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Systemic Gauge Theory

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Different topics are bringing the meaning of whole in physics. They are: nature tendency for conglomerates, confinement and complexity. Thus, one should investigate on a whole gauge symmetry. For this, a set of fields transforming under a common gauge parameter is considered. A systemic approach to gauge symmetry is studied. Different fields are introduced in a same abelian group, where their association is given through polynomial transformations. Consequently, new fields strength are introduced under such systemic gauge symmetry. It also introduces the possibility of a mass term without requiring Higgs mechanism. A systemic non-linear abelian Lagrangean is proposed. It is candidate for analysing an electromagnetic systemic phenomena.

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1. INTRODUCTION TO SYSTEMIC SYMMETRY

Considering the possibility of introducting a set of potential fields $\{A_{\mu I}\}$ transforming under a symmetry group one proposes a gauge theory based on the whole meaning. Thus, our effort is to interpret the whole meaning in terms of gauge symmetry. This lead us to develop the so-called whole gauge theory. It is a formulation that contains the usual gauge theories and extends it for a region where the parts (quantum numbers) are depending on the whole (set of fields organized by a lagrangean). It brings a step forward in the usual reductionist gauge approach [1].

Under such analysis this work involves just the abelian group. The idea for the whole concept to generate a physical model is by introducting different fields rotating under a same gauge group. It creates a fields-wholeness consisted by fields sharing a common gauge parameter. Then, given a set of fields $\{A_{\mu I}\}$, the following generic transformation law is proposed:

$$A'_{\mu I} = a_{IK} A^K_\mu + b_{IL} P'^L(\alpha)\partial_\mu \alpha \tag{1.1}$$

where a_{IK} and b_{IL} are coefficients and $P_I(\alpha)$ introduces a polynomial expansion in terms of the gauge parameter $\alpha(x)$, $P_I(\alpha) = \sum a_{Im}\alpha^m$. This expression is an evolution of two cases studied previously which are the linear interconnection $A'_{\mu I} = A_{\mu I} + \partial_\mu \alpha$ [2] and the polynomial interconnection $A'_{\mu I} = A_{\mu I} + P'_I(\alpha)\partial_\mu \alpha$ [3]. Equation (1.1) brings the so-called systemic interconnection, a new systemic gauge invariance where a field can transform itself in a set of another fields [4]. In true, a usual fact, given that it already occurs in non-abelian gauge theories.

Defining as systemic field $A^S_{\mu I} = a_{IK} A^K_\mu$ where the index S means systemic, one gets the antisystemic transformation.

$$A^{I'}_{\mu,S} = A^I_\mu + a^{IK} b_{KM} P^{M'} \partial_\mu \alpha \tag{1.2}$$

Equations (1.1 and 1.2) are showing relationships between the field and the whole.

Thus, there is a new possibility for introducting the meaning of whole through gauge symmetry. Our purpose here is to build a systemic abelian Lagrangean which provides a gauge invariant set of systemic fields. A possibility for investigating a systemic electromagnetism beyond Maxwell. At cosmological level, probably, nature contains a systemic electromagnetic phenomena. However, the source of this work is just to organize, theoretically, such systemic symmetry.

After the whole principle being a possibility for doing physics through gauge symmetry, a next step is to find out physical motivations. We are going to consider two cases. A first one it to introduce mass without Higgs. A second one is to introduce a new electromagnetism based on light. Basically, it introduces a light physics where light is not more passive as in Maxwell case, but becomes its own source of EM fields. This model provides light with photonic currents and a correspondent photonic charge. This means that there is an electromagnetism beyond the usual electric charge.

2. PHYSICAL ENTITIES INVOLVED IN THE SYSTEMIC TRANSFORMATION

The field strength tensors can be defined and built through the set of fields $\{A_{\mu I}\}$. In this work, we considered two possibilities. The first consist in a conglomerate of fields: $a_I A_\mu^{I'}$, $a_{IJ} A_\mu^{I'} A_\nu^{J'}$ and $a_{IJK} A_\mu^{I'} A_\nu^{J'} A_\rho^{K'}$. The second possibility is to establish the antisymmetric and symmetric tensors. The gauge invariance conditions are investigated and the result is shown in the next tables.

Conglomerate of fields	Invariance Conditions
$a_I A_\mu^{I'}$	$a_I b^{IL} P_L^{'} = 0$
$a_{IJ} A_\mu^{I'} A_\nu^{J'}$	$a_{IJ} b^{IL} P_L^{'} = 0$; $a_{IJ} b^{JL} P_L^{'} = 0$
$a_{IJK} A_\mu^{I'} A_\nu^{J'} A_\rho^{K'}$	$a_{IJK} b^{IL} P_L^{'} = 0$; $a_{IJK} b^{JL} P_L^{'} = 0$; $a_{IJK} b^{KL} P_L^{'} = 0$

Table 1: Gauge invariance conditions for the conglomerate of fields

Defining as field strength the expressions:

$$F_{\mu\nu}^{IJ'} = \kappa^I \partial_\nu A_\mu^{J'} - \kappa^J \partial_\mu A_\nu^{I'}$$
$$S_{\mu\nu}^{IJ'} = l^I \partial_\mu A_\nu^{J'} + l^J \partial_\nu A_\mu^{I'} \tag{2.1}$$

one gets:

$$\begin{aligned} F_{\mu\nu}^{IJ'} &= F_{\mu\nu,S}^{IJ} + P_L^{''}\left(\kappa^I b^{JL} - \kappa^J b^{IL}\right)\partial_\mu\alpha\partial_\nu\alpha \\ &\quad + P_L^{'}\left(\kappa^I b^{JL} - \kappa^J b^{IL}\right)\partial_\mu\partial_\nu\alpha \\ S_{\mu\nu}^{IJ'} &= S_{\mu\nu,S}^{IJ} + P_L^{''}\left(l^I b^{JL} + l^J b^{IL}\right)\partial_\nu\alpha\partial_\mu\alpha \\ &\quad + P_L^{'}\left(l^I b^{JL} + l^J b^{IL}\right)\partial_\nu\partial_\mu\alpha \end{aligned} \tag{2.2}$$

which yields the following gauge invariance conditions:

Tensors	Invariance Conditions
$F_{\mu\nu}^{II}$	Gauge Invariant
$S_{\mu\nu}^{II}$	$b^{IL} P_L^{'} = 0$; $b^{IL} P_L^{''} = 0$; $det B = 0$
$F_{\mu\nu}^{IJ}$	$\left(\kappa^J b^{IL} - \kappa^I b^{JL}\right) P_L^{'} = 0$; $\left(\kappa^J b^{IL} - \kappa^I b^{JL}\right) P_L^{''} = 0$; $det\left(\kappa^M b^{NM} - \kappa^N b^{MN}\right) = 0$
$a_{IJ} F_{\mu\nu}^{IJ}$	$a_{[IJ]} \kappa^I b^{JL} P_L^{'} = 0$
$S_{\mu\nu}^{IJ}$	$\left(l^J b^{IL} + l^I b^{JL}\right) P_L^{'} = 0$; $\left(l^J b^{IL} + l^I b^{JL}\right) P_L^{''} = 0$; $det\left(l^M b^{NM} + l^N b^{MN}\right) = 0$
$b_{IJ} S_{\mu\nu}^{IJ}$	$b_{(IJ)} l^I b^{JL} P_L^{'} = 0$

Table 2: Gauge invariance conditions for the field strength tensors

Consequently, one notices that the gauge invariance conditions are not necessarily depending of polynomial terms ($P_I^{'}$). This means that the coefficients a_{IJ}, b_{KL}, κ_M and l_M can control the gauge invariance. It says that at systemic level one can produce fields conglomerates and symmetric tensors with physical interpretations.

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3. SGT LAGRANGEAN

Based on the previous results a Systemic Gauge Theory (SGT) Lagrangean is written as:

$$\mathscr{L}_{SGT} = \mathscr{L}_K + \mathscr{L}_M + \mathscr{L}_I \tag{3.1}$$

Considering the kinetic Lagrangean $\mathscr{L}_K$ one gets:

$$\begin{aligned}\mathscr{L}_K = a_{IJ}a_{KL}F^{IJ}_{\mu\nu}F^{\mu\nu KL} + b_{IJ}b_{KL}S^{IJ}_{\mu\nu}S^{\mu\nu KL} + c_{IJ}c_{KL}F^{IJ}_{\mu\nu}S^{\mu\nu KL} \\ + d_{IJ}d_{KL}F^{\alpha\, IJ}_{\alpha}F^{\beta\, KL}_{\beta} + e_{IJ}e_{KL}S^{\alpha\, IJ}_{\alpha}S^{\beta\, KL}_{\beta} + f_{IJ}f_{KL}F^{\alpha\, IJ}_{\alpha}S^{\beta\, KL}_{\beta}\end{aligned} \tag{3.2}$$

In order to prove its gauge invariance, we are going to consider the following redefinitions:

$$\begin{aligned}F^{II'}_{\mu\nu} = a^{IK}F_{\mu\nu KK} \equiv F^{I,S}_{\mu\nu} \\ S^{II'}_{\mu\nu} = S^{I,S}_{\mu\nu} + 2b^{IL}P'_L\partial_\mu\partial_\nu\alpha + 2b^{IL}P''_L\partial_\mu\alpha\partial_\nu\alpha\end{aligned} \tag{3.3}$$

and

$$\begin{aligned}a_{(IJ)}F^{IJ}_{\mu\nu} = a_{(IJ)}\kappa^I F^J_{\mu\nu} \\ a_{[IJ]}F^{IJ}_{\mu\nu} = a_{[IJ]}\kappa^I S^J_{\mu\nu} \\ b_{(IJ)}S^{IJ}_{\mu\nu} = b_{(IJ)}\mathfrak{l}^I S^J_{\mu\nu} \\ b_{[IJ]}S^{IJ}_{\mu\nu} = b_{[IJ]}\mathfrak{l}^I F^J_{\mu\nu}\end{aligned} \tag{3.4}$$

which yields that the equation (3.2) contains a diagonal sector ($\mathscr{L}_K$) plus entangled sector ($\hat{\mathscr{L}}_K$):

$$\mathscr{L}_K = \mathscr{L}_K(FF) + \mathscr{L}_K(SS) + \mathscr{L}_K(FS) + \hat{\mathscr{L}}_K(FF) + \hat{\mathscr{L}}_K(SS) + \hat{\mathscr{L}}_K(FS) \tag{3.5}$$

$$\begin{aligned}\mathscr{L}_K(FF) = a_{(IJ)}a_{(KL)}\kappa_I\kappa_K F^{JJ}_{\mu\nu}F^{\mu\nu LL} + b_{[IJ]}b_{[KL]}l_I l_K F^{JJ}_{\mu\nu}F^{\mu\nu LL} \\ + c_{(IJ)}c_{[KL]}\kappa_I l_K F^{JJ}_{\mu\nu}F^{\mu\nu LL}\end{aligned} \tag{3.6}$$

$$\begin{aligned}\mathscr{L}_K(SS) = a_{[IJ]}a_{[KL]}\kappa_I\kappa_K S^{JJ}_{\mu\nu}S^{\mu\nu LL} + b_{(IJ)}b_{(KL)}l_I l_K S^{JJ}_{\mu\nu}S^{\mu\nu LL} \\ + c_{[IJ]}c_{(KL)}\kappa_I l_K S^{JJ}_{\mu\nu}S^{\mu\nu LL}\end{aligned} \tag{3.7}$$

$$\begin{aligned}\mathscr{L}_K(FS) = a_{(IJ)}a_{[KL]}\kappa_I\kappa_K F^{JJ}_{\mu\nu}S^{\mu\nu LL} + a_{[IJ]}a_{(KL)}\kappa_I\kappa_K S^{JJ}_{\mu\nu}F^{\mu\nu LL} \\ + b_{(IJ)}b_{[KL]}l_I l_K S^{JJ}_{\mu\nu}F^{\mu\nu LL} + b_{[IJ]}b_{(KL)}l_I l_K F^{JJ}_{\mu\nu}S^{\mu\nu LL} \\ + c_{(IJ)}c_{(KL)}\kappa_K l_I F^{JJ}_{\mu\nu}S^{\mu\nu LL} + c_{[IJ]}c_{[KL]}\kappa_I l_K S^{JJ}_{\mu\nu}F^{\mu\nu LL}\end{aligned} \tag{3.8}$$

where the term $\mathscr{L}_K(FF)$ is gauge invariant and verifying the symmetry properties, the term $\mathscr{L}_K(FS)$ is null. The gauge invariance conditions for the terms $\mathscr{L}_K(SS)$, $\hat{\mathscr{L}}_K(FF)$, $\hat{\mathscr{L}}_K(SS)$ and $\hat{\mathscr{L}}_K(FS)$ are shown in the section 4 where are introduced the expressions:

$$\varepsilon_{IK} = a_{[IJ]}a_{[KL]}\kappa_J\kappa_L + b_{(IJ)}b_{(KL)}l_Jl_L + c_{[IJ]}c_{(KL)}\kappa_Jl_L$$
$$\bar{\varepsilon}_{IK} = 4d_{[IJ]}d_{[KL]}\bar{\kappa}_J\bar{\kappa}_L + 4e_{(IJ)}e_{(KL)}\bar{l}_J\bar{l}_L + 4f_{[IJ]}f_{(KL)}\bar{\kappa}_J\bar{l}_L \tag{3.9}$$

The mass term is given by:

$$\mathscr{L}'_M = m^2_{IJ}A^{I'}_{\mu}A^{\mu J'} \tag{3.10}$$

or

$$\mathscr{L}'_M = m^2_{IJ}\left(A^I_{\mu S}A^{\mu JS} + b^{JL}P'_LA^I_{\mu S}\partial^\mu\alpha + b^{IL}P'_LA^{\mu JS}\partial_\mu\alpha + b^{IL}b^{JL}P'_LP'_L\partial_\mu\alpha\partial^\mu\alpha\right) \tag{3.11}$$

Using the definition $A^I_{\mu S} = a^{IK}A_{\mu K}$, $\mathscr{L}'_M$ must satisfy the following invariance conditions:

$$m^2_{IJ}\left(a^{IK}b^{JL} + a^{JK}b^{IL}\right)P'_LA_{\mu K}\partial^\mu\alpha = 0 \tag{3.12}$$
$$m^2_{IJ}b^{IL}b^{JL}P'_LP'_L\partial_\mu\alpha\partial^\mu\alpha = 0 \tag{3.13}$$

Defining $m^2_{(IJ)} = m_{II}m_{JJ}$:

$$\left[m_{II}\left(a^{IK}b^{JL} + a^{JK}b^{IL}\right)P'_L\right]\left[m_{JJ}A_{\mu K}\right]\left[\partial^\mu\alpha\right] = 0 \tag{3.14}$$
$$\left[m_{II}b^{IL}P'_L\right]\left[m_{JJ}b^{JL}P'_L\right]\left[\partial_\mu\alpha\partial^\mu\alpha\right] = 0 \tag{3.15}$$

$$\left[m_{II}b^{IL}\right] = 0 \tag{3.16}$$
$$\left[m_{JJ}b^{IL}\right] = 0 \tag{3.17}$$

The equations (3.16) and (3.17) brings the solution to introduce mass without Higgs.

Therefore, appears an alternative mechanism to generate mass diverse from Stueckelberg and Higgs mechanism [5]. Coefficients m_{IJ}, a_{KL} and b_{MN} are able to preserve the massive model gauge invariance. The introduction of a whole symmetry allows a kind of symmetry managing. In a further work the interaction terms will be explored [4].

4. MANAGING SYMMETRY

In this section, the conditions to manage the symmetry are shown. The next table describes the gauge invariance conditions for the SGT Lagrangean.

TGS Lagrangean	Invariance Conditions
$\mathscr{L}_M$	$(b^{LI})^t m^2_{IJ} b^{JL} P'_L P'_L = 0$
$\mathscr{L}_K(SS)$	$\varepsilon_{IK} S^{I,S}_{\mu\nu} b^{KL} P'_L \partial^\mu \partial^\nu \alpha = 0$ $\varepsilon_{IK} S^{I,S}_{\mu\nu} b^{KL} P''_L \partial^\mu \alpha \partial^\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} S^{\mu\nu K,S} P'_L \partial_\mu \partial_\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} b^{KL} P'_L P'_L \partial_\mu \partial_\nu \alpha \partial^\mu \partial^\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} b^{KL} P'_L P''_L \partial_\mu \partial_\nu \alpha \partial^\mu \alpha \partial^\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} S^{\mu\nu K,S} P''_L \partial_\mu \alpha \partial_\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} b^{KL} P'_L P''_L \partial^\mu \partial^\nu \alpha \partial_\mu \alpha \partial_\nu \alpha = 0$ $\varepsilon_{IK} b^{IL} b^{KL} P''_L P''_L \partial_\mu \alpha \partial_\nu \alpha \partial^\mu \alpha \partial^\nu \alpha = 0$
$\hat{\mathscr{L}}_K$	$\bar{\varepsilon}_{IK} a^{IK} b^{KL} P'_L \partial_\alpha A^\alpha_K \partial_\beta \partial^\beta \alpha = 0$ $\bar{\varepsilon}_{IK} a^{IK} b^{KL} P''_L \partial_\alpha A^\alpha_K \partial_\beta \alpha \partial^\beta \alpha = 0$ $\bar{\varepsilon}_{IK} a^{KM} b^{IL} P'_L \partial_\alpha \partial^\alpha \alpha \partial_\beta A^\beta_M = 0$ $\bar{\varepsilon}_{IK} b^{IL} b^{KL} P'_L P'_L \partial_\alpha \partial^\alpha \alpha \partial_\beta \partial^\beta \alpha = 0$ $\bar{\varepsilon}_{IK} b^{IL} b^{KL} P'_L P''_L \partial_\alpha \partial^\alpha \alpha \partial_\beta \alpha \partial^\beta \alpha = 0$ $\bar{\varepsilon}_{IK} a^{KM} b^{IL} P''_L \partial_\alpha \alpha \partial^\alpha \alpha \partial_\beta A^\beta_M = 0$ $\bar{\varepsilon}_{IK} b^{IL} b^{KL} P'_L P''_L \partial_\alpha \alpha \partial^\alpha \alpha \partial_\beta \partial^\beta \alpha = 0$ $\bar{\varepsilon}_{IK} b^{IL} b^{KL} P''_L P''_L \partial_\alpha \alpha \partial^\alpha \alpha \partial_\beta \alpha \partial^\beta \alpha = 0$

Table 3: Managing Symmetry

5. CONCLUSION

It is presented a systemic symmetry which proposal is to analyse the nature systemic phenomena. The SGT confirms the concept of whole and works with the systemic gauge transformation. It says that a field can transform itself in a set of another fields. A systemic electromagnetism becomes possible. It can be of direct importance for the interpretation on collective electromagnetic radiations and cosmic magnetism.

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