions after neutron absorption are not detected. The proposal is that gamma rays somehow transform to infrared photons, which would cause the heating. This would be a collective effect involving quantum entanglement of electrons. One might hope that by quantum coherence the neutron absorption rate could be proportional to N^2 instead of N, where N is the number of nuclei involved. This looks logical but I am not convinced about the physical realizability of this proposal.

To my opinion these objections are really serious.

2 Comparison with TGD inspired models of CF/LENR or whatever it is

I cannot avoid the temptation to compare WL to my own dilettante models for which also WL has served as an inspiration. I have two models explaining these phenomena in my own TGD Universe. Both models rely on the hierarchy of Planck constants $h_{eff} = n \times h$ [K5, K1] explaining dark matter as ordinary matter in $h_{eff} = n \times h$ phases emerging at quantum criticality. h_{eff} implies scaled up Compton lengths and other quantal lengths making possible quantum coherence is longer scales than usually.

The hierarchy of Planck constants $h_{eff} = n \times h$ has now rather strong theoretical basis and reduces to number theory [L8, L9]. Quantum criticality would be essential for the phenomenon and could explain the critical doping fraction for cathode by D nuclei. Quantum criticality could help to explain the difficulties to replicate the effect.

2.1 Simple modification of WL does not work

The first model is a modification of WL and relies on dark variant of weak interactions. In this case LENR would be appropriate term.

1. Concerning the rate of the weak process $e + p \to n + \nu$ the situation changes if h_{eff} is large enough and rather large values are indeed predicted. h_{eff} could be large also for weak gauge bosons in the situation considered. Below their Compton length weak bosons are effectively massless and this scale would scale up by factor $n = h_{eff}/h$ to almost atomic scale. This would make weak interactions as strong as electromagnetic interactions and long ranged below the Compton length and the transformation of proton to neutron would be a fast process. After that a nuclear reaction sequence initiated by neutron would take place as in WL. There is no need to assume that neutrons are ultraslow but electron mass remains the problem. Note that also proton mass could be higher than normal perhaps due to Coulomb interactions.

2. As such this model does not solve the problem related to the too small electron mass. Nor does it solve the problem posed by gamma ray production.

2.2 Dark nucleosynthesis

Also second TGD inspired model involves the h_{eff} hierarchy. Now LENR is not an appropriate term: the most interesting things would occur at the level of dark nuclear physics, which is now a key part of TGD inspired quantum biology.

1. One piece of inspiration comes from the exclusion ones (EZs) of Pollack [L1] [L1], which are negatively charged regions [K4] [L2, L4]. Also the work of the group of Prof. Holmlid [C3, L5] not yet included in the book of Krivit was of great help. TGD proposal [L2, L5] is that protons causing the ionization go to magnetic flux tubes having interpretation in terms of space-time topology in TGD Universe. At flux tubes they have $h_{eff} = n \times h$ and form dark variants of nuclear strings, which are basic structures also for ordinary nuclei but would have almost atomic size scale now.

2. The sequences of dark protons at flux tubes would give rise to dark counterparts of ordinary nuclei proposed to be also nuclear strings but with dark nuclear binding energy, whose scale is measured using as natural unit MeV/n, $n = h_{eff}/h$, rather than MeV. The most plausible interpretation is that the field body/magnetic body of the nucleus has $h_{eff} = n \times h$ and is scaled up in size. $n = 2^{11}$ is favoured by the fact that from Holmlid's experiments the distance between dark protons should be about electron Compton length.

   Besides protons also deuterons and even heavier nuclei can end up to the magnetic flux tubes. They would however preserve their size and only the distances between them would be scaled to about electron Compton length on basis of the data provided by Holmlid's experiments [C3, L5].

   The reduced binding energy scale could solve the problems caused by the absence of gamma rays: instead of gamma rays one would have much less energetic photons, say X rays assignable to $n = 2^{11} \simeq m_p/m_e$. For infrared radiation the energy of photons would be about 1 eV and nuclear energy scale would be reduced by a factor about $10^{-6} - 10^{-7}$: one cannot exclude this option either. In fact, several options can be imagined since entire spectrum of h_{eff} is predicted. This prediction is a testable.

   Large h_{eff} would also induce quantum coherence is a scale between electron Compton length and atomic size scale.

3. The simplest possibility is that the protons are just added to the growing nuclear string. In each addition one has $(A, Z) \to (A + 1, Z + 1)$. This is exactly what happens in the mechanism proposed by Widom and Larsen for the simplest reaction sequences already explaining reasonably well the spectrum of end products.

In WL the addition of a proton is a four-step process. First $e + p \rightarrow n + \nu$ occurs at the surface of the cathode. This requires large electron mass renormalization and fine tuning of the electron mass to be very nearly equal but higher than $n - p$ mass difference.

There is no need for these questionable assumptions of WL in TGD. Even the assumption that weak bosons correspond to large h_{eff} phase might not be needed but cannot be excluded with further data. The implication would be that the dark proton sequences decay rather rapidly to beta stable nuclei if dark variant of $p \rightarrow n$ is possible.

4. EZs and accompanying flux tubes could be created also in electrolyte: perhaps in the region near cathode, where bubbles are formed. For the flux tubes leading from the system to external world most of the fusion products as well as the liberated nuclear energy would be lost. This could partially explain the poor replicability for the claims about energy production. Some flux tubes could however end at the surface of catalyst under some conditions. Flux tubes could have ends at the catalyst surface. Even in this case the particles emitted in the transformation to ordinary nuclei could be such that they leak out of the system and Holmlid's findings indeed support this possibility.

   If there are negatively charged surfaces present, the flux tubes can end to them since the positively charged dark nuclei at flux tubes and therefore the flux tubes themselves would be attracted by these surfaces. The most obvious candidate is catalyst surface, to which electronic charge waves were assigned by WL. One can wonder whether already Tesla observed in his experiments the leakage of dark matter to various surfaces of the laboratory building. In the collision with the catalyst surface dark nuclei would transform to ordinary nuclei releasing all the ordinary nuclear binding energy. This could create the reported craters at the surface of the target and cause ehating. One cannot of course exclude that nuclear reactions take place between the reaction products and target nuclei. It is quite possible that most dark nuclei leave the system.

   It was in fact Larsen, who realized that there are electronic charge waves propagating along the surface of some catalysts, and for good catalysts such as Gold, they are especially strong. This would suggests that electronic charge waves play a key role in the process. The proposal of WL is that due to the positive electromagnetic interaction energy the dark protons of dark nuclei could have rest mass higher than that of neutron (just as in the ordinary nuclei) and the reaction $e + p \rightarrow n + \nu$ would become possible.

5. Spontaneous beta decays of protons could take place inside dark nuclei just as they occur inside ordinary nuclei. If the weak interactions are as strong as electromagnetic interactions, dark nuclei could rapidly transform to beta stable nuclei containing neutrons: this is also a testable prediction. Also dark strong interactions would proceed rather fast and the dark nuclei at magnetic flux tubes could be stable in the final state. If dark stability means same as the ordinary stability then also the isotope shifted nuclei would be stable. There is evidence that this is the case.

Neither "CF" nor "LENR" is appropriate term for TGD inspired option. One would not have ordinary nuclear reactions: nuclei would be created as dark proton sequences and the nuclear physics involved is in considerably smaller energy scale than usually. This mechanism could allow at least the generation of nuclei heavier than Fe not possible inside stars and supernova explosions would not be needed to achieve this. The observation that transmuted nuclei are observed in four bands for nuclear charge Z irrespective of the catalyst used suggest that catalyst itself does not determined the outcome.

One can of course wonder whether even "transmutation" is an appropriate term now. Dark nucleosynthesis, which could in fact be the mechanism of also ordinary nucleosynthesis outside stellar interiors explain how elements heavier than iron are produced, might be more appropriate term.

3 More about dark nucleosynthesis

In the sequel a more detailed view about dark nucleosynthesis is developed using the information provided by the first book of Krivit. This information allows to make also the nuclear string model much more detailed and connect CF/LENR with co called X boson anomaly and other nuclear anomalies.

3.1 Not only sequences of dark protons but also of dark nucleons are involved

Are only dark protons sequences at magnetic flux tubes involved or can these sequences consists of nuclei so that one would have nucleus consisting of nuclei? From the first book I learned, that the experiments of Urutskoev [D1] demonstrate that there are 4 peaks for the production rate of elements as function of atomic number Z. Furthermore, the amount of mass assignable to the transmuted elements is nearly the mass lost from the cathode. Hence also cathode nuclei should end up to flux tubes.

1. Entire target nuclei can become dark in the sense described and end up to the same magnetic flux tubes as the protons coming from bubbles of electrolyte, and participate in dark nuclear reactions with the incoming dark nuclei: the dark nuclear energy scale would be much smaller than MeV. For heavy water electrolyte D must become dark nucleus: the distance between p and n inside D would be usual. A natural expectation is that the flux tubes connect the EZs and cathode.

   In the transformation to ordinary nuclear matter these nuclei of nuclei would fuse to ordinary nuclei and liberate nuclear energy associated with the formation of ordinary nuclear bonds.

2. The transformation of protons to neutrons in strong electric fields observed already by Sternglass in 1951 could be understood as a formation of flux tubes containing dark nuclei and producing neutrons in their decays to ordinary nuclei. The needed voltages are in kV range suggesting that the scale of dark nuclear binding energy is of order keV implying $h_{eff}/h = n \sim 2^{11}$ - roughly the ratio m_p/m_e.

3. Remarkably, also in ordinary nuclei the flux tubes connecting nucleons to nuclear string would be long, much longer than the nucleon Compton length [K3] btartXboson. By ordinary Uncertainty Principle ($h_{eff} = h$) the length of flux tube to which binding energy is assigned would correspond to the size of nuclear binding energy scale of order few MeV. This would be also the distance between dark $h_{eff} = n \times h$ nuclei forming dark nuclear string! The binding energy would be scaled down by $1/n$.

   This suggests that $n \rightarrow 1$ phase transition does not affect the lengths of flux tubes but only turns them to loops and that the distance between nucleons as measured in $M^4 \times CP_2$ is therefore scaled down by $1/n$. Coulomb repulsion between proton does not prevent this if the electric flux between protons is channelled along the long flux tubes rather than along larger space-time sheet so that the repulsive Coulomb interaction energy is not affected in the phase transition! This line of thought obviously involves the notion of space-time as a 4-surface in crucial manner.

4. Dark nuclei could have also ordinary nuclei as building bricks in accordance with fractality of TGD. Nuclei at dark flux tubes would be ordinary and the flux tubes portions - bonds - between them would have large h_{eff} and ahve thus length considerably longer than in ordinary nuclei. This would give sequences of ordinary nuclei with dark binding energy: similar situation is actually assumed to hold true for the nucleons of ordinary nuclei connected by analogs of dark mesons with masses in MeV range [K3].

Remark: In TGD inspired model for quantum biology dark variants of biologically important ions are assumed to be present. Dark proton sequences having basic entangled unit consisting of 3 protons analogous to DNA triplet would represent analogs of DNA, RNA, amino-acids and tRNA [L3]. Genetic code would be realized already at the level of dark nuclear physics and biochemical realization would represent kind of shadow dynamics. The number of dark codons coding for given dark amino-acid would be same as in vertebrate genetic code.

3.2 How dark nuclei are transformed to ordinary nuclei?

What happens in the transformation of dark nuclei to ordinary ones? Nuclear binding energy is liberated but how does this occur? If gamma rays generated, one should invent also now a mechanism transforming gamma rays to thermal radiation. The findings of Holmlid provide valuable information here and lead to a detailed qualitative view about process and also allow to sharpen the model for ordinary nuclei.

1. Holmlid [L5] [L5] [K4] has reported rather strange finding that muons (mass 106 MeV) pions (mass 140 MeV) and even kaons (mass 497) MeV are emitted in the process. This does not fit at all to ordinary nuclear physics with natural binding energy scale of few MeVs. It could be that a considerable part of energy is liberated as mesons decaying to lepton pairs (pions also to gamma pairs) but with energies much above the upper bound of about 7 MeV for the range of energies missing from the detected gamma ray spectrum (this is discussed in the first part of the book of Krivit [C11]). As if hadronic interactions would enter the game somehow! Even condensed matter physics and nuclear physics in the same coffee table are too much for mainstream physicist!

2. What happens when the liberated total binding energy is below pion mass? There is experimental evidence for what is called X boson [C6] discussed from TGD point of view in [L6]. In TGD framework X is identified as a scaled down variant $\pi(113)$ of ordinary pion $\pi = \pi(107)$. X is predicted to have mass of $m(\pi(113)) = 2^{(113-107)/2} m(\pi) \simeq 16.68$ MeV, which conforms with the mass estimate for X boson. Note that $k = 113$ *resp.* $k = 117$ corresponds to nuclear *resp.* hadronic p-adic length scale. For low mass transmutations the binding energy could be liberated by emission of X bosons and gamma rays.

3. I have also proposed that pion and also other neutral pseudo-scalar states could have p-adically scaled variants with masses differing by powers of two. For pion the scaled variants would have masses 8.5 MeV, $m(\pi(113)) = 17$ MeV, 34 MeV, 68 MeV, $m(\pi(107)) = 136$ MeV, ... and also these could be emitted and decay to lepton pairs of gamma pairs [K2]. The emission of scaled pions could be faster process than emission of gamma rays and allow to emit the binding energy with minimum number of gamma rays.

There is indeed evidence for pion like states (for TGD inspired comments see [K2]).

1. The experimental claim (see `http://tinyurl.com/ybq323yy`) of Tatischeff and Tomasi-Gustafsson is that pion is accompanied by pion like states organized on Regge trajectory and having mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV. For TGD inspired comments see [K2].

2. A further piece of evidence for scaled variants of pion comes from two articles by Eef van Beveren and George Rupp. The first article [C4] is titled *First indications of the existence of a 38 MeV light scalar boson* (see `http://tinyurl.com/yatlb97o`). Second article [C5] has title *Material evidence of a 38 MeV boson* (see `http://tinyurl.com/yczo7juy`).

The above picture suggests that the pieces of dark nuclear string connecting the nucleons are looped and nucleons collapse to a nucleus sized region. On the other, the emission of mesons suggests that these pieces contract to much shorter pieces with length of order Compton length of meson responsible for binding and the binding energy is emitted as single quantum or very few quanta. Strings cannot however retain their length (albeit becoming looped with ends very near in $M^4 \times CP_2$) and contract at the same time! How could one unify these two conflicting pictures?

1. To see how TGD could solve the puzzle, consider what elementary particles look like in TGD Universe [K2]. Elementary particles are identified as two-sheeted structures consisting of two space-time sheets with Minkowskian signature of the induced metric connected by CP_2 sized wormhole contacts with Euclidian signature of induced metric. One has a pair of wormhole contacts and both of them have two throats analogous to blackhole horizons serving as carriers of elementary particle quantum numbers.

   Wormhole throats correspond to homologically trivial 2-surfaces of CP_2 being therefore Kähler magnetically charged monopole like entities. Wormhole throat at given space-time sheet is necessarily connected by a monopole flux tube to another throat, now the throat of second wormhole contact. Flux tubes must be closed and therefore consist of 2 “long” pieces connecting wormhole throats at different parallel space-time sheets plus 2 wormhole contacts of CP_2 size scale connecting these pieces at their ends. The structure resembles extremely flattened rectangle.

2. The alert reader can guess the solution of the puzzle now. The looped string corresponds to string portion at the non-contracted space-time sheet and contracted string to that at contracted space-time sheet! The first sheet could have ordinary value of Planck constant but larger p-adic length scale of order electron's p-adic length scale $L(127)$ (it could correspond to the magnetic body of ordinary nucleon [L6]) and second sheet could correspond to $h_{eff} = n \times h$ dark variant of nuclear space-time sheet with $n = 2^{111}$ so that the size scales are same.

   The phase transition $h_{eff} \rightarrow h$ occurs only for the flux tubes of the second space-time sheet reducing the size of this space-time sheet to that of nuclear $k = 137$ space-time sheet of size of $\sim 10^{-14}$ meters. The portions of the flux tubes at this space-time sheet become short, at most of the order of nuclear size scale, which roughly corresponds to pion Compton length. The contraction is accompanied by the emission of the ordinary nuclear binding energy as pions, their scaled variants, and even heavier mesons. This if the mass of the dark nucleus is large enough to guarantee that total binding energy makes the emission possible. The second space-time sheet retains its size but the flux tubes at it retain their length but become loopy since their ends must follow the ends of the shortened flux tubes.

3. If this picture is correct, most of the energy produced in the process could be lost as mesons, possibly also their scaled variants. One should have some manner to prevent the leakage of this energy from the system in order to make the process effective energy producer.

4. The is however an important question to be answered. The basic hypothesis has been that the dark $h_{eff}(h = n$ variants of elementary particles have same masses as the ordinary elementary particles particles. Hadrons are however many-quark systems and this need not be true anymore. Could proton and neutron masses change?

   The model for Pollack effect does not allow significant change of proton mass. If also neutron mass remains un-affected and nuclear binding energies are scaled down by factor 2^{-11}, one ends up with difficulties. n-p mass difference is about 1.3 MeV and its scale would be much higher than the few keV scale for scaled down nuclear binding energies. Stable dark nuclei would consist of protons only and the transformation to ordinary nuclei would require emission of charge particles, say scaled variants of pion (which could be emitted in any way with a higher rate than gamma rays).

   If n-p mass difference is scaled down by factor 2^{-11} to .65 keV, one has scaling invariance and the spectrum of dark nuclei would be essentially similar to that of ordinary nuclei and dark beta decays would lead rapidly to beta stable dark nuclei. In particular, dark variants of beta decays involving the emission of e^+ become possible and can transform dark protons to dark neutrons. Notice, the assumption of WL about large renormalization of proton mass implying $m_{R,p} + m_e \simeq m_n$ in an excellent approximation is analogous to this hypothesis.

3.3 Dark nucleosynthesis and stellar evolution

The temperature of the solar core is rather near to the scale of dark nuclear binding energy. This co-incidence inspires interesting questions about the dark nucleosynthesis in the stellar evolution.

3.3.1 Some questions inspired by a numerical co-incidence

The temperature at solar core is about $T = 1.5 \times 10^7$ K corresponding to the thermal energy $E = 3T/2 = 2.25$ keV obtained by a scaling factor 2^{-11} energy ~ 5 MeV, which is the binding energy scale for the ordinary nuclei. That this temperature corresponds to the binding energy scale of dark nuclei might not be an accident.

That the temperature in the stellar core is of the same order of magnitude as dark nuclear binding energy is a highly intriguing finding and encourages to ask whether dark nuclear fusion could be the key step in the production of ordinary nuclei and what is the relation of dark nucleosynthesis to ordinary nucleosynthesis.

1. Could dark nucleosynthesis occur also pre-stellar evolution and thus proceed differently from the usual p-p-cycle involving fusion processes? The resulting ordinary nuclei would undergo only ordinary nuclear reactions and decouple from the dark dynamics. This does not exclude the possibility that the resulting ordinary nuclei form nuclei of nuclei with dark protons: this seems to occur also in nuclear transmutations.

2. There would be two competing effects. The higher the temperature, the less stable dark nuclei and the longer the dark nuclear strings. At lower temperatures dark nuclei are more stable but transform to ordinary nuclei decoupling from the dark dynamics. The liberated nuclear binding energy however raises the temperature and makes dark nuclei less stable so that the production of ordinary nuclei in this manner would slow down.

   At what stage ordinary nuclear reactions begin to dominate over dark nucleosynthesis? The conservative and plausible looking view is that p-p cycle is indeed at work in stellar cores and has replaced dark nucleosynthesis when dark nuclei became thermally unstable.

   The standard view is that solar temperature makes possible tunnelling through Coulomb wall and thus ordinary nuclear reactions. The temperature is few keVs and surprisingly small as compared to the height of Coulomb wall $E_c \sim Z_1 Z_2 e^2/L$, L the size of the nucleus. There are good reasons to believe that this picture is correct. The co-incidence of the two temperatures would make possible the transition from dark nucleosynthesis to ordinary nucleosynthesis.

3. What about dark nuclear reactions? Could they occur as reconnections of long magnetic flux tubes? For ordinary nuclei reconnections of short flux tubes would take place (recall the view about nuclei as two-sheeted structures). For ordinary nuclear the reactions at energies so low that the phase transition to dark phase (somewhat analogous to the de-confinement phase transition in QCD) is not energetically possible, the reactions would occur in nuclear scale.

4. An interesting question is whether dark nucleosynthesis could provide a new manner to achieve ordinary nuclear fusion in laboratory. The system would heat itself to the temperatures required by ordinary nuclear fusion as it would do also during the pre-stellar evolution and when nuclear reactor is formed spontaneously (Oklo reactor, see `http://tinyurl.com/l3h6t9v`).

3.3.2 Could dark nucleosynthesis affect the views about stellar evolution?

The presence of dark nucleosynthesis could modify the views about star formation (see `http://tinyurl.com/ybdv79gg`), in particular about energy production in protostars (see `http://tinyurl.com/l4htsob`) and pre-main-sequence stars (PMS, see `http://tinyurl.com/y8bfbvk7`) following protostars in stellar evolution.

In protostars and PMSs the temperature is not yet high enough for the burning of hydrogen to ^{4}He, and according to the standard model the energy radiated by the star consists of the gravitational energy liberated during the gravitational contraction. Could dark nucleosynthesis provide a new mechanism of energy production and could this energy be transferred from the protostar/PMS as dark energy along dark magnetic flux tubes?

Can one imagine any empirical evidence for the presence of dark nucleosynthesis in protostars and PMSs?

1. The energy and matter produced in dark nucleosynthesis could partially leak out along dark magnetic flux tubes and give rise to astrophysical jets (see `http://tinyurl.com/yb7g9ryx`). Astrophysical jets indeed accompany protostars and the associated planetary and bipolar nebulae as well as PMSs (T Tauri stars and Herbig-Haro objects). The jets along flux tubes associated with hot spots at which dark nucleosynthesis would take place could provide also a mechanism for the transfer of angular momentum from the protostar/PMS.

2. Spectroscopic observations of dense cores (protostar) not yet containing stars indicate that contraction occurs but the predicted expansion of the contracting region has not been observed (see http://tinyurl.com/l4htsob). The energy production by dark nucleosynthesis could increase pressure and slow down and even prevent the expansion of the contracting region.

How dark nucleosynthesis could affect the evolution of protostars and PMSs?

1. In standard model the formation of accretion disk (see http://tinyurl.com/yaax8ruq) could be understood in terms of angular momentum conservation: spherical distribution of matter transforms to a planar one does not require large changes for the velocities tangential to the plane. The mechanism for how the matter from accretion disk spirals into star is however poorly understood.

2. The TGD inspired model for galaxy formation suggests that the core region of the protostar is associated with a highly knotted cosmic string (“pearl in a necklace”) forming the dark core of galaxy with constant density of dark matter [L7]. The dark matter from the cosmic string would have leaked out from the cosmic string and transformed to ordinary matter already before the annihilation of quarks and antiquarks. The CP, P, and T asymmetries predicted by twistor lift of TGD would predict that there is a net quark (antiquark) number outside (inside) the cosmic string. The locally axisymmetric gravitational potential of the cosmic string would favour disk like rather than spherically symmetric matter distribution as the initial distribution of the baryonic matter formed in the hadronization from the quarks left from the annihilation.

   Quantitative model is needed to see whether dark fusion could contribute significantly to the energy production in protostars and PMSs and affect their evolution. The nuclear binding energy liberated in dark fusion would slow down the gravitational contraction and increase the duration of protostar and PMS phases. In standard model PMS phase is possible for masses varying from 2 to 8 solar masses. Dark nucleosynthesis could increase the upper bound for the mass of PMS from that predicted by the standard model.

This is only rough overall view and it would be unrealistic to regard it as final one: one can indeed imagine variations. But even its recent rough form it seems to be able explain all the weird looking aspects of CF/LENR/dark nucleosynthesis. To pick up one particular interesting question: how significantly dark nucleosynthesis could contribute to the generation of elements heavier than Fe (and also lighter elements)? It is assumed that the heavier elements are generated in so called r-process involving creation of neutrons fusing with nuclei. One option is that r-process accompanies supernova explosions but SN1987A did not provide support for this hypothesis: the characteristic em radiation accompanying r-process was not detected. Quite recently the observation of gravitational waves from the fusion of two neutron stars generated also visible radiation, so called kilonova (see http://tinyurl.com/ycagjeau), and the radiation accompanying r-process was reported. Therefore this kind of collisions generate at least part of the heavier elements.

4 “Fusion fiasco” and “Lost history” from TGD perspective

In the following the second and third volume of “*Explorations in Nuclear Research*” of Krivit are discussed from TGD point of view. The intention is to use the information provided by these books in order to refine the model for dark nucleosynthesis.

4.1 Summary of the model of dark nucleosynthesis model

Before continuing it is good to recall first the basic ideas behind dark nucleosynthesis.

1. Dark nuclei are produced as dark proton sequences at magnetic flux tubes with distance between dark protons with $h_{eff}/h = 2^{11}$ (approximately proton/electron mass ratio) very near to electron Compton length. This makes possible formation of at least light elements when dark nuclei transform to ordinary ones and liberate almost entire nuclear binding energy.

2. Also more complex nuclei can form as nuclei of nuclei from ordinary nuclei and sequences of dark protons are at magnetic flux tubes. In particular, the basic rule $(A, Z) \to (A+1, Z+1)$ of Widom-Larsen model is satisfied although dark beta decays would break this rule.

   In this case the transformation to ordinary nuclei produces heavier nuclei, even those heavier than Fe. This mechanism could make possible the production of heavy nuclei outside stellar interiors. Also dark beta decays can be considered. They would be fast: the idea is that the Compton length of weak bosons is scaled up and within the region of size scale of Compton length weak interactions have essentially the same strength as electromagnetic interactions so that weak decays are fast and led to dark isotopes stable against weak interactions.

3. The transformation of dark nuclei to ordinary nuclei liberates almost all nuclear binding energy. This energy could induce the fission of the daughter nucleus and emission of neurons causing the decay of ordinary nuclei, at least those heavier than Fe.

4. Also the dark weak process $e^- + p \to n + \nu$ liberating energy of order electron mass could kick out neutron from dark nucleus. This process would be TGD counterpart for the corresponding process in WL but having very different physical interpretation. This mechanism could explain production of neutrons which is by about 8 orders slower than in cold fusion model.

5. The magnetic flux tubes containing dark nuclei form a positively charged system attracted by negatively charged surfaces. The cathode is where the electrons usually flow to. The electrons can generate negative surface charge, which attracts the flux tubes so that flux tubes end up to the cathode surface and dark ions can enter to the surface. Also ordinary nuclei from the cathode could enter temporarily to the flux tube so that more complex dark nuclei consisting of dark protons and nuclei are formed. Dark nuclei can also leak out of the system if the flux tube ends to some negatively charged surface other than cathode.

The findings described in the two books, in particular the production of neutrons and tritium, allow to sharpen the view about dark nucleosynthesis.

1. The simplest view about dark nucleosynthesis is as a formation of dark proton sequences in which some dark protons transform by beta decay (emission of positron) to neutrons. The objection is that this decay is kinematically forbidden if the masses of dark proton and neutron are same as those of ordinary proton and neutron (n-p mass difference is 1.3 MeV). Only dark proton sequences would be stable.

   Situation changes if also n-p mass difference scales by factor 2^{-11}. The spectra of dark and ordinary nuclei would be essentially identical. For scaled down n-p mass difference, neutrons would be produced most naturally in the process $e^- + p \to n + \nu$ for dark nuclei proceeding via dark weak interactions. The dark neutron would receive a large recoil energy about $m_e \simeq .5$ MeV and dark nucleus would decay. The electrons inducing the neutron emission could come from the negatively charged surface of cathode after the flux tube has attached to it. The rate for $e^- + p \to n + \nu$ is very law for ordinary weak Planck constant. The ratio $n/T \sim 10^{-8}$ allows to deduce information about h_{eff}/h: a good guess is that dark weak process is in question.

2. Tritium and other isotopes would be produced as several magnetic flux tubes connect to a negatively charged hot spot of cathode. A reasonable assumption is that the ordinary binding energy gives rise to an excited state of the ordinary nucleus. This can induce the fission of the final state nucleus and also neutrons can be produced. Also scaled down variants of pions can be emitted, in particular the pion with mass of 17 MeV [L6].

3. The ordinary nuclear binding energy minus the n-p mass difference 1.3 MeV multiplied by the number of neutrons would be released in the transformation of dark nuclei to ordinary ones. The table 1 gives the total binding energies and liberated energies for some lightest stable nuclei.

   Gamma rays are not wanted in the final state. For instance, for the transformation of dark ^{4}He to ordinary one, the liberated energy would be about 25.7 MeV. If the final state nucleus is in excited state unstable against fission, the binding energy can go to the kinetic energy of

Table 1: The ordinary nuclear binding energies E_B for light nuclei and the energies ΔE liberated in dark $\rightarrow$ ordinary transition.

$Element$	^4He	^3He	T	D
E_B/MeV	28.28	7.72	8.48	2.57
$\Delta E/MeV$	25.70	6.412	5.8	1.27

the final state and not gamma ray pairs are observed. If two 17 MeV pions π_{113} are emitted the other one or both must be on mass shell and decay weakly. The decay of off-mass π_{113} could however proceed via dark weak interactions and be fast so that the rate for this process could be considerably faster than for the emission of two gamma rays.

4.2 Fusion fiasco from TGD perspective

The second volume of the book "*Explorations in Nuclear Research*" of Krivit is titled (see `http://stevenbkrivit.com/fusion-fiasco/`). The book gives a very detailed view about what happened during the first years after the discovery of Pons of Fleischman of energy production in electrolysis (in 1989) not understandable in terms of chemistry. Their interpretation was as cold fusion was definitely wrong and gave an excellent weapon for those wanting to label them as crackpots.

From TGD point of view especially interesting observations related to the observations of Indian and Italian research group made immediately after the announcement of the results of Pons and Fleischman. The observations of Indian groups working in Babbha Atomic Research Center (BARC) were led by Mahadeva Shrinivasan and Padmanabha Krisnagopala Iyengar. Yengar was the director BARC and Shrinivasa the director of the physics group working in BARC. The three leading researchers in Italian ENEA-Frascati experiment were Fransesco Scaramuzzi, Antonella De Ninno and Antonio Frattolillo.

The results of both experiments were rather similar and I will summarize in the following only the findings of Indians. Tritium and neutron production were detected by 6 independent groups. The basic prediction of D+D fusion model is that equal amounts of neutrons and tritium nuclei should be produced in D+D$\rightarrow$ n+T process occurring besides D+D $\rightarrow$ ^{4}He. These groups tested this hypothesis and found that the n/T ratio is small: in the range $(10^{-9}, 10^{-8})$ in BARC experiments so that D+D fusion hypothesis cannot be correct. What is however remarkable is that neutrons were produced and one should understand this also in TGD framework.

Milton-Roy electrolytic cell consisting of 16 Pd-Ag alloy membrane tubes with total area of 300 cm^2 was used. For instance, 30 amp current rising gradually to 60 amp was used in one of the runs using Pd as host metal. Also experiments replacing Pd with Ti as a host metal were performed. Three types of neutron detectors were used to detect cold, thermal, and high energy neutrons: BF_3 detector was used for cold neutrons, ^3He detector for thermal neutrons, and scintillation counter for high energy neutrons. Comparison with the neutron background was performed. All counters detected the neutrons simultaneously.

What was found was following.

1. During 4-hour run 4×10^7 neutrons were observed: this is considerably above background. n/T ratio was in the range $10^{-6} - 10^{-9}$ and its average was 10^{-7}. This does not conform with the D+D fusion model.

2. Two groups at BARC observed n and T bursts with 10-20 neutrons in single burst. Neutron and tritium bursts were strongly correlated suggesting that some kind of chain reaction was involved. Bursts occurred only in the first day, after few hours of charging. After that the emission of neutrons stopped.

3. The interpretation was as surface phenomenon occurring only at hot spots whereas Pons and Fleischman assumed that the process occurs in the entire cathode.

What could be the TGD interpretation?

The simplest version of dark nucleosynthesis assumes only the formation of dark proton sequences.

1. The resulting dark nuclear strings suffered dark beta decays leading to the counterparts of ordinary nuclei. These transformed to ordinary nuclei and the ordinary nuclear binding energy was liberated. The transformation to ordinary nucleus in excited state suffering fission or emitting gamma ray pair (at least) are the most plausible decay channels. Fission channel is the faster one. This could explain the production of neutrons and the low n/T branching ratio.

2. One can also consider a formation of dark nuclei containing besides dark protons also ordinary nuclei: nuclear string consisting of nuclei would be in question.

3. Dark nuclear fusion does not look so plausible option.

   (a) Could a dark version p-p cycle assumed to produce ^4He in stars like Sun be involved? This process involves several steps. p+p gives rise D and positron+ neutrino. D and p fuse to ^{3}He liberating energy. Final step would be ^{3}He+ ^{3}He $\rightarrow$ ^{4}He + p+p. Could these steps could take for dark nuclei so that scale of liberated energy would be by factor 2^{-11} smaller than for ordinary nuclear process.

   (b) Also D+D, D+T, and D+^{3}He fusions could occur

      - D+D $\rightarrow$ ^{4}He
      - D+D $\rightarrow$ ^{3}He + n
      - D+D $\rightarrow$ T + p
      - D+ T $\rightarrow$ ^{4}He + n
      - D+^{3}He $\rightarrow$ ^{4}He + p

   D+D produces ^3He +n or T + p. D+T to produces $^4He + n$. It would seem that the number of neutrons should be larger than the number of T. This prediction does not conform with the small n/T branching fraction. These reactions could of course take place but their contribution should be rather small as compared to that assignable to the transformation of dark nuclei to ordinary ones.

Can one understand the other observations in TGD framework?

1. The production of tritium and neutrons seems to occur in hot spots at the surface of the cathode and only during the initial stages of the experiment. Hot spots could correspond to negatively charge pieces of the cathode surfaces. The negatively charged cathode surface attracts the magnetic flux tubes. As positive charge flows to the surface, the density of electrons at the surface is weakened and the process ceases to occur.

2. Neutrons were produced as bursts, say 10-20 neutrons. The decays of dark nuclei could explain these bursts but several flux tubes are required sin single flux tube is expected to produce only few neutrons. The total number of flux tubes is expected to be proportional to the area of hot spots.

4.3 The lost history from TGD perspective

The third volume in "*Explorations in Nuclear Research*" [C12] is about lost history: roughly the period 1910-1930 during which there was not yet any sharp distinction between chemistry and nuclear physics. After 1930 the experimentation became active using radioactive sources and particle accelerators making possible nuclear reactions. The lost history suggests that the methods used determine to unexpected degree what findings are accepted as real. After 1940 the hot fusion as possible manner to liberate nuclear energy became a topic of study but we are still waiting the commercial applications.

One can say that the findings about nuclear transmutations during period 1912-1927 became lost history although most of these findings were published in highly respected journals and received also media attention. Interested reader can find in the book detailed stories about persons involved.

This allows also to peek to the kitchen side of science and to realize that the written history can contain surprising misidentifications of the milestones in the history of science. Author discusses in detail an example about this: Rutherford is generally regarded as tje discover of the first nuclear transmutation but even Rutherford himself did not make this claim.

It is interesting to look what the vision about the anomalous nuclear effects based on dark nucleosynthesis can say about the lost history and whether these findings can provide new information to tighten up the TGD based model, which is only qualitative. Therefore I go through the list given in the beginning of book from the perspective of dark nucleosynthesis.

4.3.1 Production of noble gases and tritium

During period 1912-1914 several independent scientists discovered the production of noble gases ^{4}He, neon (Ne), and argon (Ar) using high voltage electrical discharges in vacuum or r through hydrogen gas at low pressures in cathode-ray tubes. Also an unidentified element with mass number 3 was discovered. It was later identified as tritium. Two of the researchers were Nobel laureates. 1922 two researchers in University of Chicago reported production of ^{4}He. Sir Joseph John Thomson explained the production of ^{4}He using occlusion hypothesis. In understand occlusion as a contamination of ^{4}He to the tungsten wire. The question is why not also hydrogen.

Why noble gases would have been produced? It is known that noble gases tend to stay near surfaces. In one experiment it was found that ^4He production stopped after few days, maybe kind of saturation was achieved. This suggests that isotopes with relatively high mass numbers were produced from dark proton sequences (possibly containing also neutrons resulting in the dark weak decays). The resulting noble gases were caught near the electrodes and therefore only their production was observed.

4.3.2 Production of ^{4}He in experiments of Wendle and Irion

In 1222 Wendle and Irion published results from the study of exploding current wires. Their arrangement involved high voltage of about 3×10^4 V and di-electric breakdown through air gap between the electrodes producing sudden current peak in a current wire made of tungsten (W with $(Z, A) = (74, 186)$ for the most abundant isotope) at temperature about $T = 2 \times 10^4$ C, which corresponds to a thermal energy $3kT/2$ of about 3 eV. Production of ^{4}He was detected.

Remark: The temperature at solar core is about 1.5×10^7 K corresponding to energy about 2.25 keV and 3 orders of magnitude higher than the temperature used.

The interpretation of the experimentalists was that the observed ^{4}He was from the decay of tungsten in the hot temperature making it unstable. This explanation is of course not consistent with what we known at about nuclear physics. No error in the experimental procedure was found. Three trials to replicate the experiment of Wendle and Irion were made with a negative result. The book discusses these attempts in detail and demonstrates that they were not faithful to the original experimental arrangement.

Rutherford explained the production of ^{4}He in terms of ^{4}He occlusion hypothesis of Thomson. In the explosion the ^{4}He contaminate would have liberated. But why just helium contamination, why not hydrogen? By above argument one could argue that ^4He as noble gas could indeed form stable contaminates.

80 yeas later Urutskoev repeated the experiment with exploding wires and observed besides ^{4}He also other isotopes. The experiments of Urutskoev [D1] demonstrated that there are 4 peaks for the production rate of elements as function of atomic number Z. Furthermore, the amount of mass assignable to the transmuted elements is nearly the mass lost from the cathode. Hence also cathode nuclei should end up to flux tubes.

How dark nucleosynthesis could explain the findings? The simplest model relies on a modification of the occlusion hypothesis: a hydrogen contaminate was present and the formation of dark nuclei from the protons of hydrogen at flux tubes took place in the exploding wire. The nuclei of noble gases tended to remain in the system and ^{4}He was observed.

4.3.3 Production of Au and Pt in arc discharges in Mercury vapor

In 1924 German chemist Miethe, better known as the discoverer of 3-color photography found trace amount of Gold (Au) and possibly Platinum (Pt) in Mercury (Hg) vapor photography lamp.

Table 2: The nuclear charge and mass number (Z, A) for the most abundant isotopes of W, Pt, Au,Hg, Tl and Pb.

Element	*W*	*Pt*	*Au*	*Hg*	*Tl*	Pb
(Z, A)	(74,186)	(78,195)	(79,197)	(80,202)	(81,205)	(82,208)

Scientists in Amsterdam repeated the experiment but using lead (Pb) instead of Hg and observed production of Hg and Thallium (Tl). The same year a prominent Japanese scientist Nagaoka reported production of Au and something having the appearance of Pt. Nagaoka used a an electric arc discharge between tungsten (W) electrodes bathed in dielectric liquid "laced" with liquid Hg.

The nuclear charges and atomic weights for isotopes involved are given in table 2 .

Could dark nucleosynthesis explain the observations? Two mechanisms for producing heavier nuclei relying one the formation of dark nuclei from the nuclei of the electrode metal and dark protons and their subsequent transformation to ordinary nuclei.

1. Dark nuclei are formed from the metal associated with cathode and dark protons. In Nagaoka's experiment this metal is W with $(Z, A) = (74, 186)$. Assuming that also dark beta decays are possible this would lead to the generation of heavier beta stable elements Au with $(Z, A) = (79, 197)$ or their stable isotopes. Unfortunately, I could not find what the electrode metal used in the experiments of Miethe was.

2. In the experiments of Miethe the nuclei of Hg transmuted to Au $((80, 202) \rightarrow (79, 197))$ and to Pt $((80, 202) \rightarrow (78, 195))$. In Amsterdam experiment of Pb transmuted to Hg $((82, 208) \rightarrow (80, 202))$ and Tl $((82, 208) \rightarrow (81, 205))$. This suggests that the nuclei resulted in the decay of Hg (Pb) induced by the nuclear binding energy liberated in the transformation of dark nuclei formed from the nuclei of cathode metal and dark protons to ordinary nuclei. Part of the liberated binding energy could have induced the fission of the dark nuclei. The decay of dark nuclei could have also liberated neutrons absorbed by the Hg (Pb) nuclei and inducing the decay to lighter nuclei. Thus also the analog of r-process could have been present.

4.3.4 Paneth and Peters' H$\rightarrow$ ^{4}He transmutation

In 1926 German chemists Paneth and Peters pumped hydrogen gas into a chamber with finely divided palladium powder and reported the transmutation of hydrogen to helium. This experiment resembles the "cold fusion" experiment of Pons and Fleischman in 1989. The explanation would be the formation of dark ^4He nuclei consisting of dark protons and transformation to ordinary ^4He nuclei.

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