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The unified energy as vacuum quintessence in wave equations

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Abstract

The vacuum composition determination is a great challenge in field theories. The unified field expression is yet less. Here, we completed a previous gauge field theory we established from the wave equations. This postulated the unified field manifestation from the results foreseeing that any boson is a fermion-antifermion couple. Exploring expressions defining these components, it appeared that the vacuum is stable in only two natures of fundamental fermions; otherwise it is instable. The first nature defines matter fermions generated by any particle while the second implies dark matter fermions. We determined dark particles gauge and field expressions applying the space-time symmetry in the gauge construction procedure previously got. These correspond to imaginary masses and charges. It is shown that dark particles travel at a velocity greater than that of the light to have such characteristics. Examining the simultaneous gauge and field invariances, we found that the vacuum must be defined as an elastic medium divisible in cells to explain the field propagation. These have internal properties in which the existence of a magnetic like static field. The electric like field is dynamic and admit quantized solutions. We argued that this defines the unified field and the vacuum is structured with unified matter. The general solutions of the four fundamental fields are given. We ended by showing that radiations define the frontier between matter and dark matter.

Keywords: Dark field, Dark matter, Fundamental field, Gauge invariance, Unified field, Vacuum stability.

Introduction

Usually, one defines the quantum vacuum as the fundamental state of non-interacting fields. Many authors have demonstrated theoretically that the quantum vacuum is not empty[1,2] and some experiments confirm this fact[3,4] putting in evidence the forces existence from nothing. Many findings have established its stability[5,6] as well as its instability at any scale[7-9]. The literature is full of studies treating the vacuum composition or structure; others consider vacuum manifestations according to the environment[10,11] but unfortunately, one does not yet know the real vacuum constitution. In summary, all of those studies illustrate the vacuum capacities to interact with fields, thence the definition convenience given at the beginning. To a great extend, since the field concept could explain everything, even the spirit must interact with the vacuum, taking for granted that this is also a field manifestation. In other term, the vacuum quintessence looks like the Omni-field, being aware of everything at any scale. Then, it is enough for us to recognize its existence. As we used to assume that all existing fields *came* from the unified field, can we tell that it is no more the case nowadays?

If this field seems evident in the beginning of all, we cannot take for granted its disappearance forever. The affirmative point of view seems however dominating most of physicists interested in unifying fields, mainly when one expects to observe the field unification effects at high-energy. Such a field master seems necessary to relevantly explain the phenomena of the vacuum manifestations or fluctuations[12,13]. As we do not know the real truth, we can cut short by trying to verify this rule: “The unified field originates every field by differentiation and defines the vacuum cohesiveness.”

As far as we are aware, all unification theories try to unify General Relativity with the Standard Model of particles physics into one theory[14,15]. Here, we would like show the interest of beginning otherwise in a quasi-classical way unifying all fields. We already showed in a previous article[16] that from Maxwell like fields definitions got from wave equations, all fields are quantized in the vacuum and General Relativity appears naturally to explain interactions between objects, regardless of the size. We continued then with the previous foundations through a more in-depth interpretation of expressions.

Hence, we will begin by reminding and completing the targeted aspects. We will examine the invariances of gauge and field expressions revealing the vacuum properties as well as the space-time symmetry in these, suggested by the vacuum stability condition. Then, we will discuss the determination of the four fundamental field expressions, that of the unified field and the evident proof of dark matter still poorly known. Classical notations are used.

Completeness of previous foundations

We previously showed[16] that the moving particle fields at the velocity $\vec{v}$ is describable by two kinds of 4-potentials $|A_\parallel\rangle =$

$(\vec{A}_{\parallel}, iV_{\parallel}/c_{\parallel})$ and $|A_{\perp}\rangle = (\vec{A}_{\perp}, iV_{\perp}/c_{\perp})$. These satisfy in the vacuum the two wave equations

$$\square_{\alpha}\mathbf{1}|A_{\alpha}\rangle = |s_{\alpha}\rangle \ ; \ \alpha = \parallel, \perp \tag{1}$$

with $\square_{\alpha} = \Delta - \partial_{t\alpha}^{2}$the d'Alembertian operator such as $\partial_{t\alpha} = \partial/(c_{\alpha}\,\partial t)$; $c_{\parallel}$ is the velocity c of the light and the associated scalar field (SF) is longitudinal and comes from Dirac's equation we generalized; $c_{\perp}$ is the de Broglie velocity (c^2/v) and the associated vector field (VF) is transverse and comes from the postulate of de Broglie's wave equation. The simultaneous existence of both equations shows that particles travelling at *c* also have a SF unified to a VF (same energy). The photon mass definition in electromagnetism is an evident example. Besides, one can note that the Maxwell equations are related to de Broglie's equations when $v = c$. Therefore, the latter is suitable to generalize the former.

From the wave equations, we found two SFs Γ and two VFs $\vec{E}$ of the particle given in Table-1. The below sections examine new consequences of these definitions.

Table-1: Gauge and field definitions.

Type	Gauges	Field expressions
SF	$\vec{\nabla}V_{\parallel} \pm \partial_t\vec{A}_{\parallel} = \vec{0}$	$\Gamma_{\pm} = \pm\vec{\nabla}\vec{A}_{\parallel} + \frac{1}{c_{\parallel}}\partial_{t\parallel}V_{\parallel}$
VF	$\vec{\nabla}\vec{A}_{\perp} \pm \frac{1}{c_{\perp}}\partial_{t\perp}V_{\perp} = 0$	$\vec{E}_{\pm} = -\vec{\nabla}V_{\perp} \mp c_{\perp}\partial_{t\perp}\vec{A}_{\perp}$ $\vec{B} = \vec{\nabla} \times \vec{A}_{\perp}$

Vacuum stability: In addition, we showed that any wave equation is describable by successive elastic shocks between an object and an anti-object having an opposite spin. Thus, if $\hat{p}_{1\alpha}$ and $\hat{p}_{2\alpha}$ are the respective 4- impulse operators before the shock, the following relations are valid for the mode α:

$$\begin{cases}\hat{p}_{1\alpha} = -i\hbar\hat{a}_{1\alpha}(\vec{\nabla} \mp \vec{\partial}_{t\alpha}) \\ \hat{p}_{2\alpha} = -i\hbar\hat{a}_{2\alpha}(\vec{\nabla} \mp \vec{\partial}_{t\alpha})\end{cases} \tag{2}$$

Where $\hat{a}_{1\alpha}.\hat{a}_{2\alpha} = -\mathbf{1}$, $\vec{\partial}_{t\alpha} = \vec{\tau}\partial_{t\alpha}$ and $\vec{\tau}$ is an anti-unitary vector ($\vec{\tau}^2 = -1$). The signs in parentheses indicate objects travelling in the future (-) or in the past (+), which correspond to progressive or retrograde waves. Both The matrix operators are given by

$$\hat{a}_{1\alpha} = a_{1\alpha}\hat{\sigma} \ ; \ \hat{a}_{2\alpha} = a_{2\alpha}\hat{\sigma} \tag{3}$$

Where $\hat{\sigma}$ is a linear combination of Pauli matrixes depending on the angle θ and the complex coefficients are such as $a_{1\alpha}.a_{2\alpha} = -1$ and $|a_{1\alpha}| \geq 1$.

Here, we can indicate that in the most elementary cases ($a_{1\alpha} = 1$) or ($a_{1\alpha} = i$), the object is a fermion of spin $1/2$. These correspond to a time independent module of the resulting operator $\hat{p} = \hat{p}_{1\alpha} + \hat{p}_{2\alpha}$, since one shows that $\hat{p}^2 = 4\hbar^2 1\Delta$. If the first value represents an ordinary fermion, the other might be related to *another kind of matter* to be found out. The last relation is related to the vacuum stability; others parameter values are then relative to the vacuum instability implying wave bundles.

Considering besides the Table-1 definitions, the SF wave equations also write

$$\square_{\parallel}|A_{\parallel}\rangle = \mp(\vec{\nabla} \pm \vec{\partial}_{t\parallel})\Gamma_{\mp} \tag{4}$$

By rewriting the second member multiplying and dividing by ($\pm i\hbar$), it appears that the wave source is due to a common 4-impulse operator of any particle (without parameter). This means that our moving particle (fermion or boson) generates scalar bosons composed of fermions and antifermions, whose number depends on the $a_{1\alpha}$ parameter; waves are dispersive for $\Gamma_{\mp} \neq 0$. The generation of vector bosons from the VFs relies on the wave equations

$$\square_{\perp}|A_{\perp}\rangle = -(\vec{\nabla} \mp \vec{\partial}_{t\perp}) \times \vec{B} - \frac{1}{c_{\perp}}\vec{\tau}(\vec{\nabla} \mp \vec{\partial}_{t\perp})\vec{E}_{\mp} \tag{5}$$

when assuming that $\vec{\partial}_{t\perp} \times \vec{B} = \vec{0}$, i.e. to near an imaginary factor, the temporal gradient must be parallel to the magnetic like field. This assures that any field make the vacuum vibrating. Like in elasticity theory, this can then be divided in elementary cells having properties as it appears below. The 4-potentials describe then the field propagation in the vacuum from a cell to another. The figure-1 illustrates cell surfaces around a moving particle for a classical stationary field (spin 0) whose amplitude is expressed in cardinal sinus.

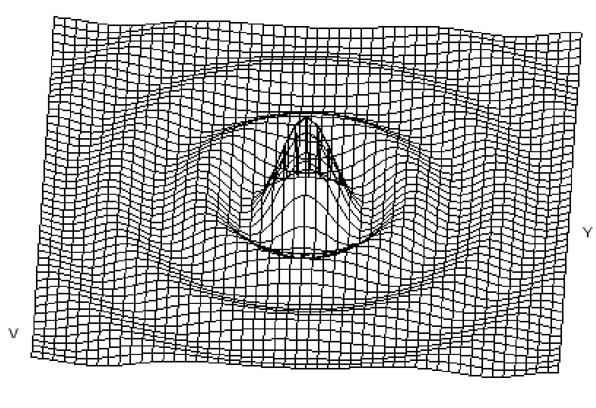

Figure-1: Example of stationary spherical wave amplitude showing the set motion of cells.

Gauge and field invariances: As we define the gauges and fields from wave equations, it is important to examine the consequences of such definitions by gauge changes. Each *VF* is invariant in the changes $\vec{A}_{\perp} \longmapsto \vec{A}_{\perp} + \vec{\nabla}f_{\perp}$; $V_{\perp} \longmapsto V_{\perp} \mp \partial_t f_{\perp}$. The corresponding gauges are respectively invariant if

$$\Box_{\perp} f_{\perp} = 0 \quad (6)$$

This is satisfied by the 4-potential $(\vec{\nabla} f_{\perp}, \mp i\, \partial_t f_{\perp}/c_{\perp})$ of a zero SF according to (4). Therefore, any VF is determined to near such a field, which has to be attributed to each *vacuum cell*. That equation admits quantum solutions for the waves having the same celerity $c_{\perp} = \omega_n/k_n \;\; \forall\, n \in N^*$ such as one can write

$$f_{\perp}(\vec{r}, t) = \sum_{n=1}^{\infty} f_n(\vec{r})\, e^{-i\omega_n t} \quad (7)$$

This yields the classical Schrödinger equation of a free particle

$$\Delta f_n + k_n^2 f_n = 0 \quad (8)$$

whose solution writes in respect to the radial and spherical functions R_l^n and Y_l^m such as

$$f_n(\vec{r}) = \sum_{l=0}^{\infty} \sum_{m=-l}^{m=+l} R_l^n(r) Y_l^m(\theta, \varphi) \quad (9)$$

Consequently, the energy of each vacuum cell is quantized.

As for the ***SFs***, each is invariant in the changes $\vec{A}_{\parallel} \longmapsto \vec{A}_{\parallel} + \partial_t \vec{f}_{\parallel}$; $V_{\parallel} \longmapsto V_{\parallel} \mp c_{\parallel}^2 \vec{\nabla} \vec{f}_{\parallel}$. The gauges also remain invariant if

$$\Box_{\parallel} \vec{f}_{\parallel} = -\vec{\nabla} \times (\vec{\nabla} \times \vec{f}_{\parallel}) \quad (10)$$

This is satisfied by the 4-potential $(\partial_t \vec{f}_{\parallel}, \mp i c_{\parallel} \vec{\nabla} \vec{f}_{\parallel})$ of a VF defined according to (4), with a zero electric like field and a magnetic like field

$$\vec{b} = \vec{\nabla} \times \partial_t \vec{f}_{\parallel} \quad (11)$$

This also must be attributed to the vacuum internal behaviour. The case $\vec{b} = \vec{0}$ corresponds simply to a single translation in the $\vec{A}_{\parallel}$ direction (that of the gradient). The evident change is a translation in the $\vec{A}_{\perp}$ direction as it appears with the preceding invariances. Thus, the role of local fields is inverted relatively to that of global: the VF invariance assumes a zero local SF while the SF invariance implies a non-zero VF. The section below shows that $\vec{b}$ is time independent.

Completing the cell internal fields: According to the Helmholtz theorem, any field vanishing to infinite can be expressed as a sum of two terms: the first is rotational and the second is a gradient. Thence, one can express the set of both scalar and VFs by the following Helmholtz displacement field, with reference to the displacement vector in elasticity

$$\vec{u} = \vec{\nabla} \times \vec{A}_{\perp} + \vec{\nabla} V_{\parallel}/c_{\parallel} \quad (12)$$

One notes that the previous change on $\vec{A}_{\perp}$ lets this invariant while that of $V_{\parallel}$ is so if $\vec{\nabla}(\vec{\nabla} \vec{f}_{\parallel}) = \vec{0}$. From (10), one gets $\partial_t^2 \vec{f}_{\parallel} = \vec{0}$, i.e. $\vec{f}_s$ is a time linear function. The local magnetic like field is then time independent.

By analogy with electromagnetism, the $\vec{u}$ first term represents the magnetic like field and the second, an electric like field interacting with the first in the motion direction. Then, one has to assume the existence of such a local field defined from the VF invariances. Then, the gauge and field invariances are defined to near both fields defined by

$$\begin{cases} \vec{e} = \mp \vec{\nabla} f_{\perp}(\vec{r}, t) \\ \vec{b} = \vec{\nabla} \times \vec{f}_{\parallel o}(\vec{r}) \end{cases} \quad (13)$$

About another kind of matter: dark matter: The gauge construction procedure we used previously with the space gradient can also be applied with the temporal gradient instead. One distinguishes both situations.

For the *SF*, one considers first the wave equation of a scalar potential and follows the below procedure: i. Take the temporal gradient of both equation members. ii. Integrate both members in respect to the scalar space ($\partial_r = \vec{r}.\vec{\nabla}/r$). iii. Assume that to near the velocity $c_{\parallel}$ and a sign, the new equation is identical to that of the vector potential. iv. Deduce the gauge relation. v. Then determine the corresponding SF expressions yielding the waves equations in combination with these relations.

One obtains at last the previous results exchanging $\vec{\nabla}$ with $\vec{\partial}_{t\alpha}$ and ∂_r with $i\, \partial_{t\alpha}$. The gauges, fields and wave equations are

$$\begin{cases} \vec{\partial}_{t\parallel} V_{\parallel} \mp i c_{\parallel} \partial_r \vec{A}_{\parallel} = \vec{0} \\ \Gamma_{\pm} = \pm \vec{\partial}_{t\parallel} \vec{A}_{\parallel} - \frac{i}{c_{\parallel}} \partial_r V_{\parallel} \\ \Box_{\parallel} |A_{\parallel}\rangle = -(\vec{\nabla} \pm \vec{\partial}_{t\parallel}) \Gamma_{\mp} \end{cases} \quad (14)$$

One notes that for real potentials, the SF is imaginary. This corresponds to an imaginary mass. Then the wave equation source can only be a particle of the corresponding matter, which generates fundamental bosons related to the parameter $a_{1\parallel} = i$.

For the *VF*, the same procedure applies from the vector potential wave equation. The corresponding gauges, fields and wave equations are

$$\begin{cases} \vec{\partial}_{t\perp} \vec{A}_{\perp} \mp \frac{i}{c_{\perp}} \partial_r V_{\perp} = 0 \\ \vec{E}_{\mp} = -\vec{\partial}_{t\perp} V_{\perp} \pm i c_{\perp} \partial_r \vec{A}_{\perp} \, ; \; \vec{B} = \vec{\partial}_{t\perp} \times \vec{A}_{\perp} \\ \Box_{\perp} |A_{\perp}\rangle = -(\vec{\partial}_{t\perp} \mp \vec{\nabla}) \times \vec{B} - \frac{1}{c_{\perp}} \vec{\tau} (\vec{\partial}_{t\perp} \mp \vec{\nabla}) \vec{E}_{\mp} \end{cases} \quad (15)$$

When assuming the relation $\vec{\nabla} \times \vec{B} = \vec{0}$, i.e. the corresponding imaginary magnetic-like field is parallel to the spatial gradient. The corresponding matter can also generate vector bosons of any kind ($a_{1\perp} = i$).

This is certainly *dark matter* related to fundamental dark fermions and bosons. In addition, both previous phenomena also exist for each gauge coupling.

Results and discussion

The four fundamental field general solutions: We showed that a free particle can generate in the vacuum four fields of long range as we already established before. These justify all wave nature of particles with any kind of field. However, they do not represent the required complete solutions. As one can note, they describe set motions in the vacuum, i.e. phonons. A complete solution must take into account the interface interactions between cells, which represent the vacuum cohesiveness. Thence, given that the local 4-potentials have an inverse behaviour than the global ones, it seems obvious that the permutation happens at interfaces between substructures. Then, both kinds of 4-potentias must be identical such as a unique 4-potential $|A\rangle = (\vec{A}, iV/c)$ satisfies both gauge relations. The different cases combination yields equations and expressions given in Table-2 where $\alpha_{\pm} = 1 \pm c_{\perp}^2/c_{\parallel}^2$ and $\bar{\Box}_{\perp} = \Delta + \partial_t^2/c_t^2$. The coupling signs are those appearing in the associated gauge relations beginning with the SF gauge. We also indicate the field identification (ID) got from the previous work.

Table-2: Field expressions at cell interfaces

Coupling	Equation	Γ	$\vec{E}$	$\vec{B}$	Field ID
(+,+)≡e	$\Box_{\perp}\lvert A\rangle_e = 0$	$\alpha_{-}\vec{\nabla}\vec{A}_e$	$\vec{0}$	$\vec{0}$	EM
(-,-)≡g	$\Box_{\perp}\lvert A\rangle_g = 0$	$-\alpha_{-}\vec{\nabla}\vec{A}_g$	$\vec{0}$	$\vec{0}$	Gravi.
(-,+)≡w	$\bar{\Box}_{\perp}\lvert A\rangle_w = 0$	$\alpha_{+}\vec{\nabla}\vec{A}_w$	$-2\vec{\nabla}V_w$	$\vec{0}$	Weak
(+,-)≡s	$\bar{\Box}_{\perp}\lvert A\rangle_s = 0$	$-\alpha_{+}\vec{\nabla}\vec{A}_s$	$-2\vec{\nabla}V_s$	$\vec{0}$	Strong

One notes that the magnetic like field is zero for each coupling. The electric like field is zero for both wave equations; these correspond then to electromagnetic and gravitational neutral fields. It is non-zero for both local fields defined by double identical charges. The SF is also non zero; otherwise for a particle travelling at the celerity of the light in the two first cases. As the given couplings remain valid everywhere, the 4-potential α general solution for each coupling β is given by the sum

$$|\mathrm{TPotential}_{\alpha}\rangle_{\beta} = |\mathrm{A}_{\alpha}\rangle_{\beta} + |\mathrm{A}\rangle_{\beta}\ ;\ \beta = \mathrm{e, g, w, s} \quad (16)$$

Outcome of fundamental particles; the unified field: The Table-3 here given proposes the set of fermions and bosons related to fundamental fields. The designations $sPhotons$ and $sGravitons$ are given in reference to the corresponding fermions of the Super Symmetry theory. The usual weak field illustrates boson compositions. For instance, the boson W^{-}appears in respect to the reversible process $W^{-} \rightleftarrows e^{-} + \bar{\nu}_e$. Due to space isotropy, we already showed that there are three fermions and antifermions defining each field, which contribute to compose three scalar and three vector bosons. This rule of three is valid in the usual strong field when considering only the lightest gluons (u, d, s) called natural. The known three others, called non-natural, would be justified otherwise as non-fundamental. Above all, the vacuum internal electric like field (13) plays the role of a fifth field. However, its status is special. It is the first of all structuring the vacuum like the electric field structures any material medium. One can call it *the unified field,* which lets others fields invariant and manifests itself in either ordinary or dark fields, according to the particle velocity as it is shown below. However the manifestation process is to find out, the quantization allows expecting its differentiation in others fields at different energy levels.

Table-3: Outcome of fundamental particles

Field	Coupling	Bosons	Fermions
EM	(+,+)	Photons	$sPhotons$
Gravi.	(-,-)	Gravitons	$sGravitons$
Weak	(-,+)	W^{+}, Z^{o}, W^{-}	Leptons
Strong	(+,-)	(light) Gluons	Quarks

The unified matter: In addition to this unified field, we also established the existence of a magnetic like field proving the charge motion in each vacuum cell. To our knowledge, such a finding is not yet known. However, if in crystals of solid state this is understandable through free electrons moving between ions in the metallic link, this is rather curious in the vacuum. One has to admit the existence of a malleable matter which behaves according to the acting field set. In our context, it must be the *unified matter* and would represent the so called virtual matter. As for the antifermions composing bosons, we did not find the related gauges. These are understandable as *vacuum holes* by analogy to semiconducting theory in solid state physics. This is in harmony with the initial Dirac interpretation of the positron.

The dark matter evidence: As the vacuum substance, the unified matter is different of the dark matter we considered belonging to imaginary mass domain. The evident illustration of its existence comes from the special relativity. A particle of initial mass m_o acquires an imaginary mass at velocity greater than that of the light according to the famous formula

$$m = m_o\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} \quad (17)$$

However, the value $v = c$ corresponds to an infinite mass. This discontinuity must be physically interpreted as corresponding to a new phenomenon occurrence. To justify this, let us take for granted the resulting velocity definition $(c_{\parallel} = c,\ c_{\perp})$ of the set of both scalar and vector fields. This also writes $\vec{\vartheta} = (\vartheta.cos\theta,\ \vartheta.sin\theta)$ i.e. $\vec{\vartheta} = (c,\ c.tg\theta)$. One can remark in particular the cases

$$c_\perp = \begin{cases} 0 \ \ if \ \theta = 0 \\ c \ \ if \ \theta = \pi/4 \\ \infty \ if \ \ \theta = \pi/2 \end{cases} \quad (17)$$

Considering a system emitting different kind of particles with the $c_\perp = c^2/v$ initial definition, we can then assume the free particle nature:
* For $v = c \Rightarrow c_\perp = c$, it is a massless particle emitted at $\theta = \pi/4$.
* For $v < c \Rightarrow c_\perp > c$, it is a matter particle emitted at $\theta > \pi/4$.
* For $v > c \ \Rightarrow c_\perp < c$, it is a dark matter emitted at $\theta < \pi/4$.

Therefore, the frontier between matter and dark-matter is radiation. Figure-2 illustrates the three situations. A velocity decrease of a dark particle can result in radiations as well as an increase of an ordinary particle velocity. Such events would happen at large scale near black holes for instance.

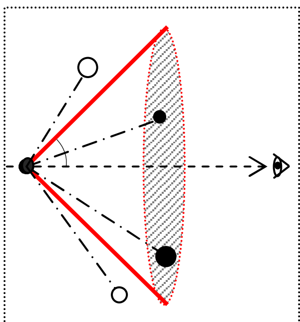

Figure-2: Emission domains of matter kind: The cone generatrix corresponds to radiation emissions; ordinary particles are emitted outside the cone; dark particles are emitted inside the cone.

Conclusion

As a complement of a preceding work, we showed the vacuum stability conditions and the generation of scalar and vector fields by a moving free particle. The stability is related to fundamental fermion generation while the instability implies wave bundles. One case relies on ordinary matter fermions and the second on fermions of another kind of matter we assumed to represent dark matter.

We studied then the gauge and field invariances due to the gauge construction procedure coming from wave equations. We found that the vacuum must be defined as a set of cells admitting internal fields: magnetic like static fields and electric like quantized fields. Applied the space-time symmetry on the previous gauge construction procedure, we determine the gauge and field expressions for dark particles. These have imaginary fields, therefore imaginary masses and charges.

We examined at last the results and found that: i. the four fields of long range justifying the wave nature of all particles are similar to sound fields in the vacuum. The combination of these with those at cell interfaces determines the general solutions of fundamental fields we indicated. ii. Photons and gravitons are then defined by phonons endowed with neutral particles while weak and strong bosons are defined with phonons. iii. The previous electric like field is suitable to define the unified field, which keeps the others invariant; this would differentiate into one or another field according to the energy level of a system to found out. iv. The frontier between matter and dark matter is radiation relatively to their particle velocities.

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