Natural limits of Electroweak Model as contraction of its gauge group

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Abstract. The low and higher energy limits of the Electroweak Model are obtained from first principles of gauge theory. Both limits are given by the same contraction of the gauge group, but for the different consistent rescalings of the field space. Mathematical contraction parameter in both cases is interpreted as energy. The very weak neutrino-matter interactions is explained by zero tending contraction parameter, which depend on neutrino energy. The second consistent rescaling corresponds to the higher energy limit of the Electroweak Model. At the infinite energy all particles lose masses, electroweak interactions become long-range and are mediated by the neutral currents. The limit model represents the development of the early Universe.

1. Introduction

The modern theory of electroweak processes is the Electroweak Model, which is in good agreement with experimental dates, including the latest ones from LHC. This model is a gauge theory based on the gauge group $SU(2) \times U(1)$, which is the direct product of two simple groups. The operation of group contraction [1] transforms a simple or semisimple group to a nonsemisimple one. In particular the special unitary group $SU(2)$ is contracted to the group isomorphic to Euclid group $E(2)$ [2]. For better understanding of a complicated physical system it is useful to investigate its behaviour for limiting values of its physical parameters. In this paper we discuss at the level of classical gauge fields the modified Electroweak Model with the contracted gauge group $SU(2; j) \times U(1)$. It was shown [3]–[6] that at low energies the contraction parameter depends on the energy $s$ in center-of-mass system, so the contracted gauge group corresponds to the zero energy limit of the Electroweak Model. The very weak neutrino-matter interactions and the linear dependence of their cross-section on neutrino energy both are explained from first principles of the Electroweak Model as contraction of its gauge group. But for the same contraction of the gauge group there is another consistent rescaling of the representation space, which lead to the infinite energy limit of the Electroweak Model. In this paper we consider the second possibility and discuss some particle properties in early Universe, where similar higher energies can exist.

2. Standard Electroweak Model

We shall follow the books [7]–[9] in description of standard Electroweak Model. Its Lagrangian is the sum of boson, lepton and quark Lagrangians

$$L = L_B + L_L + L_Q.$$  \hspace{1cm} (1)
Boson sector $L_B = L_A + L_\phi$ involve two parts: the gauge field Lagrangian
\[
L_A = \frac{1}{8g^2} \text{Tr}(F_{\mu\nu})^2 - \frac{1}{4}(B_{\mu\nu})^2 = \frac{1}{4}[(F^1_{\mu\nu})^2 + (F^2_{\mu\nu})^2 + (F^3_{\mu\nu})^2] - \frac{1}{4}(B_{\mu\nu})^2
\]
and the matter field Lagrangian
\[
L_\phi = \frac{1}{2}(D_\mu\phi)\dagger D_\mu\phi - \frac{\lambda}{4}\left(\phi\dagger\phi - v^2\right)^2.
\]
where $\phi = \begin{pmatrix} \phi_1 \\
\phi_2 \end{pmatrix} \in C_2$ are the matter fields. The covariant derivatives are given by
\[
D_\mu\phi = \partial_\mu\phi - ig\sum_{k=1}^3 T_k A^k_\mu(x), \quad B_\mu(x) = -ig'B_\mu(x)
\]
where $T_k = \frac{1}{2}\tau_k, k=1,2,3$ are generators of SU(2), $Y = \frac{1}{2}\mathbf{1}$ is generator of U(1), $g$ and $g'$ are constants. The gauge fields
\[
A_\mu(x) = -ig\sum_{k=1}^3 T_k A^k_\mu(x), \quad B_\mu(x) = -ig'B_\mu(x)
\]
take their values in Lie algebras $su(2), u(1)$ respectively, and the stress tensors are as follows
\[
F_{\mu\nu}(x) = F_{\mu\nu}(x) + [A_\mu(x), A_\nu(x)], \quad B_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu.
\]
To generate mass for the vector bosons the special mechanism of spontaneous symmetry breaking is used. One of $L_B$ ground states
\[
\phi^{vac} = \begin{pmatrix} 0 \\
v \end{pmatrix}, \quad A^k_\mu = B_\mu = 0
\]
is taken as a vacuum state of the model, and small field excitations $v + \chi(x)$ with respect to this vacuum are regarded.

The fermion sector is represented by the lepton $L_L$ and quark $L_Q$ Lagrangians. The lepton Lagrangian is taken in the form
\[
L_L = L^1_i \bar{\nu}_\tau D_\mu L_l + e_i^1 \bar{\tau}_\mu D_\mu e_r - h_e[e^1_r(\phi\dagger L_l) + (L^1_i\phi)e_r],
\]
where $L_l = \begin{pmatrix} \nu_l \\
e_l \end{pmatrix}$ is the SU(2)-doublet, $e_r$ is the SU(2)-singlet, $h_e$ is constant, $\tau_0 = \bar{\tau}_0 = 1$, $\bar{\tau}_k = -\tau_k$, $\tau_k$ are Pauli matrices and $e_r, e_l, \nu_l$ are two component Lorentzian spinors. Last terms with factor $h_e$ represent electron mass. The covariant derivatives are given by the formulas:
\[
D_\mu L_l = \partial_\mu L_l - i\frac{g}{\sqrt{2}}(W^+_\mu T_+ + W^-_\mu T_-) L_l - i\frac{g}{\cos\theta_w}Z_\mu (T_3 - Q\sin^2\theta_w) L_l - ie_\mu Q L_l,
\]
\[
D_\mu e_r = \partial_\mu e_r - ig'A_\mu e_r \cos\theta_w + ig'Q Z_\mu e_r \sin\theta_w,
\]
where $W^\pm_\mu = W^1_\mu \pm iW^2_\mu$, $Z_\mu = W^3_\mu - iQ W^1_\mu$. The gauge fields $A_\mu$ and $B_\mu$ (where $B_\mu = -ig'B_\mu$) are generated by the special mechanism of spontaneous symmetry breaking.
where $T_\pm = T_1 \pm i T_2$, $Q = Y + T_3$ is the electrical charge, $Y = \frac{1}{2}$ is the hypercharge, $e = g g'(g^2 + g'^2)^{-\frac{1}{2}}$ is the electron charge and $\sin \theta_w = eg^{-1}$. The new gauge fields

$$Z_\mu = \frac{1}{\sqrt{g^2 + g'^2}} (g A^3_\mu - g' B_\mu), \quad A_\mu = \frac{1}{\sqrt{g^2 + g'^2}} (g' A^3_\mu + g B_\mu),$$

$$W^\pm_\mu = \frac{1}{\sqrt{2}} (A^1_\mu \mp i A^2_\mu)$$

(8)

are introduced instead of (5).

The quark Lagrangian is given by

$$L_Q = Q^\dagger_l i \tilde{\tau}_\mu D_\mu Q_l + u^\dagger_l i \tau_\mu D_\mu u_r + d^\dagger_l i \tau_\mu D_\mu d_r -$$

$$- h_u [d^\dagger_l (\phi^\dagger Q_l) + (Q^\dagger_l \phi) d_r] - h_d [u^\dagger_l (\tilde{\phi}^\dagger Q_l) + (Q^\dagger_l \tilde{\phi}) u_r],$$

(9)

where left quark fields form the $SU(2)$-doublet $Q_l = \begin{pmatrix} u_l \\ d_l \end{pmatrix}$, right quark fields $u_r, d_r$ are the $SU(2)$-singlets, $\tilde{\phi}_i = \epsilon_{ik} \phi_k, \epsilon_{00} = 1, \epsilon_{ii} = -1$ is the conjugate representation of $SU(2)$ group and $h_u, h_d$ are constants. All fields $u_l, d_l, u_r, d_r$ are two component Lorentzian spinors. Last four terms with factors $h_u$ and $h_d$ specify the $d$- and $u$-quark mass. The covariant derivatives are given by

$$D_\mu Q_l = \left( \partial_\mu - ig \sum_{k=1}^3 \bar{\tau}_k A^k_\mu - ig' \frac{1}{6} B_\mu \right) Q_l,$$

$$D_\mu u_r = \left( \partial_\mu - ig \frac{2}{3} B_\mu \right) u_r, \quad D_\mu d_r = \left( \partial_\mu + ig' \frac{1}{3} B_\mu \right) d_r.$$

(10)

From the viewpoint of electroweak interactions all known leptons and quarks are divided on three generations. Next two lepton generation are introduced in a similar way to (6). They are left $SU(2)$-doublets

$$\begin{pmatrix} \nu^\dagger_l \\ \mu \end{pmatrix}_l, \quad \begin{pmatrix} \nu^\dagger r \\ \tau \end{pmatrix}_l, \quad Y = -\frac{1}{2}$$

(11)

and right $SU(2)$-singlets: $\mu_r, \tau_r$, $Y = -1$. In addition to $u$- and $d$-quarks of the first generation there are $(c, s)$ and $(t, b)$ quarks of the next generations, which left fields

$$\begin{pmatrix} c_l \\ s_l \end{pmatrix}, \quad \begin{pmatrix} t_l \\ b_l \end{pmatrix}, \quad Y = \frac{1}{6},$$

(12)

are described by the $SU(2)$-doublets and the right fields are $SU(2)$-singlets: $c_r, t_r$, $Y = \frac{2}{3}$; $s_r, b_r$, $Y = -\frac{1}{3}$. Their Lagrangians are introduced in a similar way to (9). Full lepton and quark Lagrangians are obtained by the summation over all generations. In what follows we shall regarded only first generations of leptons and quarks.

3. Low energy limit of the Electroweak Model

We consider a model where the contracted gauge group $SU(2; j) \times U(1)$ acts in the boson, lepton and quark sectors. The contracted group $SU(2; j)$ is obtained [10, 11] by the consistent rescaling of the fundamental representation of $SU(2)$ and the space $C_2$

$$z'(j) = \begin{pmatrix} j z'_1 \\ z'_2 \end{pmatrix} = \begin{pmatrix} \alpha & j \beta \\ -j \beta & \alpha \end{pmatrix} \begin{pmatrix} j z_1 \\ z_2 \end{pmatrix} = u(j) z(j),$$

3
\[
\det u(j) = |\alpha|^2 + j^2|\beta|^2 = 1, \quad u(j)u^\dagger(j) = 1
\]
in such a way that the hermitian form
\[
z^jz(j) = j^2|z_1|^2 + |z_2|^2
\]
remains invariant, when contraction parameter tends to zero \( j \to 0 \) or is equal to the nilpotent unit \( j = \iota, \iota^2 = 0 \). The actions of the unitary group \( U(1) \) and the electromagnetic subgroup \( U(1)_{em} \) in the space \( C_2(\iota) \) with the base \{\( z_2 \)\} and the fiber \{\( z_1 \)\} are given by the same matrices as on the space \( C_2 \).

The space \( C_2(j) \) of the fundamental representation of the SU(2; \( j \)) group can be obtained from \( C_2 \) by substituting \( z_1 \) by \( jz_1 \). Substitution \( z_1 \to jz_1 \) induces another ones for Lie algebra generators \( T_1 \to jT_1, \ T_2 \to jT_2, \ T_3 \to T_3 \). As far as the gauge fields take their values in Lie algebra, we can substitute the gauge fields instead of transforming the generators, namely:
\[
A^1_\mu \to jA^1_\mu, \quad A^2_\mu \to jA^2_\mu, \quad A^3_\mu \to A^3_\mu, \quad B_\mu \to B_\mu.
\]
Indeed, due to commutativity and associativity of multiplication by \( j \)
\[
su(2; \ j) \ni \{A^1_\mu(jT_1) + A^2_\mu(jT_2) + A^3_\mu T_3\} = \{j(A^1_\mu T_1 + (jA^2_\mu T_2 + A^3_\mu T_3)\}.
\]
For the gauge fields (8) these substitutions are as follows:
\[
W^\pm_\mu \to jW^\pm_\mu, \quad Z_\mu \to Z_\mu, \quad A_\mu \to A_\mu.
\]
The left lepton \( L_i = \begin{pmatrix} \nu_i \\ e_i \end{pmatrix} \) and quark \( Q_i = \begin{pmatrix} u_i \\ d_i \end{pmatrix} \) fields are SU(2)-doublets, so their components are transformed in the similar way as components of the vector \( z \), namely:
\[
\nu_i \to j\nu_i, \quad e_i \to e_i, \quad u_i \to ju_i, \quad d_i \to d_i.
\]
The right lepton and quark fields are SU(2)-singlets and therefore are not changed.

The full Lagrangian of the modified model is obtained from the standard one [7]–[9] by the above substitutions and can be represented in the form
\[
L(j) = L_b + j^2L_f,
\]
where \( L_b \) is Lagrangian of the base fields and \( L_f \) is Lagrangian of the fiber fields. The transformed boson Lagrangian was discussed in \[10, 11\] on the level of classical fields, where it was shown that masses of all particles involved in the Electroweak Model remain the same under contraction \( j^2 \to 0 \). In this limit the contribution \( j^2L_f \) of neutrino, \( W \)-boson and \( u \)-quark fields as well as their interactions with other fields to the Lagrangian (19) will be vanishingly small in comparison with contribution \( L_b \) of electron, \( d \)-quark and remaining boson fields. So Lagrangian (19) describes very weak interaction of neutrino fields with the matter. On the other hand, contribution of the neutrino part \( j^2L_f \) to the full Lagrangian is risen when the parameter \( j^2 \) is increased, that again corresponds to the experimental facts. So contraction parameter can be phenomenologically connected with neutrino energy.

To establish the precise physical meaning of the contraction parameter we need more fine consideration on the level of quantized fields. It is necessary to regard neutrino elastic scattering on electron and quarks [8]. We have found that the contraction parameter is connected with the neutrino energy \( \sqrt{s} \) in center-of-mass system and is evaluated through the fundamental parameters of the Electroweak Model as follows
\[
j^2(s) = \frac{g}{m_W} \sqrt{s},
\]
where \( m_W \) is \( W \)-boson mass and \( g \) is constant [4, 5]. Therefore, contraction \( j \to 0 \) result in low energy limit of the Electroweak Model.
Chapter 4. High-Energy Lagrangian of Electroweak Model

We introduce new contraction parameter $\varepsilon$ and new consistent rescaling of the group $SU(2)$ and the space $C_2$ as follows [12]

$$z'(\varepsilon) = \begin{pmatrix} z'_1 \\ z'_2 \end{pmatrix} = \begin{pmatrix} \alpha & \varepsilon \beta \\ -\varepsilon \beta & \alpha \end{pmatrix} \begin{pmatrix} z_1 \\ z_2 \end{pmatrix} = u(\varepsilon)z(\varepsilon),$$

$$\text{det } u(\varepsilon) = |\alpha|^2 + \varepsilon^2 |\beta|^2 = 1, \quad u(\varepsilon)u^\dagger(\varepsilon) = 1$$

Both contracted groups $SU(2; j)$ (13) and $SU(2; \varepsilon)$ (21) are the same and are isomorphic to Euclid group $E(2)$, but the space $C_2(\varepsilon)$ is split in the limit $\varepsilon \to 0$ on the one-dimension base $\{z_1\}$ and the one-dimension fiber $\{z_2\}$. From the mathematical point of view it is not important first or second Cartesian axis forms the base of fibering and in this sense constructions (13) and (21) are equivalent. But the doublet components are interpreted as a certain physical fields, therefore the fundamental representations (13) and (21) of the same contracted unitary group lead to the different limit cases of the Electroweak Model, namely, its zero energy and infinite energy limits.

In the second contraction scheme (21) all gauge bosons are transformed according to the rules (17) with the natural substitution of $j$ by $\varepsilon$. Instead of (18) the lepton and quark fields are transformed now as follows

$$e_l \to \varepsilon e_l, \quad d_l \to \varepsilon d_l, \quad \nu_l \to \nu_l, \quad u_l \to u_l.$$  

The next reason for inequality of the first and second doublet components is the special mechanism of spontaneous symmetry breaking, which is used to generate mass of vector bosons and other elementary particles of the model. In this mechanism one of Lagrangian ground states $\phi^{vac} = \begin{pmatrix} 0 \\ v \end{pmatrix}$ is taken as vacuum of the model and then small field excitations $v + \chi(x)$ with respect to this vacuum are regarded. So Higgs boson field $\chi$ and constant $v$ are multiplied by $\varepsilon$. As far as masses of all particles are proportionate to $v$ we obtain the following transformation rule for the contraction (21)

$$\chi \to \varepsilon \chi, \quad v \to \varepsilon v, \quad m_p \to \varepsilon m_p, \quad p = \chi, W, Z, e, u, d.$$  

After transformations (17), (22)–(23) the boson Lagrangian of the Electroweak Model can be represented in the form

$$L_B(\varepsilon) = -\frac{1}{4} F_{\mu\nu}^2 - \frac{1}{4} \mathcal{F}_{\mu\nu}^2 + \varepsilon^2 L_{B,2} + \varepsilon^4 gW_\mu^+ W_\mu^- \chi + \varepsilon^4 L_{B,A},$$

$$L_{B,A} = m_W^2 W_\mu^+ W_\mu^- - \frac{1}{2} m_\chi^2 \chi^2 - \frac{1}{2} \lambda v^2 \chi^2 - \frac{\lambda}{4} \chi^4 +$$

$$+ \frac{g_0^2}{4} \left( W_\mu^+ W_\mu^- - W_\mu^+ W_\mu^- \right)^2 + \frac{g_0^2}{4} W_\mu^+ W_\mu^- \chi^2,$$

$$L_{B,2} = \frac{1}{2} \left( \partial_\mu \chi \right)^2 + \frac{1}{2} m_Z^2 \left( Z_\mu \right)^2 - \frac{1}{2} W_\mu^+ W_\mu^- +$$
The quark Lagrangian in terms of u- and d-quarks fields can be written as

\[ L_Q(u) = L_{Q,0} - \epsilon m_u(u_i^\dagger u_i + u_i^\dagger u_r) + \epsilon^2 L_{Q,2}, \]

\[ L_{Q,0} = d_i^\dagger i \bar{\tau}_\mu \partial_\mu d_r + u_i^\dagger i \bar{\tau}_\mu \partial_\mu u_r + u_i^\dagger i \bar{\tau}_\mu \partial_\mu u_r - \frac{1}{3} g' \cos \theta_w d_i^\dagger \tau_\mu A_\mu d_r + \frac{1}{3} g' \sin \theta_w d_i^\dagger \tau_\mu Z_\mu d_r + \]

\[ + \frac{2 \epsilon}{3} u_i^\dagger \bar{\tau}_\mu A_\mu u_i + \frac{g}{\cos \theta_w} \left( 1 - \frac{2}{3} \sin^2 \theta_w \right) u_i^\dagger \bar{\tau}_\mu Z_\mu u_i + \]

\[ + \frac{2 \epsilon}{3} g' \cos \theta_w u_i^\dagger \tau_\mu A_\mu u_i - \frac{2 \epsilon}{3} \frac{g'}{\sin \theta_w} u_i^\dagger \tau_\mu Z_\mu u_i, \]

The lepton Lagrangian in terms of electron and neutrino fields takes the form

\[ L_L(e) = L_{L,0} + \epsilon^2 L_{L,2} = \]

\[ = \nu_i^\dagger i \bar{\tau}_\mu \partial_\mu \nu_i + e_i^\dagger i \bar{\tau}_\mu \partial_\mu e_r + g' \sin \theta_w e_i^\dagger \bar{\tau}_\mu Z_\mu e_r - \]

\[ - g' \cos \theta_w e_i^\dagger \tau_\mu A_\mu e_r + \frac{g}{2 \cos \theta_w} \nu_i^\dagger \bar{\tau}_\mu Z_\mu \nu_i + \]

\[ + \epsilon^2 \left\{ e_i^\dagger i \bar{\tau}_\mu \partial_\mu e_r - m_e(e_i^\dagger e_i + e_i^\dagger e_r) + \right\} \]

\[ + \frac{g \cos 2 \theta_w}{2 \cos \theta_w} e_i^\dagger \bar{\tau}_\mu Z_\mu e_i - e e_i^\dagger \bar{\tau}_\mu A_\mu e_i + \]

\[ + \frac{g}{\sqrt{2}} \left( \nu_i^\dagger \bar{\tau}_\mu W_\mu^+ e_i + e_i^\dagger \bar{\tau}_\mu W_\mu^- u_i \right) \].
For the infinite energy (\(L\) for example neutrinos interact only with each other by neutral currents. It looks like some part approximation of the relativistic one at low velocities. From the explicit form of the interaction as a good approximation near the Big Bang just as the nonrelativistic mechanics is a good point-like \([13, 14]\) and it is not clear what means long-range electroweak interactions. However quarks \(u\) where \(\epsilon\) are multiplied by its mass in the evolution of the Universe. Higgs boson and charged \(Z\) bosons and neutral bosons \(Z\) bosons and photons. The infinite energies can exist only in the initial moment of creation when the Universe is \(\epsilon = 0\) limit Lagrangian is equal to

\[
L_{\infty} = -\frac{1}{4} Z_{\mu \nu}^2 - \frac{1}{4} F_{\mu \nu}^2 + \nu_l^\dagger i \tau_\mu \partial_\mu \nu_l + u_l^\dagger i \tau_\mu \partial_\mu u_l + e_l^\dagger i \tau_\mu \partial_\mu e_r + d_r^\dagger i \tau_\mu \partial_\mu d_r + u_r^\dagger i \tau_\mu \partial_\mu u_r + L_{\infty}^{\text{int}}(A_\mu, Z_\mu),
\]

where

\[
L_{\infty}^{\text{int}}(A_\mu, Z_\mu) = \frac{g}{2 \cos \theta_w} \nu_l^\dagger \tau_\mu Z_\mu \nu_l + \frac{2 e}{3} u_r^\dagger \tau_\mu A_\mu u_r +
\]

\[
\left\{ \begin{align*}
&-\frac{g}{\cos \theta_w} \left( \frac{1}{2} - \frac{2}{3} \sin^2 \theta_w \right) u_l^\dagger \tau_\mu Z_\mu u_l + \\
&+ g' \sin \theta_w e_r^\dagger \tau_\mu Z_\mu e_r - g' \cos \theta_w e_r^\dagger \tau_\mu A_\mu e_r - \\
&- \frac{1}{3} g' \cos \theta_w d_r^\dagger \tau_\mu A_\mu d_r + \frac{1}{3} g' \sin \theta_w d_r^\dagger \tau_\mu Z_\mu d_r + \\
&+ \frac{2}{3} g' \cos \theta_w u_r^\dagger \tau_\mu A_\mu u_r - \frac{2}{3} g' \sin \theta_w u_r^\dagger \tau_\mu Z_\mu u_r.
\end{align*} \right.
\]

The limit model includes only massless particles: photons \(A_\mu\) and neutral bosons \(Z_\mu\), left quarks \(u_l\) and neutrinos \(\nu_l\), right electrons \(e_r\), and quarks \(u_r, d_r\). The electroweak interactions become long-range because are mediated by the massless neutral \(Z\) bosons and photons.

The infinite energies can exist only in the initial moment of creation when the Universe is point-like \([13, 14]\) and it is not clear what means long-range electroweak interactions. However more interesting is the Universe evolution and the limit Lagrangian \(L_{\infty}\) can be considered as a good approximation near the Big Bang just as the nonrelativistic mechanics is a good approximation of the relativistic one at low velocities. From the explicit form of the interaction part \(L_{\infty}^{\text{int}}(A_\mu, Z_\mu)\) it follows that there are no interactions between particles of different kind, for example neutrinos interact only with each other by neutral currents. It looks like some stratification of the Electroweak Model with only one sort of particles in each stratum.

The mass term of \(u\)-quark in the Lagrangian (27) is proportional to the first power \(\epsilon m_u(u_l^\dagger u_l + u_r^\dagger u_r)\), whereas the mass terms of \(Z\)-boson, electron and \(d\)-quark are multiplied by the second power \(\epsilon^2 \left[ \frac{1}{2} m_Z^2 (Z_\mu)^2 + m_e (e^\dagger e_l + e^\dagger e_r) + m_d (d^\dagger d_l + d^\dagger d_r) \right]\), so \(u\)-quark first restores its mass in the evolution of the Universe. Higgs boson and charged \(W\)-boson, whose mass terms are multiplied by \(\epsilon^4\), last restore their masses after all other particles of the Electroweak Model.
5. Conclusion
We have investigated the low and higher energy limits of the Electroweak Model which are obtained from first principles of gauge theory as contraction of its gauge group. Above limits are given by the same contraction of the gauge group, but for the different consistent rescalings of the representation space. It was shown that mathematical contraction parameter in both cases is interpreted as typical energy.

The very weak neutrino-matter interactions especially at low energies can be explained by this model already at the level of classical (non-quantum) gauge fields. The zero tending contraction parameter is connected with neutrino energy and reproduce the linear energy dependence of the neutrino-matter cross-section.

The alternative rescaling of the gauge group and the field space corresponds to the infinite energy limit of the Electroweak Model, which goes in this limit through the five stages depending on the powers of the contraction parameters. At the infinite energy all particles are massless and electroweak interactions become long-range. But the infinite energies can exist only in the Big Bang, i.e. in the initial moment of creation when the Universe is point-like and it is not clear what means long-range. However more interesting is the Universe development and the limit Lagrangian $L_\infty$ can be considered as a good approximation near the Big Bang just as the nonrelativistic mechanics is a good approximation of the relativistic one at low velocities. Particularly we can conclude that according to the Electroweak Model $u$-quark first restores its mass among other particles in the evolution of the Universe.

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