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Ultimate duality field-matter: fields structural unification

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Abstract

In quantum field theory, the field unification is a unsolved question. Previous studies allowed us initiating a theory which assumes the duality field-particle. Here, we demonstrated the corresponding field equations in space-time symmetry. Their origin and interpretation allowed showing or proposing: i. the specification of the duality field-matter; ii. the physical meaning of a quantum state; iii. the spin-1/2 origin of fundamental fermions; iv. the interpretation of gauge-field components as six substates representing scalar/vector gauge fermions in any field; v. the existence of four stable fermions in this while the two instable others appear with additional time dimensions; vi. the field equations validity for any system from mass and charge normalizations; vii. the possible existence of mass and charge object moving at light speed; viii. the compositeness of massive and charged gauge fermions such as leptons or quarks; ix. the evident existence of gravitational and electromagnetic fermions; x. the spin-1 for all fundamental vector bosons and the spin-0 for the scalar ones; xi. the difference between matter and antimatter and xii. a priliminary vacuum state. In all, the results show a structural unification of the four ordinary fields.

Keywords: Duality field-matter, field unification, gauge fermion, longitudinal time, normalization parameter, quantum relativity, spin origin, transverse time.

Introduction

The duality field-particle is the generalization of the classical duality wave-particle. It is then synonymous of complete Quantum Mechanics. It has to deal with fields representing any particle in the host medium and explaining wave phenomena. Quantum Field Theory (QFT) indirectly include the concept of duality via Dirac field of a particle[1,2]. However, the duality wave-particle does not exist in QFT since there are only fields; particles are excited or quantized states of these. One can ask, "where fields come from?" or "what is prior between particle and field? QFT originated Quantum Electrodynamics, Electroweak theory and Chromodynamics which constitute Standard Model (SM) of particle physics[3,4]. This is based on Yang-Mill theory which deals with symmetry groups according to the Lagrangian definition. Such a step can only correspond to evaluate particular cases. Finding the ideal Lagrangian describing all fields is somewhat a matter of riddle. One came to unite three fields with different symmetries. One can ask, "why nature has to work with such differences?" One of the answers points out our methodology defaults since considering specific cases does not help finding other unknowns. As only gauges could allow distinguishing fields one to another, one wonders whether a theory including at least four field gauges can exist.

SM looks like a harmonized collection of good theoretical recipes in order to explain the experimental results related to nuclear physics and electromagnetism. One knows that some subtleties lack then to this collection. For instance, the number of fermions or bosons is different from one field to another or the gravitation is absent while most of particles have mass; this could suggest the prior existence of this field. SM is then a partial unification calling for improvements. Supersymmetry theory is SM extension[5,6]. It generalizes space-time of QFT which only deals with Minkowsky space-time where time is only scalar. Supersymmetry establishes super-partners of all known particles and doubles then the particle number plus some others. This theory is however said speculative since no predicted particle has ever been observed. It is also said inherent to String theory[7,8] which includes gravitation in a drastic mathematical building. However, the hypothetic graviton must have the spin-2 inherent to the tensorial representation of fields; vector bosons of SM have the spin-1 inherent to the vectorial representation. The lack of agreement surely prevents a united description of all fields. One can then ask, "what is the fundamental spin in nature and where does it come from?" Quantum Mechanics which originates the concept defines this as a particle property having angular momentum properties. This origin is unknown as well as the probabilistic behavior of the wave function, which includes somewhat mystery in physics. Because of such preoccupations and uncertainties, without consideration of dark fields, many specialists propose researching a more fundamental theory.

Hence, we also found useful to propose this duality in the line of our previous works[9,10]. We did not find such a step elsewhere. This theory associates *ordinary fields in vacuum to any moving free system* using the Hamiltonian formalism with some updates. This does not require robust mathematical building. Before, we assumed by analogy scalar and vector field equations whose elastic interpretation showed the primacy of matter again fields. Moreover, the related four gauge couplings lead to fundamental fields. Here, we aim to demonstrate complete field equations after establishing the duality field-matter, indicate the general solutions and show the conservation laws implied in gauge relations. We will discuss the main consequences and outline the structural unification of fields suggested by the gauge couplings.

Foundations of the duality field-matter

We justify here the duality origin and specify some space-time concepts. Then we establish field equations from one theorem plus an axiom before indicating the conservation laws implied; the possible solutions as well.

Upgrade of the duality wave-particle: Historically, the beginning of Quantum Mechanics theory comes from de Broglie's postulate attributing the wave nature to any particle. Schrödinger found the equation for one non-relativistic particle. As well, he gave the first definitions of energy-operator ($H = i\hbar\,\partial/\,\partial t$) and impulse-operator ($P = -i\hbar\vec{\nabla}$). Considering furthermore the case of a relativistic particle, Dirac showed that the corresponding Hamiltonian is linearizable for fermions of spin-1/2; the plane wave-function having then four components for two opposite energy eigen values, each twice degenerated. This allows him to foresee the positron existence which marked the beginning of antiparticle consideration. It was wonderful to get such a result. Nowadays, this can however be reviewed in order to break the *energy degeneracies*. This can consist in finding out another observable commutating with that Hamiltonian so that both constitute a complete set; otherwise, those four components form a incomplete base of quantum states. Despite this fact, Dirac's state became standard in QFT by convenience. One can expect that the result also be incomplete. Certainly the postulated Higgs field was necessary to solve some in completions. One can ask if however this is enough... Moreover, that state remained probabilistic contrarily to Schrödinger's initial idea. To come to establishing its physical meaning, it is then necessary to proceed otherwise.

Associating gauge fields to any object: Noting that a wave function is a vector component as it appears with Dirac's state, one can begin by directly associating a field to any particle. Maxwell equations constitute the ideal framework for such a step. It is then enough to substitute wave by *field* in de Broglie's postulate to avoid any ambiguity. Hence, we can easily assume that any particle respects Maxwell-like equations relatively to a 4-potential $|A\rangle$, i.e.

$$(\Delta - \frac{1}{V_\phi^2}\frac{\partial^2}{\partial t^2})|A\rangle = |Source\_from\_c\square arge\rangle$$

where V_ϕ is the wave velocity in the host medium. This representes the speed of signal observation. One can then establish as many equations as sources disturbing that medium; the number of gauge fields relying on these. The determination of proper sources and eventual consequences constitute the duality field-matter.

Interpretating classically wave equations: The classical interpretation of such equations is often neglected in Quantum Mechanics. Hence, it is not useless to recall some details for further usage. The first member represents the derived law describing waves in the host medium. This characteristics are summarized in the celerity V_ϕ. The 4-potential represents of course the field variations in this medium. Thus, there is no confusion between the medium appearing in the first member and the source in the second. The operators appearing on the left only depend on the medium not at all on the source. The equality representing the equilibrium is translatable by the identities of energies and momentums between waves and source. It seems therefore obvious that the classical association of waves to the source genenerating them is not so extraordinary; one already knows that waves appearing in a fluid crossed by a mobile are certainly due to this. Hence, one can expect to get the same phenomenon in any medium with a moving particle. The physical principle is the same everywhere. However, the doubt appeared when speaking about vacuum.

Quantum states physical meaning: The now admitted constitution of quantum vacuum, even ill-known, solves somewhat the ancient ether question; one recognizes it as non-void of content[11,12]. Hence, the previous elastic interpretation remains valid when substituting the host medium by the quantum vacuum. This fits with phonon detection in this[13,14]. The potentials describe then gauge fields associated to the moving object. At any space-time position, the gauge-field intensity can write $\langle A|A\rangle = I$ such as $\langle A|A\rangle/I = 1$. This is interpretable in terms of total probability to find the test object somewhere in the medium whatever is the field. Hence, the vector $|A\rangle/\sqrt{I}$ is identifiable to a quantum state of probabilistic interpretation. Thence one can give this meaning:

Any quantum state is a normalized gauge field which is a description of the host medium primitive reaction to a system action.

Assuming that any field derives from a gauge field like in classical electrodynamics, one can understand that any quantum state originates a field. Where this is more intense, it is of course more likely to find the test object. The source actions, coming from the object mass and charges, constitute the causes of propagating disturbances. Hence, *one must expect to have any wave field including the weak and strong fields*; all explaining the wave nature of particles. Thus for instance, one could say that the electron interference is due to its virtual electromagnetic field or its diffraction to its wave weak field. In addition, the action and reaction principle implies in that definition justifies efficiently the equilibrium medium-system. That is, the corresponding solutions must be stationary whether the system is a particle, an atom or a more complex object. This recalls Bohr's first principle of the atomic model. Only the non-equality corresponds to instable interaction between objects and this constitutes the so-called fluctuations of the medium, if negligible.

Useful definitions in space-time symmetry

In Einstein's Relativity and classical Quantum Mechaincs, time is a scalar quantity while space is a vectorial one. Although this seems normal since one has never detected vectorial time, this is certainly doubtful in theory. Coming to put in doubt our current experimental capacities constitute besides the relativistic foundations. It is enough to admit that ideas are ahead of physical experiments. Further in this talk will appear the consequences of only considering ordinary time. Hence, in order to take into account the space-time symmetry, any 4-potential has to be substituted by a gauge field with as many space components as time. This has to deal with 6-dimension space-time in principle, unless otherwise express mention. On the other side, it is necessary to define all kinds of fields to be exhaustive. Thus, defining by $|A_l\rangle$ the longitudinal or scalar gauge field and by $|A_t\rangle$ the transverse or vector gauge field, we can write them under the forms below.

$$\begin{cases}|A_l\rangle = (\vec{A}_l, -\frac{V_l}{c_l}\vec{\tau}_l)^\dagger \\ |A_t\rangle = (\vec{A}_t, -\frac{V_t}{c_t}\vec{\tau}_t)^\dagger\end{cases} \equiv \begin{cases}|A_l\rangle = A_l|\eta_l\rangle + \frac{V_l}{c_l}|\tau_l\rangle \\ |A_t\rangle = A_t|\eta_t\rangle + \frac{V_t}{c_t}|\tau_t\rangle\end{cases} \quad (1)$$

where c_l and c_t are the speeds of observation signals in both directions; $\vec{\tau}_l$ and $\vec{\tau}_t$ are anti-unitary vectors such as their squares are $\vec{\tau}_l^2, \vec{\tau}_t^2 = -1$ and their transpositions are $\vec{\tau}_l^\dagger = -\vec{\tau}_l$ and $\vec{\tau}_t^\dagger = -\vec{\tau}_t$. We define the different vectors below.

Longitudinal and transverse times: These come from the necessity of defining both time arrows. The unitary kets are definable in the complex plane by the relations

$$\begin{cases}|\eta_l\rangle = (\vec{\eta}_l = \frac{\vec{A}_l}{|\vec{A}_l|}, 0)^\dagger; \quad |\eta_t\rangle = (\vec{\eta}_t = \frac{\vec{A}_t}{|\vec{A}_t|}, 0)^\dagger \\ |\tau_l\rangle = (0, -\vec{\tau}_l)^\dagger; \quad |\tau_t\rangle = (0, -\vec{\tau}_t)^\dagger\end{cases} \quad (2)$$

With the orthogonality condition $\langle A_l|A_t\rangle = 0$, one must have

$$\vec{\eta}_l . \vec{\eta}_t = 0; \quad \vec{\tau}_l = i\vec{\eta}_l; \quad \vec{\tau}_t = i\vec{\eta}_t \quad (3)$$

in order that the basis $\{|\eta_l\rangle, |\tau_l\rangle, |\eta_t\rangle, |\tau_t\rangle\}$ be complete. This defines Hilbert's space of any quantum state or gauge field. As the vector $\vec{\eta}_l$ corresponds to the gradient direction as it will appear, the *longitudinal time is related to that direction*. The transverse time is to that of the transverse vector-potential. This could however be unobservable since there is no propagation along this. Hence, the former defines accurately the ordinary or scalar time. To complete our notations, recall that the space gradient at the position-$\vec{r}$ can write $\vec{\nabla} = \vec{r}\,\partial_r/r$ with $\partial_r = \partial/\partial r$. Thence it is useful to define both time gradients and the related d'Alembertian operators as follows

$$\begin{cases}\vec{\partial}_{tx} = \vec{\tau}_x\, \partial_t / c_x \\ \Box_x = \Delta + \partial_{tx}^2\end{cases} \text{with } \partial_t = \partial/\partial t; \quad x = l, t \quad (4)$$

New impulse-energy operators: One knows that the first member of any wave or field equation is a derived law. Any operator originating this must depend on the medium nature as indicated before. However, the habit in classical Quantum Mechanics consists of using the initial definitions of both standard operators in any situation. For instance, it is incoherent to use the same temporal definition of the Hamiltonian in the following cases: i. for a free particle of mass m when this can simply write $H = P^2/(2m)$ and ii. for the case where the same particle is in a potential V, where it writes $H = P^2/(2m) + V$. Thence, noting that in space-time symmetry, any 6-vector is reducible to two subspaces, a field equation is writable under matrix form. Hence, due to the possibility of transforming each d'Alembertian operator into scalar product of two vectors, one can write $1\Box_x \propto \hat{P}_{1x}^\dagger . \hat{P}_{2x}$; where both operators $\hat{P}_1$ and $\hat{P}_2$ are vectors of matrices 2x2. One can show that the given product is interpretable as impulse-energy operators of two shocking particles. This is possible by applying the combined conservation laws of energy and impulse with $\hat{P}_1^\dagger . \hat{P}_2 = \hat{P}_2^\dagger . \hat{P}_1$. These operator expressions then read[10].

$$\hat{P}_{x1} = \pm i\hbar\alpha_x\hat{\sigma}_x \begin{pmatrix}\vec{\nabla} \\ \vec{\partial}_{tx}\end{pmatrix}; \quad \hat{P}_{x2} = \pm i\hbar\alpha_x^{-1}\hat{\sigma}_x \begin{pmatrix}\vec{\nabla} \\ -\vec{\partial}_{tx}\end{pmatrix} \quad (5)$$

with $\hat{\sigma}_x = \sqrt{1 - b_x^2}(cos\phi_x\sigma^1 + sin\phi_x\sigma^2) + b_x\sigma^3$; where $b_x \in [0,1]$ is a real constant relatable to spin orientation and ϕ_x is the related angle; σ^j are Pauli's matrices such as

$$\sigma^1 = \begin{pmatrix}0 & 1 \\ 1 & 0\end{pmatrix}, \quad \sigma^2 = \begin{pmatrix}0 & -i \\ i & 0\end{pmatrix}, \quad \sigma^3 = \begin{pmatrix}1 & 0 \\ 0 & -1\end{pmatrix}$$

One has $\hat{\sigma}_x^2 = 1$; α_x beging dimensionless functions completing the classical definitions. As it appears in the previous example, these depend on the potential defining the medium. In the particular case of inertial motion, they only rely on the test object speed.

Space-time symmetry consequences: One can note that both bispinors show the spin-1/2 as the manifestation of space-time symmetry. Therefore, the shocking particles must always be fermions and/or antifermions. We call them *gauge fermions* relatively to a field. By default, this defines six independent substates describing six gauge fermions. These are the so-called virtual fermions or phonon components at any object speed. Thence, one can understand the energy degeneracy of the previous Dirac's problem. The spin-1/2 in the linearized Hamiltonian is not related to the test object as interpreted at the time but to four substates appearing in vacuum. Two of them represent vacuum fermions having the object energy and the two others are vacuum antifermions having the opposite energy. This sums then up the accuracy of elastic interpretation of quantum vacuum.

New gauge-field equations

With the advantage of new operator expressions and the meaning of gauge fields, we use the Hamiltonian formalism. We consider an object moving at the speed v in vacuum; M and Q

being its mass and charge. Then, we establish equations valid at any scale from the theorem below.

Gauge-field theorem: To establish universal equations showing the existence of scalar and vector gauge fields, we state the theorem below which is valid for any object or medium:

Any charged object in motion must have energies of mass and charge generating scalar and vector wave fields in the host medium.

Demonstration from mass-energy As the test object is in inertial motion, the mass-energy relation expresses the conservation of the 4-momentum square between two reference systems. For an elementary mass, this writes $(\vec{p}, iE/c)^2 = (0, iMc)^2$. Classically, one multiplies this by an arbitrary wave function ψ and applies Bohr Correspondence Principle (BCP) to obtain Klein-Gordon equation. The transformation is linear. If the correspondence is made to obtain a field equation, this becomes non-linear. One has for the mode-x.

$$(\vec{p}, iE/c) \overset{BCP}{\mapsto} \hat{P}_{x1} \text{and} (\vec{p}, iE/c)\psi \overset{BCP}{\mapsto} \hat{P}_{x1}|A_x\rangle$$

$$\text{or} (\vec{p}, iE/c) \overset{BCP}{\mapsto} \hat{P}_{x2} \text{and} (\vec{p}, iE/c)\psi \overset{BCP}{\mapsto} \hat{P}_{x2}|A_x\rangle$$

Hence, if $|A_l\rangle$ is the corresponding field, one can apply this transformation relatively to $\hat{P}_{l1}$ for one fermion or antifermion. After substitution in the previous relation, one easily gets to the field equation

$$\Box_l 1|A_l\rangle = \left(\frac{Mc}{\alpha_l \hbar}\right)^2 |A_l\rangle \quad (6)$$

provided that $c_l \equiv c$. We already established the $|A_l\rangle$ scalar nature (see the next section). Note that in comparison to the shock originating operators, the square of one of them corresponds to the particle action onto its self. The corresponding 6-vector is then a particle self-consistent field. Besides, each gauge-field substate is a Klein-Gordon equation for the mass $m = M/\alpha_l$. Relatively to the initial mass M, m is the *normalized mass*; α_l is then the *normalization parameter*. This last is equal to unit for a fundamental mass. Remark that the use of $\hat{P}_{l2}$ expression would lead to multiplying by α_l instead of dividing. The choice of one operator or another does not change the interpretations. One the other hand, this equation is valid even for macroscopic objects due to the normalization. This leads to the scale of smaller masses composing the test object.

Demonstration from charge-energy For stationary states suitable for a free system, one has $|A_l\rangle \propto exp(-iE_l t/\hbar)$, the previous field equation is equivalent to the following

$$\Box_t 1|A_l\rangle = 0 \quad (7)$$

such as $c_t = c^2/v$ is de Broglie's celerity. Total energy E_l, kinetic energy K_l and momentum p_l of the component are definable by

$$E_l = \gamma \frac{M}{\alpha_l} c^2; \quad K_l = (\gamma - 1)\frac{M}{\alpha_l} c^2; \quad \vec{p}_l = \gamma \frac{M}{\alpha_l} \vec{v} \quad (8)$$

where $\gamma = 1/\sqrt{1-\beta^2}$ (with $\beta = v/c$) is the usual relativistic parameter. Coming back to the previous equation, one knows that v is energy speed of de Broglie's waves. One can establish that this is also true for waves of celerity $c_K = K_l/p_l$. Thus, the equation below is also valid

$$(\Delta - \frac{1}{c_K^2}\partial_t^2)1|A_t\rangle = 0; \quad c_K = \frac{c}{\beta}(1 - \frac{1}{\gamma}) \quad (9)$$

The field $|A_t\rangle$ depends on kinetic energy and is also stationary, i.e. $|A_t\rangle \propto exp(-iK_l t/\hbar)$. This must also satisfy an equation similar to that of the scalar gauge field. The preceding equations then allow deducting the following axiom.

Observation Axiom: As the speed c of light allows observing mass-energy events in the gradient direction, de Broglie's celerity c_t allows observing charge-energy events in the transverse plane.

Hence, as the observation of mass-energy relies on the gravitational potential c^2 in inertial motion that of charge-energy must rely on a charge potential U_o. The related 4-impulse conservation in two reference systems can write $(\vec{p}_t, iK_l/c_t)^2 = (0, iQU_o/c_t)^2$; if $\vec{p}_t$ is the charge momentum. Applying now Bohr correspondence principle as before, relatively to the operator $\hat{P}_{t1}$, one obtains the corresponding field equation:

$$\Box_t 1|A_t\rangle = \left(\frac{QU}{\alpha_t \hbar c}\right)^2 |A_t\rangle; \quad U = \beta U_o \quad (10)$$

where U is the dynamical tension submitting the object. This is zero at rest. We already have established the vectorial nature of the corresponding gauge field (see the next section). More again, the quantity $q = Q/\alpha_t$ is the *normalized charge* and α_t is the corresponding *normalization parameter*, equal to unit for a fundamental charge. In the gravitation case, the object charge is the rotating mass. The tension U_o must be then relative to the square of rotation velocity.

Quantum relativity consequences: i. The vector gauge-field existence relies on that of the scalar gauge field. Therefore, *where there is no scalar field there is no vector field too*. Both are indissociable as the total and kinetic energies. ii. For objects moving at light speed ($v = c$), one notices two special situations: (a) From energy expressions above, remark that $\gamma = \infty$, $M \neq 0$ if $\alpha_l = \infty$. This parameter dependence in speed should change the classical result of relativity. This is rather Quantum Relativity. (b) The field equations remain unchanged if the ratios M/α_l and Q/α_t are non-zero, i.e. $\alpha_x \neq \infty$ or $M = 0$, $Q = 0$ when $\alpha_x = 0$. This is not contradictory at all to the previous situation. One has then to distinguish two possible expressions of each α_x with respect to speed. The previous case is relative to the whole object while this is to its components. The normalization is then undetermined. Hence, *as massless objects can travel at the speed of light, mass objects can too* (see the result section).

Maxwell-like equations and connection to dark fields: Any vector field is comparable to Maxwell equations. Writing the equation (10) under the known form $\Box_t|A_t\rangle = -\mu_f|j_t\rangle$ lets deducing the charge current-density for a field-f as

$$|j_t^f\rangle = -\varepsilon_f\left(\frac{Q_f U_f}{\alpha_t^f \hbar c}\right)^2 |A_t^f\rangle \quad \text{with} \mu_f\varepsilon_f = \frac{1}{c_t^2} \tag{11}$$

where ε_f and μ_f are respectively the field f permittivity and permeability. When $c_t = c$one has in electromagnetism $\varepsilon_f = \varepsilon_o$, $\mu_f = \mu_o$ and in gravitation $\varepsilon_f = -1/(4\pi G)$; where G is the gravitation constant. In both other fields, one can expect to have at least one constant to deduce the other. Note that such densities attest the existence of *more elementary fermions generating the field substates* when the object moves ($v \neq 0$); this also applies with the scalar mode. These fermions can only come from vacuum state. Moreover, if $|j_t^f\rangle$ and $|A_t^f\rangle$ must have the same sense for $\varepsilon_f > 0$, U_f must be imaginary. Conversely, this is valid regarding the contrary senses for $\varepsilon_f < 0$. We had already established that imaginary quantities are relatable to *dark-fields*[10]. Hence, the tensions U_f are the sole connections to these through dark energies definable by $|Q_f U_f/\alpha_t^f|$.

Gauge-field natures

Here, we show the achievement of the theorem demonstration with gauges relations derived from field equations. As well, we interpret their meanings to demonstrate gauge completeness in terms of conservation laws.

Procedure of gauge obtainment: We already found these from the *relation cause-effect*[10]. To understand the necessity of additional time dimensions, we can specify the following. This relation appears as below: i. the scalar potential is the cause of the vector potential in a scalar field; ii. the vector potential is the cause of the scalar potential in a vector field. From the corresponding initial equations, we determined relations between the causes and their effects. For ordinary fields, one then applies the space gradient which turns a scalar equation into a vectorial one and conversely. Then, one integrates with respect to scalar time. Such a procedure supposes that ordinary field equations are observable in *Minkowsky space-time*. However, this corresponds to assume that the additional times do not fit with the description of these. That is, the corresponding substates are instable. Hence, there are only *four stable gauge fermions by definition*: three of space and one of time.

Gauges and conservation laws: Although dealing only with Minkowsky space-time, one must expect to imply the existence of the six gauge fermions of a given field with their characteristics. Applying now the previous procedure, one distinguishes both cases of fields:

* *Case of scalar field* We found two gauges and two scalar fields respectively defined by the relations

$$\begin{cases}\partial_t\vec{A}_l \pm \vec{\nabla}V_l = \vec{0}\\ \Gamma_\pm = \pm\vec{\nabla}\vec{A}_l + \partial_t V_l/c^2\end{cases} \tag{12}$$

In quantum interpretation, the different terms in equations must have meanings. Those of gauge relations represent different particles. Here, we can note that: i. as both gauge relations are relative to mass existence, the potentials are gravitational, i.e. $[V_l] = m^2.s^{-2}$, $[A_l] = m.s^{-1}$ then $[\Gamma_\pm] = s^{-1}$. One can then define the vectors $\vec{g}_\pm = \mp\vec{\nabla}V_l$. The first (-) is the classical definition of gravitation. Therefore, the sign (+) in the initial relations defines matter and the sign (-) defines antimatter. These relations express besides the *equivalence principle* of General Relativity: a (scalar) gravitation is equivalent to an acceleration ($\partial_t\vec{A}_l$). One can then note the non-uniform motion of gauge fermions. This is relatable to the general solutions putting in view angular momentums. ii. To show that those relations also represent conservation laws, one can resort to the elastic interpretation of wave propagation in homogeneous and isotropic media like vacuum. In this, the displacement field of cells according to Helmholtz theorem[15] can write under the form $\vec{D} = \vec{\nabla}\times\vec{A'}_t - \vec{\nabla}V'_l/c'_l$; where V'_l is the flow through the surface defined by $\vec{A'}_l$; c'_l being the longitudinal sound celerity. The equivalence is immediate by defining here an equivalent Helmholtz field[9]. The scalar potential is then proportional to the flow ($V_l \propto V'_l$) and the vector potential is identically to the flow surface ($\vec{A}_l \propto \vec{A'}_l$). Hence, the initial relations are equivalent to $\partial_t\vec{A'}_l = \mp\vec{\nabla}V'_l$. This expresses the conservation law of surface velocity in central plane motion. Therefore, the conservations of *kinetic momentum* and *mechanical energy* of gauge fermions in the field. iii. In addition, the initial relations also write $\partial_t A_l^i \pm \partial_i V_l = 0 \quad \forall i = 1,2,3$, i.e. the plane motion is defined relatively to each space axis and the conservation laws too. All of this is illustratable in homogeneous and isotropic media by a cubic structure at a given space-time position. Figure-1 shows a possible snapshot of the three couples around the test object. iv. Moreover, one notes the three kinds of independent couples. According to the scalar field origin, this shows that each variation of space substate in time is due to the variation of the related time substate in space. In particle physics, one would distinguish each couple by the so-called *flavor*. That is, if $\mathcal{F}$ is the transformation of each term into flavor, one has $\mathcal{F}(\partial_t A_l^i) = \mp\mathcal{F}(\partial_i V_l)$. The flavor of one space fermion is identical or opposite to that of the related time fermion. All fields have therefore three different flavors. Figure-1 representation then fits with the three favors illustration.

* *Case of vector field* We found two gauges and two vector fields respectively defined by the relations

$$\begin{cases}\vec{\nabla}\vec{A}_t \pm \frac{1}{c_t^2}\partial_t V_t = 0 \\ \vec{E}_\pm = -\vec{\nabla}V_t \mp \partial_t\vec{A}_t; \quad \vec{B} = \vec{\nabla}\times\vec{A}_t\end{cases} \tag{13}$$

whereas one can recognize the electric-like field $\vec{E}_\pm$; the magnetic-like field $\vec{B}$ as well for any charge. i. The first relations represent Lorentz gauges for fermions (+) and antifermions (-). These correspond to *charge conservations* and complete the preceding laws. ii. They are also expressible in charge term. Indeed, if $\mathcal{C}$ is the transformation of each term into charge, one can write $\mathcal{C}(\partial_t V_t) = \mp[\mathcal{C}(\partial_1 A_t^1) + \mathcal{C}(\partial_2 A_t^2) + \mathcal{C}(\partial_3 A_t^3)]$. That is, *the charge of a time gauge-fermion is the combination of those of space gauge-fermions.* This corroborates with the vector field origin.

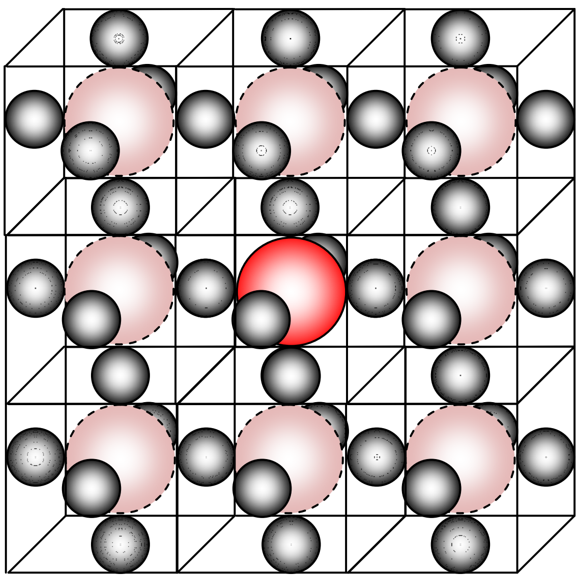

Figure-1: A configuration of three gauge-fermion pairs The test object defines the central cube around which appear virtual cubes in all directions. Each small sphere represents one interacting couple (a boson) on a cube face. The color attenuations reflect the decreasing field amplitude.

Gauge couplings: Let us note that the field equations attribute the same energies to fields of any existing charge. Therefore, these are united in vacuum for the test object. The general solutions (17) show that an object can manifest itself by one field or another depending on gauge couplings. Relatively to the signs identifying gauge fermions in the previous relations, the possible couplings are then $\{(-,-), (+,+), (-,+), (+,-)\}$. This means that there are only four ways of field propagation in vacuum, i.e. four possible differentiations of the object unified field. We already showed that these fields are respectively gravitational, electromagnetic, weak and strong[10]. Here, note that the signs imply the couplings antifermion-antifermion, fermion-fermion or fermion-antifermion. It will appear further that accordingly to the general solutions, any field also admits four couplings of spin orientations such as all kinds of *gauge bosons* are possible.

Equations general solutions

Using the normalized mass and charge, the equations of a given field-f can read

$$\begin{cases}\Box_l 1|A_l^f\rangle = (\frac{m_f c}{\hbar})^2|A_l^f\rangle \\ \Box_t 1|A_t^f\rangle = (\frac{q_f U_f}{\hbar c})^2|A_t^f\rangle\end{cases} \text{with } m_f = \frac{M}{\alpha_l^f}; q_f = \frac{Q_f}{\alpha_t^f} \tag{14}$$

These describe each kind of gauge fermions inside the test object. These number in the x-mode is estimable to the rounded value of α_x^f by excess. Thence, if N_x^f designates each integral number, those linked fermions interact in respect to the field-f with the negative energies

$$\begin{cases}I_l = (\alpha_l^f - N_l^f)m_f c^2 \\ I_t = (\alpha_t^f - N_t^f)q_f U_f\end{cases} \tag{15}$$

According to the equations (7) and (9), the field general solution is the linear combination of N_x^f solutions $|A_x^f\rangle_{n_x}$ having the same celerity $c_x' = E_x/p_l$. If $(\vec{k}, i\omega_x/c_x')$ is the object 4-wavenumber of the mode-x, one has $E_x = \hbar\omega_x$ and $p_l = \hbar k$ such as one can also write for each solution-n_x the relation $c_x' = \hbar\omega_{n_x}/(\hbar k_{n_x})$. The field solution reads then

$$|A_x^f\rangle = \sum_{n_x=1}^{N_x^f} |A_x^f\rangle_{n_x} \tag{16}$$

One deducts that $\omega_{n_x} = w_{n_x}\omega_x$; where $w_{n_x} = k_{n_x}/k$ is a real number. The energy differences indicate the existence of local motions (of rotation) inside the test object.

Quantum solutions: If $\hat{L}$ is then the operator of the orbital momentum of gauge fermions in n-level and $\hat{S}$ is the spin-1/2 operator, their global angular momentum is $\hat{J} = \hat{L} + \hat{S}$. Each substate-$i$ admits quantum solutions in spherical coordinates (r_i, θ_i, ϕ_i). Taking count of both *possible* spin orientations relatively to the motion direction, the amplitudes can write under the form below of alternative solutions for each mode-x.

$$(A_x^{f\pm})_{n_x\ell_x}^i = R_{n_x\ell_x}(r_i)\begin{cases}(a_x^{f+})_{n_x\ell_x}^i \sum_{m=-\ell_x-\frac{1}{2}}^{\ell_x-\frac{1}{2}} Y_{\ell_x}^{m+\frac{1}{2}}(\theta_i,\phi_i) \\ (a_x^{f-})_{n_x\ell_x}^i \sum_{m=-\ell_x+\frac{1}{2}}^{\ell_x+\frac{1}{2}} Y_{\ell_x}^{m-\frac{1}{2}}(\theta_i,\phi_i)\end{cases} \tag{17}$$

with $i = 1,\ldots,6$; One can define ℓ_x such as $\ell_x = 0,\ldots,n_x - 1$ so that for only one energy level ($N_x^f = 1 \Rightarrow \ell_x = 0$), the object corresponds to a unique set of gauge fermions. $(a_x^f)_{n_x\ell_x}^i$ are integration constants, $R_{n_x\ell_x}(r_i)$ are the radial functions and $Y_{\ell_x}^{m\pm1/2}(\theta_i,\phi_i)$ are the spherical harmonics functions. The amplitude of i-substate of the gauge-field at n_x-level expresses then by

$$(A_x^{f\pm})_{n_x}^i(\vec{r}_i) = \sum_{\ell_x=0}^{n_x-1} (A_x^{f\pm})_{n_x\ell_x}^i(\vec{r}_i) \tag{18}$$

On field coupling constants: Each field equation of the system (12) is multipliable by a non-zero constant χ_x^f relatable to the number of identical and independent objects. This only affects the field intensity whose amplitude is χ_x^f times stronger. The test object general solutions for the four fields translate by

$$\begin{cases}|A_l\rangle = \Sigma_{f=1}^{4} b_l^f |A_l^f\rangle \\ |A_t\rangle = \Sigma_{f=1}^{4} b_t^f |A_t^f\rangle\end{cases} \quad (19)$$

in normalized units. Where b_l^f are dimensionless constants contrarily to the constants b_t^f. Relatively to a non-zero one in each final mode, the others are coupling constants between different gauge fields of the test object. Besides, those equations show that an object has as many vector modes as scalar. These are extendable to macroscopic systems due to mass and charge normalizations.

Results and discussion

We found that: i. the fundamental spin-1/2 of fermions represents space-time symmetry. This defines fermions-1/2 as space-time units in nature such as any other spin can only come from these composition, i.e. matter is prior to field. Hence, any boson is not really a fundamental particle as one often used to consider. Their constitution relies on gauge couplings. This also applies on photons and gravitons. ii. Gauge fermions can be composite objects. Such a concept already exists with preons supposed constituting elementary particles[16]. Besides, this seems obvious due to the fact that they are described by self-consistent fields which imply spatial extensions. This suggests that *quantum vacuum originating each is made of fermions without any self-consistent field*. These should be excited and gathered by any field around the test object. iii. We also found that mass objects can move at light speed. As known, this is forbidden in classical Relativity. However, this is certainly the case of neutrinos[17,18] and quarks. This is relevant to understand the impact of mass and charge normalizations. iv These are certainly the counterpart of renormalization procedures so useful in SM. One knows that these are however impracticable in General Relativity. v. The normalizations are valid here for all fields. Due to two spins-1/2 composition in each gauge coupling, the vector bosons have the spin-1 and the scalar bosons the spin-0.

On fundamental fermions: These correspond to gauge fermions moving at light speed. The field equations expressing local vacuum vibrations define fundamental fields[10]. Here, we illustrate those results. Hence, due to gauge couplings, one has to specify that: i. one graviton is made of one antifermion couple. This is rather strange but there is no choice. Such antifermions explain besides the effect of static and scalar gravitation (see illustrations below). ii. One photon is an electromagnetic fermion pair. The effects of static electric and magnetic fields suggest these fermions existence; the contrary behavior of electric forces relatively to the gravitational ones as well. Figure-2 illustrates such differences from static force lines between masses or charges of identical signs. The contrary case appears in Figure-3. Hence, it seems obvious that *positives quantities represent matter and negative ones represent antimatter*. This fits with the compositeness of gauge fermions. For instance, the negative electric charge of electrons means the dominating presence of electric antifermions in these! iii. Weak bosons are couples antifermion-fermion. When manifested, the related SM gauge fermions are the six leptons $\{\nu_e, \nu_\mu, \nu_\tau, e^-, \mu^-, \tau^-\}$. The three firsts are then space gauge fermions which are stable with the electron.

The two lasts are indeed instable and decay into the preceding, e.g. the common decay[19] $\mu^- \rightarrow e^- + \nu_e + \nu_\mu$. iv. Strong bosons are fermion-antifermion couples. The SM related gauge fermions are the six quarks $\{u, d, s, c, b, t\}$. The lightest three firsts should be space fermions which are stable with the fourth. The heaviest two lasts should be instable. Moreover, the so-called quark confinement suggests that the strong field can only exist in dynamic regime... All of these findings are germane in showing phenomena origins.

Conclusion

After specifying the duality field-particle and the physical meaning of any quantum state, we reviewed the theory we initiated before. We defined longitudinal and transverse times fitting with Hilbert space definition. From bispinors of two kinds of impulse-energy operators, we established new gauge-field equations coupling scalar and vector modes.

From natural subdivisions of system mass and charge we called normalizations, we showed the equation validity for any system; the existence of those traveling at light speed in Quantum Relativity as well; while having mass and charge.

We also established the following: i. both gauge-field modes are self-consistent fields of gauge fermions. ii. Four gauge couplings identify the fundamental fields and explain any wave phenomenon. iii. In each field, there are conservations of energy, kinetic momentum, flavor and charge. iv. Each is definable by six gauge fermions and these can be composite. v. There are four stable of these in ordinary time; the two others are instable and should rely on additional time dimensions. vi. The composition of gravitons are antifermion couples, photons are fermion couples and nuclear bosons are fermion-antifermion pairs. vii. Graviton and photon components are observable in static fields. viii. Matter is defined by positive scalar quantities and antimatter by negative ones.

Among numerous involvements, it remains determining vacuum state which originates gauge fermions; the tension connecting ordinary fields to dark fields (via dark energy) and the normalization parameters as well. Figure-4 then summarizes the structural unification schema of fields suggested by the duality. These are our findings.

Gravitational or electric lines of static field for identical signs of quantities (Figure-2). The line orientations do not depend on the other object presence in both cases (*same sign of matter*). In the interacting region at the left, the mass attraction is mediated by the respective gravitational antifermions (see arrows opposite signs); at the right, the charge repulsion is mediated by the respective electric fermions (see arrows identical signs).

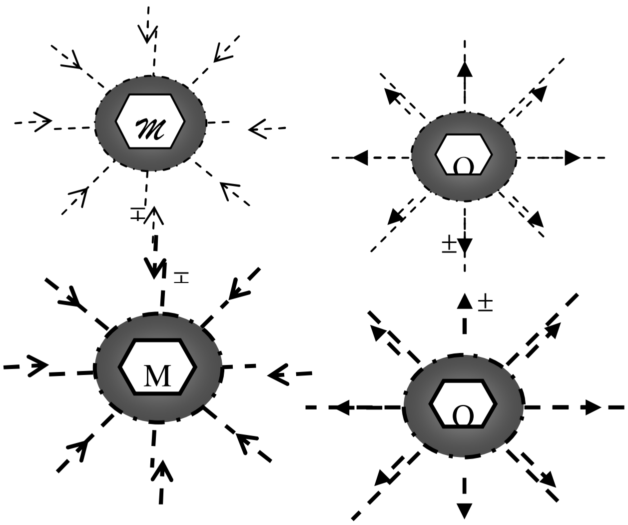

Figure-2: Gravitational or electric lines of static field for identical signs of quantities.

Gravitational or electric lines of static field for opposite signs of quantities (Figure-3). The line orientations depend on the other object presence in both cases (*different sign of matter*). As before in the interacting region at the left, the opposite mass repulsion is mediated by the respective gravitational fermions (see arrows same signs); at the right, the opposite charge attraction is mediated by the respective electric antifermions (see arrows opposite signs).

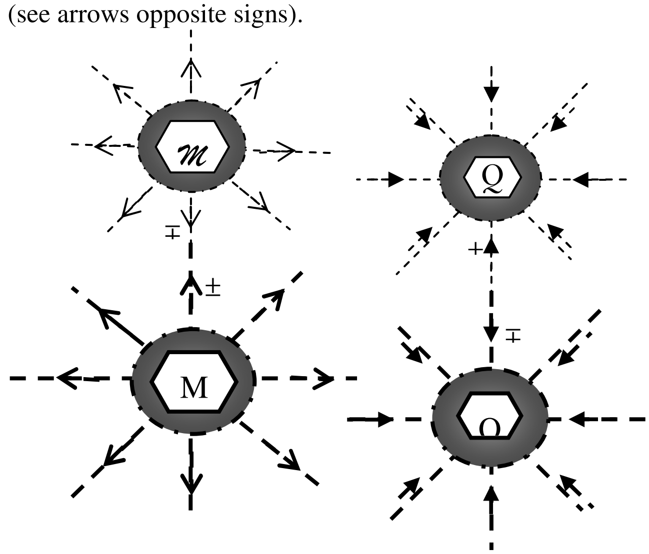

Figure-3: Gravitational or electric lines of static field for opposite signs of quantities.

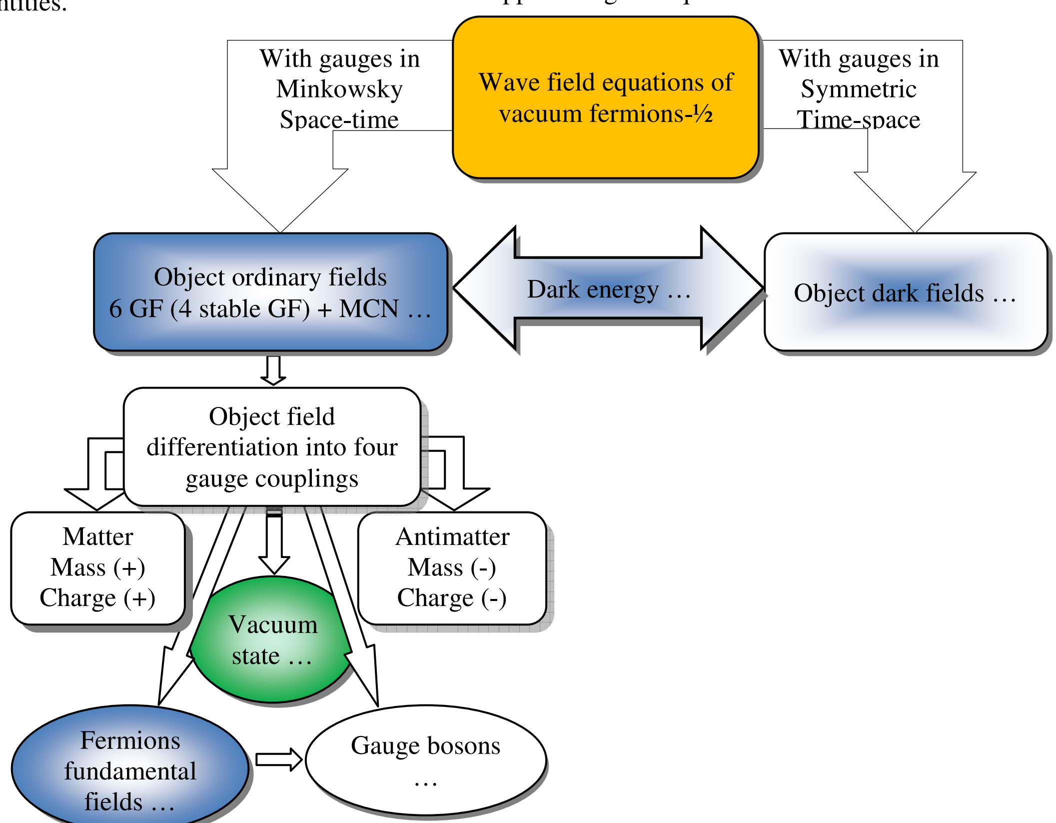

Figure-4: Structural unification schema of fields GF= Gauge Fermion; MCN= Mass and Charge Normalizations. The three dots indicate expectable developments having to yield the achievement.

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