This chapter is devoted to the possible implications of TGD for nuclear physics. In the original version of the chapter the focus was in the attempt to resolve the problems caused by the incorrect interpretation of the predicted long ranged weak gauge fields. What seems to be a breakthrough in this respect came around 2005, more than a decade after the first version of this chapter, and is based on TGD based view about dark matter inspired by the developments in the mathematical understanding of quantum TGD. In this approach condensed matter nuclei can be either ordinary, that is behave essentially like standard model nuclei, or be in dark matter phase in which case they generate long ranged dark weak gauge fields responsible for the large parity breaking effects in living matter. This approach resolves trivially the objections against long range classical weak fields.

About 7 years later (2012) it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced W gauge fields. It is quite possible that this localization is consistent with K\"ahler-Dirac equation only in ther Minkowskian regions were the effective metric defined by K\"ahler-Dirac gamma matrices can be effectively 2-dimensional.

One can pose the additional condition that also classical Z^0 field vanishes - at least above weak scale. Fundamental fermions would experience only em field so that the worries related to large parity breaking effects would disappear. The proportionality of weak scale to $h_{eff}=n\times h$ however predicts that weak fields are effectively massless belong scaled up weak scale. Therefore worries about large parity breaking effects in nuclear physics can be forgotten.

The basic criterion for the transition to dark matter phase having by definition large value of $\hbar$ is that the condition $\alpha Q_1Q_2\simeq 1$ for appropriate gauge interactions expressing the fact that the perturbation series does not converge. The increase of $\hbar$ makes perturbation series converging since the value of α is reduced but leaves lowest order classical predictions invariant.

This criterion can be applied to color force and inspires the hypothesis that valence quarks inside nucleons correspond to large $\hbar$ phase whereas sea quark space-time sheets correspond to the ordinary value of $\hbar$. This hypothesis is combined with the earlier model of strong nuclear force based on the assumption that long color bonds with p-adically scaled down quarks with mass of order MeV at their ends are responsible for the nuclear strong force.

\vm{\it 1. Is strong force due to color bonds between exotic quark pairs?}\vm

The basic assumptions are following.

\begin{enumerate} \item Valence quarks correspond to large $\hbar$ phase with p-adic length scale $L(k_{eff}=129)= L(107)/v_0\simeq 2^{11}L(107)\simeq 5\times 10^{-12}$ m whereas sea quarks correspond to ordinary $\hbar$ and define the standard size of nucleons.

\item Color bonds with length of order $L(127)\simeq \simeq 2.5\times 10^{-12}$ m and having quarks with ordinary $\hbar$ and p-adically scaled down masses $m_q(dark)\simeq v_0m_q$ at their ends define kind of rubber bands connecting nucleons. The p-adic length scale of exotic quarks differs by a factor 2 from that of dark valence quarks so that the length scales in question can couple naturally. This large length scale as also other p-adic length scales correspond to the size of the topologically quantized field body associated with system, be it quark, nucleon, or nucleus.

\item Valence quarks and even exotic quarks can be dark with respect to both color and weak interactions but not with respect to electromagnetic interactions. The model for binding energies suggests darkness with respect to weak interactions with weak boson masses scaled down by a factor v_0. Weak interactions remain still weak. Quarks and nucleons as defined by their $k=107$ sea quark portions condense at scaled up weak space-time sheet with $k_{eff}=111$ having p-adic size 10^{-14} meters. The estimate for the atomic number of the heaviest possible nucleus comes out correctly.

The wave functions of the nucleons fix the boundary values of the wave functionals of the color magnetic flux tubes idealizable as strings. In the terminology of M-theory nucleons correspond to small branes and color magnetic flux tubes to strings connecting them. \end{enumerate}

\vm{\it 2. General features of strong interactions} \vm

This picture allows to understand the general features of strong interactions. \begin{enumerate}

\item Quantum classical correspondence and the assumption that the relevant space-time surfaces have 2-dimensional CP_2 projection implies Abelianization. Strong isospin group can be identified as the SU(2) subgroup of color group acting as isotropies of space-time surfaces. and the U(1) holonomy of color gauge potential defines a preferred direction of strong isospin. Dark color isospin corresponds to strong isospin. The correlation of dark color with weak isospin of the nucleon is strongly suggested by quantum classical correspondence.

\item Both color singlet spin 0 pion type bonds and colored spin 1 bonds are allowed and the color magnetic spin-spin interaction between the exotic quark and anti-quark is negative in this case. p-p and n-n bonds correspond to oppositely colored spin 1 bonds and p-n bonds to colorless spin 0 bonds for which the binding energy is free times higher. The presence of colored bonds forces the presence of neutralizing dark gluon condensate favoring

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states with $N-P>0$.

\item Shell model based on harmonic oscillator potential follows
naturally
from this picture in which the magnetic flux tubes connecting
nucleons take
the role of springs. Spin-orbit interaction can be understood in
terms of
the color force in the same way as it is understood in atomic
physics.
\end{enumerate}


\vm{\it 3. Nuclear binding energies}\vm

\begin{enumerate}

\item The  binding energies per nucleon for $A\leq 4$ nuclei can be
understood if they form closed string like structures, nuclear
strings, so
that only two color bonds per nucleon are possible. This could be
understood if ordinary quarks and exotic quarks possessing much
smaller
mass behave as if they were identical fermions. p-Adic mass
calculations
support this assumption.  Also the average behavior of binding
energy for
heavier nuclei is predicted correctly.

\item For  nuclei with $P=N$ all color bonds can be pion type bonds
and
have thus  largest color magnetic spin-spin interaction energy. The
increase of color Coulombic binding energy between colored exotic
quark
pairs and dark gluons however favors $N>P$ and explains also the
formation
of neutron halo outside $k=111$ space-time sheet.

\item Spin-orbit interaction provides the standard explanation for
magic
numbers. If the maximum of the binding energy per nucleon is taken
as a
criterion for magic, also  Z=N=4,6,12 are magic. The alternative TGD
based
explanation for magic numbers $Z=N=4,6,8,12,20$ would be in terms of
regular Platonic solids. Experimentally also other magic numbers are
known
for neutrons. The linking of nuclear strings provides a possible
mechanism
producing new magic nuclei from lighter magic nuclei.
\end{enumerate}

\vm{\it 4. Stringy description of nuclear reactions}\vm
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The view about nucleus as a collection of linked nuclear strings suggests stringy description of nuclear reactions. Microscopically the nuclear reactions would correspond to re-distribution of exotic quarks between the nucleons in reacting nuclei.

\vm{\it 5. Anomalies and new nuclear physics}\vm

The TGD based explanation of neutron halo has been already mentioned. The recently observed tetra-neutron states are difficult to understand in the standard nuclear physics framework since Fermi statistics does not allow this kind of state. The identification of tetra-neutron as an alpha particle containing two negatively charged color bonds allows to circumvent the problem. A large variety of exotic nuclei containing charged color bonds is predicted.

The proposed model explains the anomaly associated with the tritium beta decay. What has been observed is that the spectrum intensity of electrons has a narrow bump near the endpoint energy. Also the maximum energy E_0 of electrons is shifted downwards. I have considered two explanations for the anomaly. The original models are based on TGD variants of original models involving belt of dark neutrinos or antineutrinos along the orbit of Earth. Around 2008)I realized that nuclear string model provides much more elegant explanation of the anomaly and has also the potential to explain much more general anomalies.

Cold fusion has not been taken seriously by the physics community but the situation has begun to change gradually. There is an increasing evidence for the occurrence of nuclear transmutations of heavier elements besides the production of ^4He and ^3H whereas the production rate of ^3He and neutrons is very low. These characteristics are not consistent with the standard nuclear physics predictions. Also Coulomb wall and the absence of gamma rays and the lack of a mechanism transferring nuclear energy to the electrolyte have been used as an argument against cold fusion. TGD based model relying on the notion of charged color bonds could explain the anomalous characteristics of cold fusion. The basic mechanism making possible to circum vent Coulomb wall could be large h_{eff} phase for weak bosons scaling the weak length scale to atomic length scale so that proton could transform to neutron by the exchange of dark W boson with target nucleus.