A MASS - STRUCTURAL COMPLEXITY CONNECTION FOR THE ELEMENTARY PARTICLES, WILSON'S RENORMALIZATION GROUP FIXED POINTS IN THE REALM OF THE STRUCTURAL COMPLEXITY ANALYSIS

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The trios aspect of the elementary particle physics, three generation of fermions three quark colors is analyzed in the realm of the structural complexity approach. Similarity of the structures feature of this model leads to the novel understanding of the masses of the elementary particles, they are the reflection of the configurations of the existing ensembles of the elementary particles. Wilson's renormalization group flow fixed points behavior of the mass and coupling constants is analyzed with the structural complexity approach to this question. It is shown that the scaling feature of the renormalization group equation is identical to the main equation of the structural complexity in one dimensional case. The logarithmic spiral often met in nature is also considered in the domain of this analysis. It is shown that its scaling feature is also identical to the main equation of the structural complexity.

Keywords: dependence of the structural complexity on the energy, the connection between the charges and masses of the elementary particles, trios in elementary particle physics, mass and structural complexity connection, Lorentz invariant quantities, renormalization group equation, renormalization group fixed points, equation of the logarithmic spiral
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INTRODUCTION

The coupling constant - electroweak gauge boson mass relation

$$\frac{M_W}{g} = \frac{M_B}{g'} \quad (1)$$

enables one to get the Standard Model form of the charged W boson, the Z boson and the photon in a compact, natural manner ([1], [2], [3]). One can observe that the approximate form of this type of relation between the mass and coupling constants holds for all known elementary particles including all quarks and leptons [3]. Eq.(1) can also be considered as a manifestation of the connection between the energy and the structural complexity of the quantum systems [3]. This approach to the analysis of the properties of crystals sheds light to the drastic differences of their latent heat of fusion. This latent heat of fusion difference aspect of the connection between the energy and structural complexity reveals itself in the case of the so called conventional superconductors too in a sharp form [4]. The drastic difference in the latent heat of fusion of the crystals tell us that atoms and molecules are not like flamboyant objects moving chaotically within quantum systems, they are more likely follow the certain pattern in their thermal motion: under extreme conditions the whole structure of this pattern breaks down, this phase transition induces the superconducting state in the case of metals. 'Halogens' vs 'alkali metals' type of relations between the groups of the elementary particles discussed in this work sheds light to the structure of these patterns of the thermal motion too. As it was indicated in [21] the structural complexity approach sheds light to the origin of the quantum dualism, the matter reveals itself in a corpuscular form whenever there is an opportunity of the exchange of the structural complexities of the interacting particles. This approach also softens the enigma of the second principle of special relativity.

METHODS

A. Trios in the world of the elementary particles, three generations of fermions, three quark colors and their indispensable connection to the $SU(2)_L$ x $SU(2)_R$ symmetry of the elementary particles

The structural complexity approach may well decipher the mechanism of the fermion generations' mass hierarchy. If you compare the bottom quark and top quark masses through the structural complexity (Q/M), the difference of their masses does not look that sharp. The ratio of the structural complexity values for the b quarkand t quark (around twenty) is very close to that for the muon and the tau lepton (around seventeen). Further discussions bring a certain clarity to this closeness of the structural complexity values. Quarks have subtler structures than leptons. The structural complexity feature that reveals itself at the level of the isospin for quarks appears in the larger context for leptons, in their SU(3) 'flavor' domain.

Can the structural complexity approach have an answer to the question why we have three generations of fermions? It seems that this approach has a simple answer to this question. We have several sets of trios in the world of the elementary particles: well proven three quark colors, the left - handed quarks having three times smaller value for the hypercharge than the left - handed leptons, three generations of leptons, three generations of quarks? The Standard Model in its current form treats even the left-handed quarks and the right - handed quarks essentially aa different particles.

We can say that there is another spin 1/2 like degree of freedom (besides the customarily discussed spin 1/2 of the elementary particles) inducing three generations of fermions and some fundamental

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fermions which eventually generate triplet $\vec{W}$ and singlet *B* electroweak gauge bosons by the same scheme: |1/2> x |1/2> = |0,0> (singlet) + triplet. W. Pauli also considered spin of the particles just as two valuedness, One would say as another feature of the structural complexity of the quantum systems. SU(3) group also has another feature making it a good candidate as a fundamental group for the elementary particles: its complex conjugate representation, $\bar{3}$ acting on upper spinors ψ^{a}, is a different, inequivalent irrepresentation while these two irrepresentations for the SU(2) group are not inequivalent. SU(3) contraction of the upper and lower spinors induces stronger bond (similar to the 'alkali metals' and 'halogens' bond discussed shortly after this). The *Z* boson and the photon have the same constituents, the third component of the $\vec{W}$ boson and the *B* boson. The slightly different arrangement of these bosons induces two different types of particles, the heavy, unstable *Z* boson and the massless photon. One can say that particles' masses are indeed among the quantities reflecting their structural complexity. The photon, the particle with the symmetrized distribution of the original bosons is massless and is aware of the electric charge, which is also the pre shift in the symmetry (spontaneous symmetry breaking) type of quantity.

The masses of the elementary particles can be regarded as an analogue of the chemical bond energy. In this particular case the *Z* boson can be regarded as a bond of the 'halogen', the $\vec{W}$ boson and an 'alkali metal', the *B* boson. A strong bond and a heavy elementary particle, the *Z* boson. Quarks have a more complex structure than leptons: let's associate the color quantum number of quarks with the triplet part of the structure

$$|1/2> \times |1/2>= |0,0> + (|1,1> + |1,0> + |1,-1>)$$

and associate leptons with the singlet part of this structure. This association is in agreement with the distribution of the hypercharge among the elementary particles: leptons have three times bigger value for the hypercharge than quarks provided that the hypercharge is distributed equally between the singlet part and the triplet part of this $|1/2> \times |1/2>$ type of structure. The number of the quark colors also gets a natural explanation this way. About the mass difference of the triplet part and singlet part of the fermions: Quarks are significantly heavier than the corresponding leptons. The *W* boson is also almost twice as heavy as the *B* boson (if we assign a mass to it). So quarks have one more layer of matter than leptons, in the form of the quark colors, the triplet part discussed above. Therefore it is natural to expect that the feature of leptons revealing itself at the level of the fermion generations, the structural complexity ratio for the tau lepton and muon, reveals itself within one generation of fermions for the quarks. The deeper layer spin nature of the quark colors could well induce the quark confinement. The main equation of the structural complexity Eq. (1) is also consistent with these conclusions. The coupling constant g which is the (explicit) generator of the configuration of the ensemble of the particles is directly proportional to the value of the mass for the give structural complexity.

If we get a complete picture of the mass - structural complexity connection of the elementary particles by incorporating QCD too, theoretical predictions for the masses of quark flavors, we will also have an excellent opportunity for using the nuclear energy for the practical purposes.

It is true that we have to change somewhat ou approach to Quantum Field Theory if we follow concepts promoted in this work. However all these ideas are indispensable parts of one whole structure. The mystery of the quark colors has been around for more than fifty years. If we use the $SU(2)_L$ x $SU(2)_R$ symmetry approach instead of $SU(2)_L$ x U(1) symmetry of the Standard Model, the distribution of the hypercharge among the leptons and quarks gets a simple and natural explanation (see the discussion above). The right - handed fermion - the $\vec{W}$ boson interaction is present in the Standard Model too, through the components of the photon and the *Z* boson, simply the sum of these terms adds up to zero. One can say that the rearrangement of the elementary particles' interactions after the spontaneous symmetry breaking is like the protein folding process. Here this process is irreversible. The shift in the symmetry in the universe can not be simply like a fragmentation process. There must be the conserved structural complexities which eventually give rise to the living creatures including humans with the consciousness.

A few words about the meltdown of the right - handed fermion isospins. This must be an extremely intricate and subtle process. Different levels of matter, the $\vec{W}$ boson level and the *B* boson level, mix up in two different ways, generating the symmetric part, the electromagnetic interaction part and the *Z* boson related part, which we should relate to the antisymmetric part of the interactions. The W_1 and the W_2 components related interactions of the right - handed fermions is neither symmetric nor antisymmetric, this part of the interactions disappears.

B. The structural complexity approach to the analysis of renormalization group flows, life – like nature of the Lorentz invariant quantities, similarities of the main equation of the structural complexity, renormalization group equation and the equation of the logarithmic spiral

In description of Wilson's approach to renormalization there is one enigmatic moment: all of the examples of quantum field theories that are important for physical applications have been found to be controlled by one ofthe two types of the fixed points, the free - field fixed point or the certain non -zero value of the coupling constant fixed point [20]. The structural complexity approach has a simple explanation for this enigma. The structural complexity Q/M (Q is the charge of the particle and M is the particle's mass) decreases towards the free - field fixed point in both cases as you integrate over the large values of the momentum. Smaller values of Q/M and small values of the momentum, both correspond to the tree level diagrams, to the quasi - classical case. The loop diagrams contributions simply lead to the slight modifications of the original tree - level diagrams values. The electric field and the magnetic field components of the electromagnetic field may have fundamentally different origins. The magnetic field is the reflection of structural complexity of our space - time, like the three –dimensional momentum. The electric field incorporates into itself the features of nature before the shift in the symmetry/spontaneous symmetry breaking (through the electric charge) and after the shift in the symmetry which makes it similar to the energy of the particle. The innner product of the antisymmetric second rank electromagnetic tensor produces the Lorentz invariant quantity:

$$F_{\mu\nu}F^{\mu\nu} = 2(\vec{B}^2 - \vec{E}^2) \qquad (2)$$

If we multiply the antisymmetric electromagnetic tensor by $i/\sqrt{2}$ (like multiplying the ct term by the imaginary number i in the case of the four - momentum), on the right hand of the equation we will get $\vec{E}^2 - \vec{B}^2$, the quantity reminding us $E^2 - \vec{p}^2$ for the four – momentum (We have to notice that the electric field $\vec{E}$ has richer space - time structure than the energy of the particle, E. This association is consistent with the previous discussion about the magnetic field $\vec{B}$ expressing the complexity degree of the space - time and the electric field $\vec{E}$ being of a more fundamental nature. So the electromagnetic tensor can be considered as the reflection of the same aspect of the structural complexity of nature as the four - momentum is.

In special relativity, we combine the tree - dimensional quantity, the coordinates *x, y, z* with time axis coordinate *i ct* to get the Lorentz invariant quantity $-c^2t^2 + x^2 + y^2 + z^2$. *i ct* is just a mathematical quantity, it does not have a meaning physics wise. This division into components and loss of information reminds one division of the living creature into parts, components. The living creature has a meaningful existence only as a whole. The structural complexity approach to the interpretation of the second principle of special relativity [21] implies that the light (electromagnetic waves) interacts in essence with the entire universe as a whole. In the earlier work we argued that there are indications that the life is also a manifestation of the processes at the scale of the universe (see the discussions around Eq. (4) in [22]. This statement combined with the above mentioned interpretation of the second principle of special relativity becomes a steadfast support of the idea about the life – like nature of the Lorentz invariant quantities. The electric field component and the magnetic field component of the electromagnetic field are also inseparable, only together they make up the electromagnetic field. Similarly, the 'superposed' quantum state cannot be separated into the component quantum states, only the ensemble of the component quantum states together induces the given quantum state. The possible connection of the decision making capacity of the living creatures and the superposition principle in quantum mechanics was discussed in [22].

Both of the above discussed Lorentz invariant quantities have another attention - getting aspect, they consist of the difference of the more fundamental quantity (the electric field or energy related quantity) and three – dimensional space related quantity (the magnetic field or three - dimensional momentum related quantity). Structural complexity wise they are similar to the Lagrangian, which also consists of the difference of the more fundamental quantity, the particle's own (kinetic) energy and its three - dimensional space related potential energy. The Lagrangian is the central component of the least action principle. Maxwell equations (with no sources case) themselves can be obtained from the action where the role of the Lagrangian is played by the above discussed inner product of the electromagnetic tensor. We see that the least action principle gets a clearer physical interpretation with the structural complexity approach to this fundamental aspect of physics. Nature tries to minimize the difference of the quantity relating to the original symmetry (before the shift in thesymmetry) of nature and the quantity relating to our three - dimensional space. We can also say that the photon has a dynamic nature of mass in more generalized form, equal to the squre root of the difference of the squared electric and magnetic fields, $\vec{E}^2 - \vec{B}^2$. The square of the rest energy of the particle, the minimum value of the square of its energy, can also be treated along the similar lines: as a manifestation of the least action principle. This quantity is also the difference of the quantity relating to the original symmetry, the square of the particles's energy and the space - time only related quantity, the square of the three - dimensional momentum.

The scaling property of the coupling constants in the renormalization theory must be a special case of the similarity of the structural complexity aspect of the QFT: the scaling of the variables may be in the continuumform and in the discrete form. The latter has a richer content and reminds one the way multicellular living organisms are built. The 'alkali metals' vs the 'halogens' relation also has this feature. Similarity of the structural complexities aspect of this model tells us about its pertinence to finding a path from quantum field theory to deciphering the energy, the mechanism of life (living creatures). S. Weinberg hoped that we can one day see the mechanism of life including the human consciousness in the equations of the quantum field theory. The similarity feature of the structural complexity model of the universe tells us that our one way attempts for this purpose, from currently existing quantum field theories towards the description of the living organisms, is unlikely to succeed. We also have to attempt to build quantum field theories reflecting the mechanisms of life. There is also a good chance that the structural complexity approach may dramatically shorten, simplify the quantum field theory calculations by the novel approach to the renormalization procedures. The main equation of the structural complexity, Eq. (1) can be considered as a special case of the main equation of the renormalization theory of Murray Gell-Mann and Francis E. Low

$$G(g(\mu)) = G(g(M))(\mu/M)^{d} \qquad (3)$$

with d =1 and $G(g(M)) = g(M)$. Here $G(g(M))$ is Wegner's scaling function.

The logarithmic spiral equation which describes shapes of the objects from the living creatures up to the galaxies

$$\theta = \frac{1}{b} \ln(\frac{r}{a}) \qquad (4)$$

can also be associated with the main equation of the structural complexity. A scaled logarithmic spiral, $\frac{r}{a}$, is congruent (by rotation) to the original curve. When 'digging' deeper into nature, by moving from the coupling constant g, $\frac{M_W}{g}$ to the coupling constant g', $\frac{M_B}{g'}$, the value of the structural complexity remains constant, Eq. (1).

Scale invariance is a cornerstone of the nowadays theory of phase transitions and conformal field theory. This 'alkali metals', 'halogens' (triplet part and singlet part) association of the elementary particles in regard to the values of their masses must not be accidental. It is quite possible that a significant part of the information about the chemical properties of atoms is contained in the distribution picture of the masses of the elementary particles (including the condition when the folding of the particular protein begins). Our standard renormalisation procedures may not be able to fully clarify this 'chemistry' of the elementary particles. The fruitful structural complexity of the elementary particles approach can be used here. Everyone would agree that eventually, in quantum field theory everything should be as clear as in chemistry, in the sense of intuitive acceptance of its postulates and conclusions.

DISCUSSIONS AND CONCLUSIONS

Three generations of fermions, three quark colors aspect of the elementary particles is discussed in this work. Their possible |1/2> x |1/2> fermionic origin is analyzed. It is emphasized that these trios of the elementary particles are indispensably connected to the $SU(2)_L$ x $SU(2)_R$ type of the original symmetry of the elementary particles. Eq.(1) related physics of this work brings together several key features of high energy physics and explains them from a unified point of view: a) the *W* boson and *Z* boson mass ratio, b) the existence of three quark colors, c) the difference of the hypercharge values of leptons and quarks, d) the bizarre right – handed fermion hypercharge values emerging as a sum of the isospin and the original hypercharge quantum numbers e) Eq.(1) related physics allows us to consider the gauge transformations as a consequence of the more general feature of quantum physics, the consequence of the phase shifts of the wave functions. The gauge transforma – tions are not just mathematical transformations of the wave functions/quantum fields, they reflect the change of the physical quantity, the phase of the wave function.

K. Wilson's renormalization group flows to the fixed point is analyzed with the structural complexity approach to the problem. This approach brings clarity to the behavior of the mass and coupling constants near the fixed point. The life - like nature of the Lorentz invariant quantities, e.g., electromagnetic tensor contraction is also discussed. It is emphasized that the main equation of the structural complexity, the main equation of the renormalization group and the equation of the logarithmic spiral are identical for many applications.

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