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# INFORMATION ON THE GAUGE PRINCIPLE FROM AN N = 1/2, D = 2 SUPERSYMMETRIC MODEL

by

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## ABSTRACT

The gauge principle does not only work to generate interactions. It potentially yields an abundance of gauge-potential fields transforming under the same local symmetry group. In order to show evidences of this property this work gauge-covariantizes an N = 1/2, D = 2 supersymmetric theory. Then, by relaxing the so-called conventional constraint, a second gauge-potential field naturally emerges.


Key-words: Gauge principle; Supersymmetry; Two dimensional models.

## 1. INTRODUCTION

A viewpoint to systematize a theory is to contemplate it as a book made up of three chapters. In the first chapter, one is left with a principle to be introduced in the room and to relativize the scenario. After this, different faces of this writer-principle take shape through the different mathematical dialogues that its dynamics creates. Finally, in the chapter three, with enough material about the antagonism between mathematical fiction and experimental reality been collected, from a good book one expects enough circumstances in order to establish an epilogue predicting a fate. Massive gauge bosons with 80 Gev are a destiny written in the Glashow-Weinberg-Salam book.

The equivalence principle is a classical reference of an element for a chapter one. Although in our days there already exist considerations where the Einstein equivalence principle can be observed as a consequence of the conformal properties of superstring theories, we still prefer to meditate about it, at least in four dimensions, as a principle necessary to be built in. This means that such a mass universality represents the attitude to write a chapter one. It dictates an equation of motion by fixing a geodesic equation and writes physics equally for any reference system. Cataloguing the volume of facts and pages coordinated by this principle, one is led to express its intrinsic force. This book [1] gauges a laboratory where the species generated by the general relativity code are left to survive or die depending on selection rules determined by the appearance of new species that other principles can generate. Principles are not innocent objects.

A principle must be focused more through its own force of generating substantial things than by its experimental background. Under this aspect we would like to discuss another principle that has been guiding physics in this century: the gauge principle. It is strong enough to fix a Lagrangian and the interactions, to organize internal reference systems and to obtain an universality for the coupling constant. However a stimulating insight would be to compare it with the equivalence principle. For this, a strategy is to develop its chapter one (pages where the dynamics is frozen).

A channel to understand the force of a principle is through the abundance of constraints that it originates. In field theory the most immediate constraint is the reality condition. The adoption of the gauge principle brings together two kinds of constraints. They are identities obtained from covariant derivatives. Remember that the initial spark to surpass the static through gauge theories is the covariant derivative. Thus as a chapter one, for the gauge principle book, this entity generates a space made by the following two identities:

$$[\nabla_A , \nabla_B\} = T_{AB}^{\ \ C} \nabla_C + F_{AB} \qquad (1)$$

and

$$[\nabla_A, [\nabla_B, \nabla_C\}\} + [\nabla_B, [\nabla_C, \nabla_A\}\} + [\nabla_C, [\nabla_A, \nabla_B\}\} = 0 \qquad (2)$$

where $\nabla_A$ means a bosonic or a fermionic covariant derivative, $T_{AB}^{\ \ C}$ is a torsion term and $F_{AB}$ a field strength. The presence of (1) and (2) confirms that symmetry already propitiates paths before any dynamics is born. This means that in its most primitive layer gauge theories contain not only covariant derivatives but also constraints. Consequently, a field must be submitted to the constraint inquiry.

Supersymmetry is a rich laboratory to split the meaning of the gauge principle. Therefore this work intends to focus its different instructions through a very simple case. It is to covariantize an U(1), N = 1/2 supersymmetry in two dimensions [2,3]. Thus considering the superspace formulation

$$z^A \equiv ( x^+, x^-; \theta ) \qquad (3)$$

with the following supersymmetry transformations

$$x^{+\prime} = x^+$$

$$x^{-\prime} = x^- + i\varepsilon\theta \qquad (4)$$

$$\theta' = \theta + \varepsilon$$

one gets a global U(1) action given by

$$S = \frac{i}{2} \int d^2x \, d\theta \, [ \, (D\Phi)^* \partial_+ \Phi - (D\Phi)(\partial_+ \Phi)^* \, ] \tag{5}$$

where $\Phi$ is a complex scalar superfield defined by its component-field content according to:

$$\Phi \equiv ( \, \phi(x), \, i2^{1/4}\psi(x) \, ) \tag{6}$$

where $\phi(x)$ is a scalar and $\psi(x)$ is a right-handed Majorana spinor. Elevating (5) to a local transformation,

$$\Phi \longrightarrow \Phi'(x,\theta) = e^{iq\Lambda(x,\theta)}\Phi(x,\theta) \tag{7}$$

where $\Lambda(x,\theta)$ is a real scalar superfield and q is the U(1)-charge corresponding to the field $\Phi$, the gauge principle writes the following covariant derivatives,

$$\nabla_+\Phi \equiv (\partial_+ + iqg\Gamma_+)\Phi \tag{8}$$

$$\nabla\Phi \equiv (D + qg\Gamma)\Phi \tag{9}$$

$$\nabla_-\Phi \equiv (\partial_- + iqg\Gamma_-)\Phi \tag{10}$$

where $\Gamma_+$, $\Gamma$ and $\Gamma_-$ are superfield connections transforming under U(1) symmetry as

$$\Gamma'_+ = \Gamma_+ - \frac{1}{g} \partial_+\Lambda \tag{11}$$

$$\Gamma' = \Gamma - \frac{i}{g} D\Lambda \tag{12}$$

$$\Gamma'_- = \Gamma_- - \frac{i}{g} \partial_-\Lambda \tag{13}$$

Thus different connection superfields are generated by gauge covariantizing the space-time and supersymmetric covariant derivatives. In components they are read as

$$\Gamma_+ = ( A_+ ,\ i2^{3/4}\rho ) \tag{14}$$

$$\Gamma = ( 2^{3/4}\xi ,\ A_- ) \tag{15}$$

$$\Gamma_- = ( B_- ,\ i2^{3/4}\chi ) \tag{16}$$

Observe that the two components of the gauge field $A_+(x)$ and $A_-(x)$ belong to different superfields. $\rho(x)$ and $\xi(x)$ are spinors, but $\xi(x)$ does not have an appropriated dimension for being interpreted as a physical field. Thus the gaugino will be determined through a composition, $\partial_+\xi(x) + \rho(x)$, that is gauge-invariant. The condition that the fields must be real guides for spinorial fields both possibilities of being hermitean or anti-hermitean. (8) - (10) definitions have chosen the first case. Both physics are equivalent although do not necessarily contain the same terms. Finally note that the space derivative $\partial_-$ does not contribute to covariantization process. However it influences in the constraint mechanism that the theory formulates. It is the main aspect of this work.

A study of gauge principle properties through a supersymmetric model $N = 1/2$ in $D = 2$ is the motivation of this work. In this introduction we have noted that preceding any dynamics it already exists facts as (1), (2), (8) - (13). Another intrinsic aspect that the gauge principle develops is about the possibility of cutting some physical regions through constraints. Sections 2 and 3 develop both sides of this relaxing strategy of the constraints. Finally, in the conclusion a comment about the nature of the physics of the gauge principle is made.

## 2. STANDARD CASE

The systematics to be followed here consists of two considerations. First, to impose constraints in the gauge covariant commutation relations and then, to consult the Bianchi identities in order to stipulate relationships between the various superfields. From (1) and taking the torsion identically to the case with ordinary supersymmetry-covariant derivatives one gets,

$$\{ \nabla , \nabla \} = - 2i\nabla_{-} + W \tag{17}$$

Similarly the superfields field strength $W_{+}$, $W_{-}$ and $W_{+-}$ are obtained

$$[ \nabla_{+} , \nabla ] = W_{+} \tag{18}$$

$$[ \nabla_{-} , \nabla ] = W_{-} \tag{19}$$

$$[ \nabla_{+} , \nabla_{-} ] = W_{+-} \tag{20}$$

Nonetheless, the determinism that symmetry generates for this model contain circumstances. This means that it contains the property of imposing constraints. For this, take the following relationship

$$W = 0 \tag{21}$$

and substitute it in (17). Then the connection $\Gamma_-$ is eliminated through

$$\Gamma_- = D\Gamma \tag{22}$$

writing in components, such arranged dependence shows

$$B_- = A_-$$

$$\chi = -\partial_-\xi \tag{23}$$

A second limitation to be considered is that (18), (19) and (20) are related through the Bianchi identity. It yields,

$$W_- = 0 \tag{24}$$

$$W_{+-} = iDW_+ \tag{25}$$

Thus there is only one independent field-strength,

$$W_+ = qg(\ \partial_+\Gamma - iD\Gamma_+\ ) \tag{26}$$

that in components is written as

$$W_+ \equiv (\ 2^{3/4}qg\lambda,\ qgF_{+-}\ ) \tag{27}$$

where

$$\lambda = \partial_+ \xi + \rho \tag{28}$$

$$F_{+-} = \partial_+ A_- - \partial_- A_+ \tag{29}$$

Observe that $W_+$ is real, gauge invariant, accommodates the gaugino and the gauge field strength.

(21) yields the so-considered as standard case [3],

$$S = S_{gauge} + S_{g.f.} + S_{matter} \tag{30}$$

where

$$S_{gauge} = - \frac{1}{2q^2 g^2} \int d^2x \, d\theta \; W_+ D W_+ \tag{31}$$

$$S_{g.f.} = \frac{1}{2\alpha} \int d^2x \, d\theta \; GDG$$

with

$$G = \partial_+ \Gamma + iD\Gamma_+ \tag{32}$$

$$S_{matter} = \int d^2x \, d\theta \left\{ \frac{i}{2} [\nabla\Phi \, (\nabla_+\Phi)^* - (\nabla\Phi)^* \, \nabla_+\Phi \,] + \right.$$

$$\left. + \frac{1}{2} [\, \Psi^* \nabla\Psi + \Psi(\nabla\Psi)^* \,] + \frac{1}{2} m \, [\, \Phi^*\Psi + \Phi\Psi^* \,] \right\} \tag{33}$$

considering the field contents (6) and

$$\Psi = ( 2^{1/4}\beta(x) \ , \ F(x) ) \qquad (34)$$

$$\Lambda = ( \alpha(x), \ i2^{1/4}\eta(x) ) \qquad (35)$$

one gets

$$\mathcal{L} = -\frac{1}{2} F^2_{+-} - i\sqrt{2}\ \lambda\partial_-\lambda +$$

$$+ \frac{1}{\alpha} [ \ \frac{1}{2} (\partial_+A_- + \partial_-A_+)^2 + i\sqrt{2}\ (\partial_+\xi - \rho)\ \partial_-(\partial_+\xi - \rho) \ ] +$$

$$+ \frac{1}{2} [(D_-\phi)(D_+\phi)^* + (D_-\phi)^*(D_+\phi)] + gq\xi \ [ \ \psi(D_+\phi)^* - \psi^*D_+\phi \ ] +$$

$$+ \frac{i\sqrt{2}}{2} A \ [ \ (D_+\psi)^* - igq\sqrt{2}\rho\phi^* \ ] + \frac{i\sqrt{2}}{2} A^* \ [ \ D_+\psi + iqg\sqrt{2}\rho\phi \ ] +$$

$$+ \frac{i\sqrt{2}}{2} \beta^* \ [ \ D_-\beta - i\sqrt{2}qg\xi F \ ] + \frac{i\sqrt{2}}{2} \beta \ [(D_-\beta)^* + i\sqrt{2}qg\xi F^*] +$$

$$+ \frac{1}{2} [ \ F^*B + FB^* \ ] \ \frac{1}{2} m \ [ \ i\sqrt{2}(\psi^*\beta + \psi\beta^*) + \phi^*F + \phi F^* \ ]$$

$$(36)$$

where

$$D_{\pm} = \partial_{\pm} + iqgA_{\pm}$$

$$A = \psi - i\sqrt{2}qg\xi\phi$$

$$B = F + 2qg\xi\beta \qquad (37)$$

with the following transformations

$$F'_{+-} = F_{+-}$$

$$\lambda' = \lambda$$

$$A' = e^{i\alpha(x)}A$$

$$B' = e^{i\alpha(x)}B \qquad (38)$$

For a more physical approach to analyze the quanta involved in (36) one can take the unitary Wess Zumino gauge.

$$\xi(x) = 0$$

$$\rho(x) = \lambda(x) \qquad (39)$$

Calculating the equations of motion in terms of superfields one gets for $\Gamma_+$ .

$$\partial_- W_+ + \frac{qg}{\alpha}\partial_- G = iq^2g^2J_- \qquad (40)$$

For $\Gamma$,

$$\partial_+ DW_+ - \frac{qg}{\alpha}\,\partial_+ DG = -\,q^2 g^2 J \tag{41}$$

Where

$$J_- = -\frac{i}{2}\left[\,\Phi(\nabla\Phi)^* + \Phi^*\nabla\Phi\,\right] \tag{42}$$

$$J = \frac{i}{2}\left[\Phi(\nabla_+\Phi)^* - \Phi^*\nabla_+\Phi\,\right] + \Psi\Psi^* \tag{43}$$

For the matter superfield $\Phi$,

$$\frac{i}{2}\{\,\nabla\,,\,\nabla_+\,\}\,\Phi - \frac{1}{2}\,m\,\Psi = 0 \tag{44}$$

and for $\Psi$

$$\nabla\Psi + \frac{m}{2}\,\Phi = 0 \tag{45}$$

In components, one reads for $A_+$ and $A_-$

$$\partial_- F_{+-} + \frac{1}{\alpha}\,\partial_-(\,\partial_+ A_- + \partial_- A_+\,) = iqgj_- \tag{46}$$

$$\partial_+ F_{-+} + \frac{1}{\alpha}\,\partial_+(\,\partial_+ A_- + \partial_- A_+\,) = iqgj_+ \tag{47}$$

where

$$j_- = \frac{1}{2}\,[\phi(D_-\phi)^* - \phi^* D_-\phi] - qg\xi(\phi\psi^* + \phi^*\psi) + \frac{i\sqrt{2}}{2}(\psi^* A - \psi A^*) \tag{48}$$

$$j_+ = \frac{1}{2}\,[\ \phi(D_+\phi)^* - \phi^* D_+\phi\ ] - i\sqrt{2}\beta\beta^* \tag{49}$$

The dynamics for the gaugino-components $\xi$ and $\rho$ fields is

$$\partial_-\lambda + \frac{1}{\alpha}(\partial_+\xi - \rho) = iqg\,\frac{\sqrt{2}}{2}\,[\ \phi^* A - \phi A^*\ ] \tag{50}$$

$$\partial_+\partial_-\lambda - \frac{1}{\alpha}\,\partial_+\partial_-(\partial_+\xi - \rho) = -\,i\rho gDJ\,\Big|_{\theta=0} \tag{51}$$

Observe that in order to show consistency between (46) and (47) and between (50) and (51), theory should provide another information. The matter-fields components $\phi$, $\psi$, $\beta$ and F yields, respectively, the following equations of motion,

$$(D_+D_-\phi)^* - \frac{m}{2}\,F^* = -\,gqj_\phi \tag{52}$$

$$(D_+\psi)^* + m\beta^* = -\,gqj_\psi \tag{53}$$

$$(D_-\beta)^* - \frac{1}{2}\,m\psi^* = -\,gqj_\beta \tag{54}$$

$$F^* + \frac{m}{2}\,\phi^* + 2gq\beta^*\xi = 0 \tag{55}$$

With

$$j_{\phi} = \psi^{*}(D_{+}\xi)^{*} + (D_{+}\psi)^{*}\xi + \psi^{*}\rho - \xi\partial_{+}\psi^{*} + i2\sqrt{2}gq\xi\rho\phi^{*} \qquad (56)$$

$$j_{\psi} = [\ i\sqrt{2}\xi(D_{+}\phi)^{*} + \frac{1}{gq}(\partial_{+}\xi - \rho)\psi^{*}\ ] \qquad (57)$$

$$j_{\rho} = i\sqrt{2}F^{*}\xi \qquad (58)$$

A next information that theory provides is the Noether current conservation. For a supersymmetric theory

$$\mathcal{L} = \int d\theta\ \mathcal{P}(\Phi_i,\ \partial_{\pm}\phi_i,\ D\Phi_i,\ \partial_{\pm}D\Phi_i) \qquad (59)$$

there are two independent invariances in the superspace that depend on the parameters $\varepsilon$ and $\Lambda(x,\theta)$. They are

$$\delta_{su.sy.}\mathcal{P} = -\ \varepsilon Q\mathcal{P} \qquad (60)$$

and

$$\delta_{gauge}\mathcal{P} = 0 \qquad (61)$$

substituting (60) in (30) one gets a continuity equation in superspace that expresses the invariance under supersymmetry

$$\partial_{+}\mathcal{J}_{-} + D\mathcal{J} = S$$

$$\mathcal{J}_- = \frac{i}{2} [ (Q\Phi^*)\nabla\Phi - (Q\Phi)(\nabla\Phi)^* ] - \frac{1}{qg} (Q\Gamma)DW_+$$

$$\mathcal{J} = \frac{i}{2} [(Q\Phi^*)\nabla_+\Phi + (Q\Phi)(\nabla_+\Phi)^*] + \frac{1}{2} [(Q\Psi)\Psi^* + (Q\Psi^*)\Psi] + \\ + \frac{i}{qg} (Q\Gamma_+)DW_+ - \frac{1}{2q^2g^2} W_+QW_+$$

$$S = Q \left\{ \frac{i}{2} [\nabla\phi(\nabla_+\phi)^* - (\nabla\phi)^*\nabla_+\phi] + \frac{i}{2} [\Psi^*\nabla\Psi + \Psi(\nabla\Psi)^*] + \\ + \frac{1}{2} m (\Phi^*\Psi + \Phi\Psi^*) - \frac{1}{2q^2g^2} W_+DW_+ \right\} \tag{62}$$

Using (61) in (30) one gets the following relationship from gauge invariance

$$iq\Lambda [ \partial_+J_- + DJ ] = 0 \tag{63}$$

(63) coincides for $\Lambda(x,\theta)$ being global or local. Considering the global condition

$$D\Lambda = \partial_+\Lambda = 0$$

it yields,

$$\partial_+(DJ_-) - i\partial_-J \Big|_{\theta=0} = \partial_\mu J^\mu_a = 0 \tag{64}$$

where $J_a \equiv (iDJ_-, J)\Big|_{\theta=0}$. In components,

$$\partial_+ j_- + \partial_- j_+ = 0 \tag{65}$$

Now it has appeared the information that the equations of motion for the potential fields were expecting. (64) shows that although the structure of the field strength $F_{+-}$ does not propitiate a conservation law, there is a combination between (46) and (47) such that there appears a conserved current $J_a(x)$ whose components are coupled to the potential fields $A_+(x)$, $A_-(x)$ respectively. Similarly the spinorial equations (50) and (51) work consistently with (64) by showing the presence of only one equation of motion for the photino. These aspects show that the gauge principle offers a closure relation for the field-dynamics. It is important to note that though the parameter $\Lambda(x,\theta)$ contains two parameters $\alpha(x)$ and $\eta(x)$, the symmetry of the theory does not work as a U(1)xU(1) mechanism with two conservation laws. (64) prints out the presence of just one conserved current as in ordinary QED. The other current, the one coupled to the photino, contains just a gauge invariant behavior as shown in (50). Again such results carry consistency due to the fact that while the potential fields suffer gauge transformations the gaugino is properly an invariant.

## 3. NATURAL ACTION

The most immediate action taken from the gauge principle is the one for which no constraints are used. Practical experiences with the reality constraint, as in four dimensions, have been showing that degrees of freedom of the fields can be eliminated from the theory by imposing suitable constraints on the superfields. This shows that the same symmetry is realized in different layers depending on the constraints' nature. Thus this section intends to explore this fact by digging down the su.sy. region for N = 1/2, d = 2 till to find out a symmetry layer with no constraint [4].

Relaxing (21), we have

$$W = 2qg(D\Gamma - \Gamma_-) \qquad (66)$$

The field-strength superfields $W_-$ and $W_{+-}$ are fixed from (2) as

$$W_- = \frac{i}{2}(DW) \qquad (67)$$

and

$$W_{+-} = -i\left(\frac{1}{2}\partial_+ W_- - DW_+\right) \qquad (68)$$

Thus (66) - (68) shows the existence of three independent potential superfields: $\Gamma_+$, $\Gamma$ and $\Gamma_-$. Reading off the gauge invariant W components, one gets

$$A'_{\pm}(x) = A_{\pm}(x) - \frac{1}{g}\,\partial_{\pm}\alpha(x) \qquad (69)$$

$$B'_{-}(x) = B_{-}(x) - \frac{1}{g}\,\partial_{-}\alpha(x) \qquad (70)$$

$$\xi' = \xi + \frac{1}{g\sqrt{2}}\,\eta \quad ; \quad \rho' = \rho - \frac{1}{g\sqrt{2}}\,\partial_{+}\eta \qquad (71)$$

$$\chi' = \chi - \frac{1}{g\sqrt{2}}\,\partial_{-}\eta \qquad (72)$$

Where (70) informs about the existence of a second gauge potential in theory.

A next stage is to show that (69) and (70) does not represent a version of a same field obtained from a linear combination. Thus it becomes necessary to study the quanta and interaction between such involved fields. The following bilinear terms are added to (31)

$$S_1 = \frac{\lambda_1}{(2qg)^2}\int d^2x\, d\theta\; W_+(\partial_+W) \qquad (73)$$

$$S_2 = \frac{\lambda_1}{(2qg)^2}\int d^2x\, d\theta\; \theta\,(DW_+)(\partial_+W) \qquad (74)$$

$$S_g = \frac{\lambda_2}{(2qg)^2} \int d^2x \, d\theta \, \theta \, (\partial_+ W)^2 \qquad (75)$$

where $\lambda_1$, $\lambda_2$ are free coefficients. Expressing the kinetic part in momentum space one gets the following set of propagators

$$\text{F.T.} \begin{bmatrix} \langle A_+A_+\rangle & \langle A_+A_-\rangle & \langle A_+B_-\rangle \\ \langle A_-A_+\rangle & \langle A_-A_-\rangle & \langle A_-B_-\rangle \\ \langle B_-A_+\rangle & \langle B_-A_-\rangle & \langle B_-B_-\rangle \end{bmatrix} =$$

$$= \frac{1}{4\Delta} \begin{bmatrix} \frac{p}{k_+^{\,2}} & \frac{m}{k_+k_-} & \frac{n}{k_+k_-} \\ \frac{m}{k_+k_-} & \frac{p}{k_-^{\,2}} & \frac{\ell}{k_-^{\,2}} \\ \frac{n}{k_+k_-} & \frac{\ell}{k_-^{\,2}} & \frac{p+q}{k_-^{\,2}} \end{bmatrix} \qquad (76)$$

Where

$$\Delta = \lambda_1^2 + 2\lambda_2$$

$$p = 2\lambda_2(1 - \alpha) + \alpha\lambda_1^2$$

$$m = - 2\lambda_2(1 + \alpha) - \alpha\lambda_1^2$$

$$n = - 2\lambda_2(1 + \alpha) - \lambda_1(2 + \alpha\lambda_1)$$

$$\ell = 2\lambda_2(1 - \alpha) + \lambda_1(2 - \alpha\lambda_1)$$

$$q = - 4[1 - \lambda_1(1 - \alpha) + \frac{1}{2}\alpha\lambda_1^2] \qquad (77)$$

(76) is not to be diagonalized, otherwise it would loose its local interpretation. This is due to the fact that its eigenvalues would be determined in terms of non-polynomial functions of the momentum. Nevertheless (76) is enough to inform about the theory spectrum. From the first line one reads that there is a probability related to the residue p to create a quantum of $A_+$. Similarly the $A_-$ and $B_+$ quanta are determined with probabilities related to p and p + q. In order to obtain the mass eigenvalue that is expressed from the square of a quadrimomentum operator, it is necessary to read off the pole of a corresponding two-point Green function. Thus, observing (76), we note that each line contain at least one term whose denominator is in the Lorentz manifest form $k_+k_-$. This yields that the quanta associated with $A_+$, $A_-$, B are massless. Note that a massive term might be obtained from (69) and (70), but it would violate Lorentz covariance.

Thus (70) and (76) show that $B_-(x)$ does not belong to the class of compensating fields. However it is still necessary to analyse its physical consistency. First, the inclusion of a $B_-(x)$

field without a partner $B_+(x)$ does not break the manifest Lorentz covariance. However the propagator is able to reproduce a well-defined mass term. Second, is about the presence of ghosts. Considering that residues p and p + q depend on parameters $\lambda_1$, $\lambda_2$, $\alpha$, the theory is provided with enough circumstances to build up probabilities with same sign. Thus a health quantum for $B_-(x)$ exists.

Now we should understand the presence of this non-covariant $B_-(x)$ field through its interactions. Selection rules made by Lorentz weight, dimensional analysis, renormalizability are guiding aspects for possible interacting terms. As an example to show how the interaction terms are selected we are going to study the case involving the field-strengths $W_+$ and W. The general expression is

$$\frac{1}{g^s}\int d\theta\ W^m\ W_+^n\ D^p\ \partial_+^q\ \partial_-^r \tag{77}$$

Then considering the above conditions respectively, it yields

$$\frac{1}{2} + m - \frac{n}{2} + \frac{p}{2} - q + r = 0 \tag{78}$$

$$-s + \frac{1}{2} + m + \frac{3n}{2} + \frac{p}{2} + q + r = 2 \tag{79}$$

$$m + n \geq s \tag{80}$$

and including the interaction condition.

$$m + n \geq 3 \tag{81}$$

one gets only one possibility. It is the non-abelian term

$$\frac{1}{g^4} \int d^2x \, d\theta \, \mathrm{Tr}(WW_+^3) \tag{82}$$

Similarly, through explicitly breaking the abelian supersymmetric case, one obtains

$$\frac{\lambda_3}{g^4} \int d^2x \, d\theta \, \theta \, W^2 W_+ (\partial_+ W_+) \tag{83}$$

Matter couplings involving $\Gamma_-$ are also obtained by breaking supersymmetry,

$$\lambda_4 \int d^2x \, d\theta \, \theta \, (\nabla_+ \Phi)^* (\nabla_- \Phi)(\Phi^* \Phi)^n + \text{h.c.} \tag{84}$$

$$\lambda_5 \int d^2x \, d\theta \, \theta \, \Psi^* (\nabla_- \Psi)(\Phi^* \Phi)^r + \text{h.c.} \tag{85}$$

Finally there is a massive term

$$S_{mass} = \int d^2x \, d\theta \, (m\Phi^* \Psi + m\Phi\Psi^*) \tag{86}$$

The new equations of motion for this considered as the natural region are:

For $\Phi$,

$$\frac{i}{2}(\nabla_-,\nabla_+)\Phi-\frac{1}{2}m\Psi+\frac{\lambda_4\theta}{2}\Big\{\nabla_+[(\nabla_-\Phi)(\Phi\Phi^*)^n]+$$

$$+\nabla_-[(\nabla_+\Phi)(\Phi\Phi^*)^n]-\frac{n}{2}[(\nabla_+\Phi)^*\nabla_-\Phi+(\nabla_+\Phi)(\nabla_-\Phi)^*](\Phi\Phi^*)^{n-1}\Phi\Big\}+$$

$$-\frac{i\lambda_5 r}{4}\theta\Big\{[\Psi^*\nabla_-\Psi+\Psi(\nabla_-\Psi)^*](\Phi\Phi^*)^{r-1}\Phi\Big\}=0$$

(87)

For $\Psi$,

$$\nabla\Psi+\frac{1}{2}m\Phi+\frac{i\theta\lambda_5}{2}\Big\{\nabla_-[\Psi(\Phi\Phi^*)^r]+(\nabla_-\Psi)(\Phi\Phi^*)^r\Big\}=0 \qquad (88)$$

For $\Gamma_+$

$$\partial_-W_+-\frac{i\lambda_1}{4}(\partial_+DW-i\theta\partial_-\partial_+W)+$$

$$-\frac{1}{4(2qg)^2}D[\theta W^2\partial_+W_++\theta\partial_+(W^2W_+)]=iq^2g^2J'_-$$

(89)

For $\Gamma$,

$$\partial_+ DW_+ + \frac{i\theta}{(2qg)^2} D\,[WW_+\partial_+ W] - \partial_+[\frac{\lambda_1}{4}\,\partial_+ W - \frac{i\theta}{4(2qg)^2}\,W^2\partial_+ W_+] +$$

$$- \partial_+ D\,[\,\frac{\lambda_1\theta}{4}\,\partial_+ W + \frac{1}{2}\,\lambda_1 W_+ + \frac{\lambda_1\theta}{2}\,DW_+ + \lambda_2\theta\partial_+ W\,] +$$

$$+ \partial_+\partial_+[\,\frac{i\theta}{4(2qg)^2}\,W^2 W_+\,] = - q^2 g^2 J' \qquad (90)$$

For $\Gamma_-$,

$$\partial_+[-\frac{\lambda_1}{2}\,W_+ - \frac{\lambda_1\theta}{2}\,DW_+ - \lambda_2\theta\partial_+ W] + \frac{i\theta}{(2qg)^2}\,WW_+\partial_+ W_+ = iq^2g^2 J'_+ \qquad (91)$$

Where

$$J'_- = J_- + \frac{\lambda_4\theta}{2}\,[\,\Phi(\nabla_-\Phi)^* - \Phi^*\nabla_-\Phi\,](\Phi\Phi^*)^n \qquad (92)$$

$$J'_+ = \frac{\lambda_4\theta}{2}\,[\Phi(\nabla_+\Phi)^* - \Phi^*\nabla_+\Phi](\Phi\Phi^*)^n + i\lambda_4\theta(\Psi^*\Psi)(\Phi\Phi^*) \qquad (93)$$

$$J' = J \qquad (94)$$

Finally the Noether theorem gives the following conserved current

$$\partial_+ J'_- + \partial_- J'_+ + DJ = 0 \qquad (95)$$

## 4. CONCLUSION

A principle should not be judged. Perhaps it would be more human to work out only on its consequences. They are objects to consolidate its meaning. Thus this work has understood that a debate on the gauge principle should be organized by dividing its facts in three chapters . They would correspond to the three stages that it takes for the body of a field to get maturity in field theory. Chapter one shows where a field is generated through a symmetry, in chapter two a dynamics to express its quantum is obtained, and finally in the chapter three challenge, a model guiding a performance for this field is expected to be developed.

The main effort in this work was to understand the instructions that the gauge principle contains. For this identification it was entitled a so-called chapter one. It is a zone where theory is made only with the intrinsic facts that its correspondent principle generates. These equations, as the Bianchi identities, contain an implicit character and does not have necessarily an experimental contact. The investigation of this area turns relevant because it allows to observe more purely about the kind of ideology that a determined principle is offering and also about the existence of engraved fields in theory (fields with no experimental reality). Thus before numbers and measurements the most primordial question to be formulated about a principle is – Does the gauge principle discuss the reality meaning under an idealistic or a materialistic approach? A clearer perception in order to provide some answer should be to compare the E.P. with the G.P.. Then we note that while the former has a materialistic origin based on Eötvos experiment, the later develops contact with the experimental reality only on its output. The gauge principle does not contain only experimental backgrounds, as massless photons, but also the presence of theoretical layers whose investigation was the object of this work. This means that experimental facts like interactions and charge conservation should be understood as the surface of a theoretical territory.

Globally speaking the E.P. represents geometrical and kinematical approaches. On the other hand the G.P. reveals a more direct dynamical vision for physics. However it becomes necessary to dig down in the layers under the surface made by quarks and leptons dynamics whether we intend to find out arguments for its idealistic approach. Does the gauge principle big-bang generates different layers that precede laboratory confrontation? Perhaps the existence of an archeological richness would mean its great difference from E.P.. At least this context offers more subtility for an argument prepared through gauge principle. Thus the most primitive layer to be looked for is that one where no constraint exists. In order to do this reserch this text has studied a supersymmetric theory $N = 1/2$, $D = 2$ and has localized the $B_{-}(x)$ field as the archeological object to be looked for. This means that although it does not necessarily appears with a dynamics it can be founded in the inferior layers. Observe that the initial

Lagrangian (5) does not relate the presence of this field. However, intrinsically, the gauge principle manifests its force by allowing the derivative (10) to be written. Then by relaxing the constraint (21) the initial clue for such archeological field be investigated appears. The first result from this excavation informing about the existence of this engraved field was detected through the identification of a gauge transformation in (70). A further research discovered its quantum in (76). Then an interaction between $B_-(x)$ and the potentials $A_+(x)$ and $A_-(x)$ was observed at non-abelian level in (82) or by breaking supersymmetry in (83). The existence of other fields with a similar behavior to $B_-(x)$ and their corresponding properties, as the anomaly and constraints questions, is a further study in preparation.

The relevant aspect to be noticed is that although the gauge principle carries an idealistic source, it forces a strong pragmatism. All this richness of layers and keys that it generates work as a logical mechanism that antedates the measurement. Thus there is a ceremony invoked by the gauge principle for the candidates to physical models. In order to realize this idealistic-non measurable ceremony made by the constraints and by the conditions for a symmetry be implemented two examples will be shown. Similarly to the Gupta - Bleuler formalism that restricts the Hilbert space, the gauge principle also allows some regions that it generates to be cut off by physical models. For instance, the covariantization process

$$(\nabla_-\Phi)' = e^{i\Lambda(x,\theta)}\nabla_-\Phi \qquad (96)$$

just indicates the fields $B_{\mu}(x)$ and $\chi(x)$ but does not impose them. A second intrinsic correlation is a type of education that the physical models must receive. This means that in order to a particle be moved on the surface of the gauge principle it must contain not only an Action-Lagrangian gauge invariant but also its vacuum and its corresponding functional measure. Then, as a response for this education, theory offers Ward Identities to simplify the verification of its experimental results.

Another character to observe the instructions of a principle is on the experimental institutions that it emerges. In nature surface the perihelium shift of Mercury and the $W^{\pm} - Z^{0}$ masses are enough results for physics be lucky of assuming both such principles, although with their different backgrounds. Our conclusion is that the main structural difference is that each principle shows its cohesion in different instants of a physical theory. For instance, it takes three chapter for the gauge principle be submitted to the trial and error method. The discussion about the range of the gauge principle is left uncompleted.

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