# THE CONNECTION BETWEEN THE ENERGY AND STRUCTURAL COMPLEXITY OF THE MATTER, STRUCTURAL COMPLEXITY ORIGIN OF THE ELECTROWEAK BOSON MASSES AS WELL AS METABOLISM IN LIVING ORGANISMS

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The connection between the energy and structural complexity of the materials is discussed in terms of the crystals of the different chemical elements, the latent heat of fusion and crystal structure connection is analyzed. This type of connection equation paves a way to calculating the electroweak gauge boson masses in an alternative way, on the basis of the same concepts. Specific values of the parameters for carbon crystals, water, lithium and beryllium are analyzed which sheds light to the origin of the cancer disease. The right - handed neutrino question and the strong CP problem in quantum chromodynamics are also analyzed in the context of the symmetry changes, phase transitions at the early stages of the formation of the universe.

**Keywords:** dependence of the structural complexity on the energy, structural complexity - latent heat of fusion connection of the substances, the connection between the charges and masses of the elementary particles.
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## INTRODUCTION

A quick look at the parameters of the elementary particles tells us that the connection between the mass and coupling constant discussed in the previous works for the electroweak gauge bosons

$$M_W/g = M_B/g' \qquad (1)$$

is present for all the known elementary particles, but only in an approximate form. For the second and third generation of quarks up quarks are significantly heavier than down quarks. Electroneutral neutrinos have no mass or tiny mass only. The exact nature of Eq.(1) indicates that the electroweak gauge bosons are indeed the fundamental level of particles, the intermediaries of the fundamental level of interactions. This equation can be interpreted as follows: the bigger the energy (mass) of the system, the bigger the value of the coupling constant and hence the higher the structural complexity of the system where these interactions occur.

Charge conjugation operator aspect of the electron wave function also confirms this interpretation of the equation above. Charge conjugation operator changes a negative - energy solution for the electron with the certain momentum $p_i$ and polarization $S_i$ to a positive - energy solution with the same $p_i$ and $S_i$:

$$\Psi_C = C\gamma_0\Psi^* = C\gamma_0((\varepsilon\gamma_i p^i + m)/(2m))^*(1 + \gamma^5(p_i S^i)/2)^*\Psi^* \rightarrow (-\varepsilon\gamma_i p^i + m)/(2m)(1 + \gamma^5(p_i S^i)2)\Psi_C \qquad (2)$$

Here ε = 1 for positive energy states and ε = -1 for negative energy states.

When applied to Eq.(1), we can say that both numerator and denominator change sign which has no impact on the equation.

## METHODS

### A. The connection between the structural complexity and latent heat of fusion for crystals

We can observe a similar mass - coupling constant connection tendency relating to the values of the atomic nuclei masses. Iron and Nickel have the biggest binding energy per nucleon which means relatively small nuclear mass. Nickel has face centered cubic crystal structure, Iron has body centered cubic crystals and face centered cubic crystals: the nucleus with the smaller mass can accommodate relatively simpler crystal form only. One can explain this with the smaller interaction force between the nuclei. Certainly one can explain this a slightly different way. Iron nuclei have relatively small nuclear size, approximately 3.7 fm: they experienced the shift in the symmetry process in a lesser degree [3] and they tend to have simpler crystal structure. Gold nuclei with slightly smaller binding energy per nucleon can accommodate more complex forms of crystal structure. The connection between the structural complexity and energy of the system reveals itself in a different form when we look at the values of the latent heat of fusion of the chemical elements. Both diamond and graphite crystals of carbon (the most abundant forms of carbon) have noticeably high latent heat of fusion, around 120 kJ/mol. Both of these one chemical element based crystals have the higher melting temperature than any other one chemical element based crystal. Carbon is at the core of the organic substances, the substances that give rise to the life on Earth, to the most complex structures in the universe. The major ingredients of life, carbohydrates, fats and proteins contain a large portion of the hydrogen atoms besides the carbon atoms. What is more important here, the simple structure of the hydrogen atoms or the fact that hydrogen $H_2$ has the lowest melting point among the chemically active one



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chemical element based substances? Combination of the element with the highest melting point (3652 ºC) for the graphite) and with the lowest melting point might give rise to an enormous flexibility in chemical reactions keeping the structural complexity of the molecule essentially intact. 20 ºC is considered optimal condition for life on Earth. Small departures from this temperature would not also affect significantly the complexity type of the molecule.

Perhaps it is not accidental that Lithium which is used for the treatment of the nervous disorders has a latent heat per gram close to that of water, 422 J/g vs 334 J/g. Lithium has smaller value for the latent per mole than that of water. This can be considered as an indication of even closer values for the latent heat of these two substances. Lithium also prevents the development of different cancers. The next to lithium chemical element, Berillium has relatively high latent heat per gram, 1350 J/g and is considered as carcinogenic. One would say that Berillium's crystal making tendency is significantly different from the structural complexity that the living creatures strive to have (see also [3] for the interpretation of the peculiar values of the binding energies per nucleon for the Lithium and Beryllium). Liquid (one - dimensional) crystal properties of the human DNA have been known for a very long time.

It is natural to expect that the human DNA's and water's structural complexity making tendencies are close to each other. Magnesium is a chemical element with both the molecular mass and latent heat of fusion slightly bigger than those of water, 24.3 a.u. vs 18 a.u and 8.48 kJ/mol vs 6.02 kJ/mol. Magnesium has a numerous health benefits and low level of magnesium in human body leads to the cancer disease. From the other side, Lithium, Beryllium and Magnesium's role in the human health conditions also tells us about the strong connection between the chemical substance's structural complexity making tendencies and their latent heat of fusion.

### B. The connection between the structural complexity and elementary particle's mass in quantum field theory

Do we have a certain etalon or maximum of the structural complexity of the systems for our particular universe that all the living creatures strive to achieve (by their own approach to this goal)? If yes, this complexity type must be at the core of the electroweak gauge boson masses too. As the universe expands and cools at the early stages of its formation it gains an opportunity to accommodate more complex structures/particles at some point. The original $SU(2)_L$ x $SU(2)_R$ symmetry is replaced by the U(1) gauge symmetry that we observe around today [1]. The original $SU(2)_L$ x $SU(2)_R$ symmetry based calculations and the Standard Model make the same predictions for the W and Z boson masses. Notice that these predictions are independent of the interactions with the Higgs particle and its mass. A plenty of information available on the latent heat of fusion and crystal structures of the one chemical element based substances could be used for further clarification of this pivotal connection between the structural complexity of the systems and their energy, in other words, for bringing some clarity to the question what approximations and priorities does the nature use for choosing this or another crystal structure.

A few words about the role of the group theory in the structural complexity analysis. Perhaps the existing group theory needs to be expanded and made more versatile to achieve this goal. The fruitful character aspect of the group theory is a quite promising venue in this sense. One can consider the character for the given irreducible representation as bringing the state vectors of a system to one dimensional space. Liquids can be considered as one dimensional crystals to some extent. If you isolate two molecules of the liquid and consider their motion along the circle with the center in the midst of them it would not change the interaction force between them and this is an allowed motion for the liquid molecules. One needs such a decomposition of the original irreducible representations that the small variations of the parameters of the subgroups would have an impact on their complexity aspect.

Due to $SU(2)_L$ x $SU(2)_R$ symmetry originally both left - handed and right - handed fermions interact with the triplet of electroweak vector bosons W. After the first stage of the shift in the symmetry, after meltdown (rapid decay) of the right – handed fermion doublets the fermion – electroweak gauge boson interaction part of the Lagrangian obtains the form which the Standard Model based theories consider as a starting point of symmetry breaking:

$$L_{int} = i\bar{R}\gamma^i(\partial_i + ig'B_i - (i/2)g\sigma^l W_i^l)R + i\bar{L}\gamma^i(\partial_i + ig'B_i - (i/2)g\sigma^l W_i^l)L \rightarrow$$

$$i\bar{R}\gamma^i(\partial_i + ig'B_i)R + i\bar{L}\gamma^i(\partial_i + ig'B_i - (i/2)g\sigma^l W_i^l)L \qquad (3)$$

Meltdown of the right - handed doublet looks similar to getting character of the given representation discussed above. Isospin aspect and $B_i$ field aspect of the state vector merge together, isospin doublet disappears This merge does not affect the electric charge of the right - handed fermions which is the sum of the isospin quantum number $I_W$ and hypercharge Y. But the structural complexity of the system certainly gets altered. Right –handed neutrinos disappear. Right - handed fermions no longer interact with the W bosons. $SU(2)_L$ x $SU(2)_R$ fermion symmetry model readily explains the absence of right - handed neutrinos in the experiments and somewhat odd hypercharge numbers of the right - handed quarks. It is not because of different values of hypercharge that right -handed quarks do not form a doublet. Contrary, because of the meltdown of the isodoublet right - handed quarks get these hypercharge numbers. The Standard Model procedure of getting the $Z_\mu$ boson and photon $A_\mu$ structures from the covariant derivative of the Higgs field is also simply bringing into one dimension the isospin doublet related structure of the W bosons. According to the fermionic origin of the gauge bosons theory gauge transformations are not simply mathematical transformations: they reflect the change of the phase factor of the fermionic wave functions [3]. The probability is essentially zero that nature will choose some particular gauge of the local SU(2) symmetry out of infinite number options, the gauge which would produce the desired W boson and $B_\mu$ boson mixing. It is the meltdown of the right - handed fermion doublets that leads to the W boson and $Z_\mu$ boson mixing.

The d quark is heavier than the u quark and we do not see Eq. (1) type mass - coupling constant relation in this particular case which could be the result of restoration of the original $SU(2)_L$ x $SU(2)_R$ symmetry for the significant interval of the strong interactions of these quarks. This aspect of the light quarks also sheds light to the strong CP problem in quantum chromodynamics.

We can describe the emergence of the $Z_\mu$ boson and photon $A_\mu$ after redistribution of the masses of the original

electroweak bosons by using the Dirac bra - ket formalism (see also [1]). The W bosons and the B boson belong to the triplet and the singlet states of the two spin ½ particles and this reveals itself manifestly in the Dirac bra - ket formalism. Here we treat Dirac ket vectors |> as the vectors pointing in the certain direction in the quantum mechanical state space to get a clear idea about the $Z_\mu$ boson, photon $A_\mu$ structures and Z boson - W boson mass connection ($Z_\mu$ boson mass - electroweak interactions coupling constants connection).

$$\begin{aligned}
&M_W^2\,|W_1\rangle|W_1\rangle + M_W^2\,|W_2\rangle|W_2\rangle + M_W^2\,|W_3\rangle|W_3\rangle + M_B^2\,|B\rangle|B\rangle = \\
&M_W^2\,|W_1\rangle|W_1\rangle + M_W^2\,|W_2\rangle|W_2\rangle + M_W^2/g^2(g^2|W_3\rangle|W_3\rangle + g'^2\,|B\rangle|B\rangle) = \\
&M_W^2\,|W_1\rangle|W_1\rangle + M_W^2\,|W_2\rangle|W_2\rangle + M_W^2/g^2(g|W_3\rangle - g'\,|B\rangle)^2 + \\
&4\,(M_W^2/g^2)gg'|W_3\rangle|B\rangle = M_W^2\,|W^+\rangle|W^-\rangle + M_Z^2\,|Z\rangle|Z\rangle \qquad (4)
\end{aligned}$$

with $M_Z = M_W \Big/ \sqrt{\frac{g^2}{g^2+g'^2}} = M_W/\cos\theta_W$ and

$|Z\rangle = (g|W_3\rangle - g'\,|B\rangle)/\sqrt{g^2 + g'^2} = |W_3\rangle\cos\theta_W - |B\rangle\sin\theta_W$

$\cos\theta_W = \frac{g}{\sqrt{g^2+g'^2}}$ is the Weinberg angle here.

The $(M_W^2/g^2)gg'|W_3\rangle|B\rangle$ term in the equation above disappears because of orthogonality of $|W_3\rangle$ and $|B\rangle$ states.

In reality everything could be more complex during the phase transitions at the early stages of the formation of the universe than this presented picture of the phase transitions. This is a multistage phase transition process similar to the cell division process. Many facts tells us that shift in the symmetry process is a second order phase transformations type. Coupling constants would disappear from the interaction Lagrangian if we use its Eq. (3) form and represent electroweak gauge bosons as fused states of fermions [3]. One can interpret this as a sign of the presence of the long range correlations. Right - handed quarks and electron preserve an important aspect of their structural complexity, their electric charge during the phase transition process which is an indication of the no latent heat of 'fusion' process, the second order phase transition process.

## DISCUSSION AND CONCLUSIONS

The equation connecting electroweak interactions coupling constants and electroweak boson masses is just one manifestation of the much broader connection between the energy and structural complexity of the quantum mechanical systems. Structures of the different crystals and their latent heat of the fusion values are analyzed for this purpose. It is emphasized that phase transitions, symmetry changes during early stages of the universe's formation are complex, multistage process. It is also pointed out that the original $SU(2)_L$ x $SU(2)_R$ fermion symmetry approach to these phase transitions answers the question of the absence of the right – handed neutrinos and sheds light to the strong CP problem in quantum chromodynamics. Somewhat odd values of the right - handed quarks are naturally explained by the meltdown of the right - handed isodoublets in this work.

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