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Research Article

# Remark on Lehnert's Revised Quantum Electrodynamics (RQED) as an Alternative to Francesco Celani's et al. Maxwell–Clifford Equations: With an Outline of Chiral Cosmology Model and its Role to CMNS

Victor Christianto*

*Malang Institute of Agriculture (IPM), Malang, Indonesia*

Florentin Smarandache†

*Department of Mathematics and Sciences, University of New Mexico, Gallup, USA*

Yunita Umniyati‡

*Head of Physics Lab, Department of Mechatronics, Swiss-German University, BSD City, Indonesia*

**Abstract**

In a recent paper published in *JCMNS* in 2017, Francesco Celani, Di Tommaso and Vassalo argued that Maxwell equations rewritten in Clifford algebra are sufficient to describe the electron and also ultra-dense deuterium reaction process proposed by Homlid et al. Apparently, Celani et al. believed that their Maxwell–Clifford equations are an excellent candidate to surpass both Classical Electromagnetic and *Zitterbewegung* QM. Meanwhile, in a series of papers, Bo Lehnert proposed a novel and revised version of Quantum Electrodynamics (RQED) based on Proca equations. Therefore, in this paper, we gave an outline of Lehnert's RQED, as an alternative framework to Celani et al Zitterbewegung-Classical EM. Moreover, in a rather old paper, Mario Liu described hydrodynamic Maxwell equations. While he also discussed potential implications of these new approaches to superconductors, such a discussion of electrodynamics of superconductors is made only after Tajmar's paper. (continued in the next page)


*Keywords:* Chiral medium, Chiral gravitation theory, Electrodynamics of superconductor, Hirsch theory, Hydrodynamics Maxwell equations, LENR, London equations, Maxwell equations, Proca equations, Revised QED

*Corresponding author. http://researchgate.net/profile/Victor_Christianto, E-mail: victorchristianto@gmail.com.
†E-mail: florentin.smarandache@laposte.net.
‡E-mail: yunita.umniyati@sgu.ac.id.

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Therefore, in this paper we present for the first time a derivation of fluidic Maxwell–Proca equations. The name of *fluidic Maxwell–Proca* is proposed because the equations were based on modifying Maxwell–Proca and Hirsch's theory of electrodynamics of superconductors. It is hoped that this paper may stimulate further investigations and experiments in superconductors It may be expected to have some impact to cosmology modeling too, for instance we consider a hypothetical argument that the photon mass can be the origin of gravitation. Then, after combining with the so-called chiral modification of Maxwell equations (after Spröessig), we consider chiral Maxwell–Proca equations as a possible alternative of gravitation theory. Such a hypothesis has never considered in the literature to the best of our knowledge. In the last section, we discuss the plausible role of chiral Maxwell–Proca (RQED) in CMNS process. It is hoped that this paper may stimulate further investigations and experiments in particular for elucidating the physics of LENR and UDD reaction from classical electromagnetics.

## 1. Introduction

In a recent paper published in *JCMNS* in 2017, Francesco Celani, Di Tommaso and Vassalo argued that Maxwell equations rewritten in Clifford algebra are sufficient to describe the electron and also ultra-dense deuterium reaction process proposed by Homlid et al Apparently, Celani et al. believed that their Maxwell–Clifford equations are quite excellent candidate to surpass both Classical Electromagnetics theory and *Zitterbewegung* QM [1].

In the meantime, it is known that conventional electromagnetic theory based on Maxwell's equations and quantum mechanics has been successful in its applications in numerous problems in physics, and has sometimes manifested itself in a good agreement with experiments. Nevertheless, as already stated by Feynman, there are unsolved problems leading to difficulties with Maxwell's equations that are not removed by and not directly associated with quantum mechanics [17–20]. Therefore QED, which is an extension of Maxwell's equations, also becomes subject to the typical shortcomings of electromagnetic in its conventional form. This reasoning makes a way for Revised Quantum Electrodynamics as proposed by Bo Lehnert [17–19].

Meanwhile, according to J.E. Hirsch, from the outset of superconductivity research it was assumed that no electrostatic fields could exist inside superconductors and this assumption was incorporated into conventional London electrodynamics [23] Hirsch suggests that there are difficulties with the two London equations. To summarize, London's equations together with Maxwell's equations lead to unphysical predictions [22] Hirsch also proposes a new model for electrodynamics for superconductors [22–23].

In this regard, in a rather old paper, Mario Liu described a hydrodynamic Maxwell equations [25]. While he also discussed potential implications of these new approaches to superconductors, such a discussion of electrodynamics of superconductors is made only after Tajmar's paper. Therefore, in this paper we present for the first time a derivation of fluidic Maxwell–Proca–Hirsch equations. The name of Maxwell–Proca–Hirsch is proposed because the equations were based on modifying Maxwell–Proca and Hirsch's theory of electrodynamics of superconductor. Therefore, the aim of the present paper is to propose a version of fluidic Maxwell–Proca model for electrodynamics of superconductor, along with an outline of a chiral cosmology model.

This may be expected to have some impact to cosmology modeling too, which will be discussed in the last section. It is hoped that this paper may stimulate further investigations and experiments in particular for fractal superconductor.

## 2. Lehnert's Revised Quantum Electrodynamics

In a series of papers Bo Lehnert proposed a novel and revised version of Quantum Electrodynamics, which he refers to as RQED. His theory is based on the hypothesis of a nonzero electric charge density in the vacuum, and it is based on *Proca-type* field equations ([20], p. 23):

$$\left(\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \nabla^2\right) A_\mu = \mu_0 J_\mu, \qquad \mu = 1, 2, 3, 4, \tag{1}$$

where

$$A_\mu = \left(A, \frac{i\varphi}{c}\right) \tag{2}$$

with $A$ and $\phi$ standing for the magnetic vector potential and the electrostatic potential in three-space. In three dimensions, we got ([20], p. 23):

$$\frac{\operatorname{curl} B}{\mu_0} = \varepsilon_0 \left(\operatorname{div} E\right) C + \frac{\varepsilon_0 \partial E}{\partial t}, \tag{3}$$

$$\operatorname{curl} E = -\frac{\partial B}{\partial t}, \tag{4}$$

$$B = \operatorname{curl} A, \quad \operatorname{div} B = 0, \tag{5}$$

$$E = -\nabla\varphi - \frac{\partial A}{\partial t}, \tag{6}$$

$$\operatorname{div} E = \frac{\bar{\rho}}{\varepsilon_0}. \tag{7}$$

These equations differ from the conventional form with a nonzero electric field divergence equation (7) and by the additional space–charge current density in addition to displacement current at Eq. (3). The extended field equations (3)–(7) are easily found also to become invariant to a gauge transformation ([20], p. 23).

The main characteristic new features of the present theory can be summarized as follows ([20], p. 24):

(a) The hypothesis of a nonzero electric field divergence in the vacuum introduces an additional degree of freedom, leading to new physical phenomena. The associated nonzero electric charge density thereby acts somewhat like a hidden variable.
(b) This also abolishes the symmetry between the electric and magnetic fields, and then the field equations obtain the character of intrinsic linear symmetry breaking.
(c) The theory is both Lorentz and gauge invariant.
(d) The velocity of light is no longer a scalar quantity, but is represented by a velocity vector of the modulus c.
(e) Additional results: Lehnert is also able to derive the mass of Z boson and Higgs-like boson [21]. These would pave an alternative way to new physics beyond the Standard Model.

Now it should be clear that Lehnert's RQED is a good alternative theory to QM/QED, and therefore it is also interesting to ask whether this theory can also explain some phenomena related to LENR and UDD reaction proposed by Homlid (as argued by Celani et al.) [1].

It should be noted too that Proca equations can be considered as an extension of Maxwell equations, and they have been derived in various ways. It can be shown that Proca equations can be derived from first principles, and also that Proca equations may have a link with the Klein–Gordon equation [6,7].

One persistent question concerning these Proca equations is how to measure the mass of the photon. This question has been discussed in lengthy by Tu et al. [12]. According to their report, there are various methods to estimate the

**Table 1.** Upper bound on the dispersion of the speed of light in different ranges of the electromagnetic spectrum, and the corresponding limits on the photon mass ([12], p. 94).

| Author (year) | Type of measurement | Limits on $m_\gamma$ (g) |
|---|---|---|
| Ross et al. (1937) | Radio waves transmission overland | $5.9 \times 10^{-42}$ |
| Mandelstam and Papalexi (1944) | Radio waves transmission over sea | $5.0 \times 10^{-43}$ |
| Al'pert et al. (1941) | Radio waves transmission over sea | $2.5 \times 10^{-43}$ |
| Florman (1955) | Radio-wave interferometer | $5.7 \times 10^{-42}$ |
| Lovell et al. (1964) | Pulsar observations on flour flare stars | $1.6 \times 10^{-42}$ |
| Frome (1958) | Radio-wave interferometer | $4.3 \times 10^{-40}$ |
| Warner et al. (1969) | Observations on Crab Nebula pulsar | $5.2 \times 10^{-41}$ |
| Brown et al. (1973) | Short pulses radiation | $1.4 \times 10^{-33}$ |
| Bay et al. (1972) | Pulsar emission | $3.0\times 10^{-46}$ |
| Schaefer (1999) | Gamma ray bursts | $4.2 \times 10^{-44}$ |
| | Gamma ray bursts | $6.1 \times 10^{-39}$ |

upper bound limits of photon mass. In Table 1, some of upper bound limits of photon mass based on dispersion of speed of light are summarized.

From Table 1 and also from other results as reported in [12], it seems that we can expect that someday photon mass can be observed within experimental bounds.

## 3. Hirsch's Proposed Revision of London's Equations

According to J.E. Hirsch, from the outset of superconductivity research it was assumed that no electrostatic fields could exist inside superconductors and this assumption was incorporated into conventional London electrodynamics [22] Hirsch suggests that there are difficulties with the two London equations. Therefore he concludes that London's equations together with Maxwell's equations lead to *unphysical* predictions [1] However he still uses four-vectors $J$ and $A$ according to Maxwell's equations:

$$\Box^2 A = -\frac{4\pi}{c} J \tag{8}$$

and

$$J - J_0 = -\frac{c}{4\pi\lambda_{\mathrm{L}}^2}(A - A_0). \tag{9}$$

Therefore Hirsch proposes a new fundamental equation for electrodynamics for superconductors as follows [22]

$$\Box^2(A - A_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(A - A_0), \tag{10a}$$

where London penetration depth $\lambda_{\mathrm{L}}$ is defined as follows [23]:

$$\frac{1}{\lambda_{\mathrm{L}}^2} = \frac{4\pi n_{\mathrm{s}} e^2}{m_{\mathrm{e}} c^2}, \tag{10b}$$

also d'Alembertian operator is defined as [22]:

$$\Box^2 = \nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial_t^2}. \tag{10c}$$

Then he proposes the following equations [22] :

$$\Box^2(F - F_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(F - F_0) \tag{11}$$

and

$$\Box^2(J - J_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(J - J_0), \tag{12}$$

where $F$ is the usual electromagnetic field tensor and $F$ is the field tensor with entries $\vec{E}_0$ and 0 from $\vec{E}$ and $\vec{B}$, respectively, when expressed in the reference frame at rest with respect to the ions.

In the meantime, it is known that Proca equations can also be used to describe electrodynamics of superconductors, see [25–33]. The difference between Proca and Maxwell equations is that Maxwell equations and Lagrangian are based on the hypothesis that the photon has zero mass, but the Proca's Lagrangian is obtained by adding mass term to Maxwell's Lagrangian [33] Therefore, the Proca equation can be written as follows [33]:

$$\partial_\mu F^{\mu\nu} + m_\gamma^2 A_\nu = \frac{4\pi}{c} J^\nu, \tag{13a}$$

where $m_\gamma = \frac{\omega}{c}$ is the inverse of the Compton wavelength associated with photon mass [38]. (Note: 'omega' is the angular frequency $= 2\pi f$, where $f$ is the frequency, the definition of omega involves the "reduced" Compton wavelength, corresponding with the reduced Planck constant $\hbar$). It is also clear that in the particular case of $m = 0$, then that equation reduces to the Maxwell equation. In terms of the vector potentials, Eq. (13a) can be written as [33]:

$$(\Box + m_\gamma)A_\mu = \frac{4\pi}{c} J_\mu. \tag{13b}$$

Similarly, according to Kruglov [31] the Proca equation for a free particle processing the mass $m$ can be written as follows:

$$\partial_\nu \varphi_{\mu\nu}(x) + m^2 \varphi_\mu(x) = 0. \tag{14}$$

Now, the similarity between Eqs. (8) and (13b) are remarkable with the exception that Eq. (8) is in quadratic form. Therefore we propose to consider a modified form of Hirsch's model as follows:

$$(\Box^2 - m_\gamma^2)(F - F_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(F - F_0) \tag{15a}$$

and

$$(\Box^2 - m_\gamma^2)(J - J_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(J - J_0). \tag{15b}$$

The relevance of the proposed new equations in lieu of Eqs. (11)–(14) should be verified by experiments with superconductors [37]. For convenience, the Eqs. (15a)–(15b) can be given a name: *Maxwell–Proca–Hirsch equations.*

## 4. Fluidic Maxwell–Proca Equations

In this regard, in a rather old paper, Mario Liu described a hydrodynamic Maxwell equations [24] While he also discussed the potential implications of these new approaches to superconductors, such a discussion of electrodynamics of superconductors is made only after Tajmar's paper. Therefore, in this section we present for the first time a derivation of *fluidic* Maxwell–Proca–Hirsch equations.

According to Blackledge, Proca equations can be written as follows [7]:

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0} - \kappa^2 \phi, \tag{16}$$

$$\nabla \cdot \vec{B} = 0, \tag{17}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}, \tag{18}$$

$$\nabla \times \vec{B} = \mu_0 j + \varepsilon_0 \mu_0 \frac{\partial \vec{E}}{\partial t} + \kappa^2 \vec{A}, \tag{19}$$

where (without assuming Planck constant, $\hbar = 1$):

$$\nabla \phi = -\frac{\partial \vec{A}}{\partial t} - \vec{E}, \tag{20}$$

$$\vec{B} = \nabla \times \vec{A}, \tag{21}$$

$$\kappa = \frac{mc_0}{\hbar}. \tag{22}$$

Therefore, by using the definitions in Eqs. (16)–(19), and by comparing with hydrodynamic Maxwell equations of Liu ([24], Eq. (2)), now we can arrive at fluidic Maxwell–Proca equations, as follows:

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0} - \kappa^2 \phi, \tag{23}$$

$$\nabla \cdot \vec{B} = 0, \tag{24}$$

$$\dot{B} = -\nabla \times E - \nabla \times \left( \hat{\beta} \nabla \times H_0 \right), \tag{25}$$

$$\varepsilon_0 \mu_0 \dot{E} = \nabla \times B - \mu_0 j - \kappa^2 A - \left( \hat{\sigma} E_0 + \rho_e v + \hat{\gamma} \nabla T \right) - \nabla \times \left( \hat{a} \nabla \times E_0 \right), \tag{26}$$

where:

$$\nabla \phi = -\frac{\partial \vec{A}}{\partial t} - \vec{E}, \tag{27}$$

$$\vec{B} = \nabla \times \vec{A}, \tag{28}$$

$$\kappa = \frac{mc_0}{\hbar}. \tag{29}$$

Since according to Blackledge, the Proca equations can be viewed as a *unified wavefield* model of electromagnetic phenomena [7], therefore we can also regard the fluidic Maxwell–Proca equations as a *unified wavefield* model for electrodynamics of superconductor.

Now, having defined fluidic Maxwell–Proca equations, we are ready to write fluidic Maxwell–Proca equations using the same definition, as follows:

$$(\Box_\alpha^2 - \kappa^2)(F - F_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(F - F_0) \tag{30}$$

and

$$(\Box_\alpha^2 - \kappa^2)(J - J_0) = \frac{1}{\lambda_{\mathrm{L}}^2}(J - J_0), \tag{31}$$

where

$$\Box_\alpha^2 = \nabla^{\alpha 2} - \frac{1}{c^2}\frac{\partial^{\alpha 2}}{\partial_t^{\alpha 2}}. \tag{32}$$

As far as we know, the above fluidic Maxwell–Proca equations have never been presented elsewhere before. Provided the above equations can be verified with experiments, they can be used to describe electrodynamics of superconductors.

As a last note, it seems interesting to remark here that Kruglov [31] has derived a square-root of Proca equations as a possible model for hadron mass spectrum, therefore perhaps Eqs. (30)–(32) may be *factorized* too to find out a model for hadron masses. However, we leave this problem for future investigations.

## 5. Towards Chiral Cosmology Model

The Maxwell–Proca electrodynamics corresponding to a finite photon mass causes a substantial change of the Maxwell stress tensor and, under certain circumstances, may cause the electromagnetic stresses to act effectively as "*negative pressure*." In a recent paper, Ryutov, Budker, Flambaum [34] suggest that such a negative pressure imitates gravitational pull, and may produce an effect similar to gravitation. In the meantime, there are other papers by Longo, Shamir, etc. discussing observations indicating handedness of spiral galaxies, which seem to suggest chiral medium at large scale. However, so far there is no derivation of Maxwell–Proca equations in chiral medium

In a recent paper, Ryutov, Budker, Flambaum suggest that Maxwell–Proca equations may induce a negative pressure imitates gravitational pull, and may produce effect similar to gravitation [34]

In the meantime, there are other papers by Longo, Shamir et al. discussing observations indicating handedness of spiral galaxies, which seem to suggest chiral medium at large scale. As Shamir reported:

> "*A morphological feature of spiral galaxies that can be easily identified by the human eye is the handedness—some spiral galaxies spin clockwise, while other spiral galaxies rotate counterclockwise. Previous studies suggest large-scale asymmetry between the number of galaxies that rotate clockwise and the number of galaxies that rotate counterclockwise, and a large-scale correlation between the galaxy handedness and other characteristics can indicate an asymmetry at a cosmological scale*" [40].

However, so far there is no derivation of Maxwell–Proca equations in a chiral medium. Therefore, inspired by Ryutov et al paper, in this paper, we present for the first time a possibility to extend Maxwell–Proca-type equations to chiral medium, which may be able to explain origin of handedness of spiral galaxies as reported by Longo et al. [39,40].

The present paper is intended to be a follow-up paper of our preceding paper, reviewing Shpenkov's interpretation of classical wave equation and its role to explain periodic table of elements and other phenomena [38].

## 6. Maxwell–Proca Equations in Chiral Medium

Proca equations can be considered as an extension of Maxwell equations, and they have been derived in various ways. It can be shown that Proca equations can be derived from first principles [6], and also that Proca equations may have link with Klein–Gordon equation [7].

It should be noted that the relations between flux densities and the electric and magnetic fields depend on the material. It is well known, for instance, that all organic materials contain carbon and realize in this way some kind of optical activity. Therefore, Lord Kelvin introduced the notion of the chirality measure of a medium. This coefficient expresses the optical activity of the underlying material. The correspondent constitutive laws are the following [35]:

$$D = \varepsilon E + \varepsilon\beta\sqrt{E} \quad \text{(Drude–Born–Feodorov laws)}, \tag{33}$$

$$B = \mu H + \mu\beta\sqrt{H}, \tag{34}$$

where $e = E(t, x)$ is the electric permittivity, $j = p(t, x)$ is the magnetic permeability and the coefficient $\beta$ describes the *chirality measure* of the material [35].

Now, since we want to obtain Maxwell–Proca equations in chiral medium, then Eq. (28) should be replaced with Eq. (34). But such a hypothetical assertion should be investigated in more detailed.

Since according to Blackledge, the Proca equations can be viewed as a unified wavefield model of electromagnetic phenomena [7], then we can also regard the Maxwell–Proca equations in chiral medium as a further generalization of his *unified wavefield picture.*

## 7. Plausible Role of Chiral Superconductor Model to LENR/CMNS

According to R.M. Kiehn, chirality already arises in electromagnetic equations, i.e. Maxwell equations [41]:

> "*From a topological viewpoint, Maxwell's electrodynamics indicates that the concept of Chirality is to be associated with a third rank tensor density of Topological Spin induced by the interaction of the four vector potentials* $\{A, \varphi\}$ *and the field excitations (D,H). The distinct concept of Helicity is to be associated with the third rank tensor field of Topological Torsion induced by the interaction of the 4 vector potentials and field intensities (E,B) . . .*
>
> *In the electromagnetic situation, the constitutive map is often considered to be (within a factor) a linear mapping between two six dimensional vector spaces. As such the constitutive map can have both a right- or a left-handed representation, implying that there are two topologically equivalent states that are not smoothly equivalent about the identity".*

Therefore, here we will review some models of chirality in superconductors and other contexts, in hope that we may elucidate the chirality origin of spiraling wave as considered by Celani et al. for explaining UDD reaction (cf. Homlid).

Here, we summarize some reports on chirality as observed in experiments:

(a) F. Qin et al. reported "Superconductivity in a chiral nanotube" [42]. Their abstract goes as follows: "Chirality of materials are known to affect optical, magnetic and electric properties, causing a variety of nontrivial phenomena such as circular dichiroism for chiral molecules, magnetic Skyrmions in chiral magnets and nonreciprocal carrier transport in chiral conductors. On the other hand, effect of chirality on superconducting transport has not been known. Here we report the nonreciprocity of superconductivity—unambiguous evidence of superconductivity reflecting chiral structure in which the forward and backward supercurrent flows are not equivalent because of inversion symmetry breaking. Such superconductivity is realized via ionic gating in individual chiral nanotubes of tungsten disulfide. The nonreciprocal signal is significantly enhanced in the superconducting state, being associated with unprecedented quantum Little-Parks oscillations originating from the interference of supercurrent along the circumference of the nanotube. The present results indicate that the nonreciprocity is a viable approach toward the superconductors with chiral or noncentrosymmetric structures". In other words, chirality may play a significant role in electromagnetic character of superconductors.

(b) In other paper, Kung et al. reported: "Using polarization-resolved resonant Raman spectroscopy, we explore collective spin excitations of the chiral surface states in a three dimensional topological insulator, $Bi_2Se_3$. We observe a sharp peak at 150 meV in the pseudovector A2 symmetry channel of the Raman spectra. By comparing the data with calculations, we identify this peak as the transverse *collective spin mode* of surface Dirac fermions. This mode, unlike a Dirac plasmon or a surface plasmon in the charge sector of excitations, is analogous to a spin wave in a partially polarized Fermi liquid, with spin-orbit coupling playing the role of an effective magnetic field" [43]. What we would emphasize here is that the collective spin mode may alter the Dirac fermions, see also [44].

(c) Karimi et al. studied deviation from Larmor's theorem, their abstract begins as follows: "Larmor's theorem holds for magnetic systems that are invariant under spin rotation. In the presence of spin–orbit coupling this invariance is lost and Larmor's theorem is broken: for systems of interacting electrons, this gives rise to a subtle interplay between the spin-orbit coupling acting on individual single-particle states and *Coulomb many-body efects*" [45]. What we would emphasize here is possible observation of Coulomb many-body effects, and this seems to attract considerable interests recently, see also ([45], part a).

## 8. Concluding Remarks

In a series of papers, Bo Lehnert proposed a novel and revised version of Quantum Electrodynamics (RQED) based on Proca equations. We submit a viewpoint that Lehnert's RQED is a good alternative theory to QM/QED, and therefore it is also interesting to ask: Can this theory also explain some phenomena related to LENR and UDD reaction of Homlid (as argued by Celani et al)? While we do not pretend to hold all the answers in this regard, we just gave an outline to Proca equations to electrodynamics of superconductors, then to chirality model.

Nonetheless, one of our aims with the present paper is to propose a combined version of London–Proca–Hirsch model for electrodynamics of superconductor. Considering that Proca equations may be used to explain electrodynamics in superconductor, the proposed fluidic London–Proca equations may be able to describe electromagnetic of superconductors. It is hoped that this paper may stimulate further investigations and experiments in particular for superconductor. It may be expected to have some impact to cosmology modeling too.

Another purpose is to submit a new model of gravitation based on a recent paper by Ryutov, Budker, Flambaum, who suggest that Maxwell–Proca equations may induce a negative pressure imitates gravitational pull, and may produce effect similar to gravitation. In the meantime, there are other papers by Longo, Shamir etc. discussing observations indicating handedness of spiral galaxies, which seem to suggest chiral medium at large scale.

However, so far there is no derivation of Maxwell–Proca equations in chiral medium. In this paper, we propose Maxwell–Proca-type equations in chiral medium, which may also explain (albeit hypothetically) origin of handedness of spiral galaxies as reported by M. Longo et al.

It may be expected that one can describe handedness of spiral galaxies by chiral Maxwell–Proca equations. This would need more investigations, both theoretically and empirically

This paper is partly intended to stimulate further investigations and experiments of LENR inspired by classical electrodynamics, as a continuation with our previous report.

## 9. Postscript

It shall be noted that the present paper is not intended to be a complete description of physics of LENR and UDD reaction (Homlid et al.). Nonetheless, we can remark on three things:

(1) Although usually Proca equations are considered not gauge invariant, therefore some researchers tried to derive a gauge invariant massive version of Maxwell equations, a recent experiment suggest U(1) gauge invariance of Proca equations, see [46].
(2) Since Proca equations can be related to electromagnetic Klein–Gordon equation, and from Klein–Gordon equation one can derive hydrino states of hydrogen atom, then one can also expect to derive ultradense hydrogen and hydrino states from Proca equation. This brings us to a consistent picture of hydrogen, see also Mills et al. [47–50].
(3) Chirality effect of hydrino/UDD may be observed in experiments in the near future.

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## References

[1] F. Celani, A. Di Tommaso and G. Vassalo, The electron and occam's razor, *J. Condensed Matter Nucl. Sci*. **25** (2017) 1–24, url: www.iscmns.org.
[2] Niels Gresnigt. Relativistic physics in the Clifford algebra, Ph.D. Thesis, University of Canterbury. January 2009, 139p.
[3] John Denker. Electromagnetism using geometric algebra versus components. url: https://www.av8n.com/physics/maxwell-ga.htm.
[4] M. Tajmar, Electrodynamics in Superconductor explained by Proca equations, 2008, arXiv:cond-mat/0803.3080.
[5] Maknickas Algirdas, Spooky action at a distance, in *the Micropolar Electromagnetic Theory*, Dec. 5, 2014, http://vixra.org/pdf/1411.0549v4.pdf.
[6] Gondran Michel, Proca equations derived from first principles, 2009, arXiv:0901.3300 [quant-ph], URL: http://arxiv.org/pdf/0901.3300.pdf.
[7] Blackledge Jonathan M., An approach to unification using a linear systems model for the propagation of broad-band signals, *ISAST Transaction on Electronics and Signal Processing*, Vol. 1, No. 1, 2007, URL: http://eleceng.dit.ie/papers/100.pdf.
[8] Demir Suleyman, Space–time algebra for the generalization of gravitational field equations, *Pramana* (Indian Academy of Sciences) **80** (5) (2013) 811–823, URL: http://www.ias.ac.in/pramana/v80/p811/fulltext.pdf.
[9] Schwinger Julian, DeRaad Jr., Lester L., Milton Kimball A. and Tsai Wu-yang, *Classical Electrodynamics*, Perseus Books. Reading, Massachusetts, 1998, 591 p.
[10] Penrose Roger, *The Road to Reality: A Complete Guide to the Laws of the Universe*, Jonathan Cape, London, 2004, 1123 p. URL: http://staff.washington.edu/freitz/penrose.pdf.
[11] Christianto Victor, London–Proca–Hirsch equations for electrodynamics of superconductors on Cantor Sets, *Prespacetime Journal*, November 2015, http://www.prespacetime.com.
[12] L.-C. Tu, J. Luo and T. George Gillies, The mass of the photon, *Rep. Prog. Phys*. **68** (2005)77–130, doi:10.1088/0034-4885/68/1/R02.
[13] Dmitriyev Valery P., *Elasticity and Electromagnetism,* 2004, URL: http://aether.narod.ru/elast1.pdf .
[14] Zareski David, Is dark matter a particular state of the ether?, *Intr. Res. J. Pure and Appl. Phys.* **3**(3) (2015) 1–7.
[15] Zareski David, *Unification of Physics by the Ether Elasticity Theory*, LAP Lambert Academic, Saarbrucken, Germany, 2015.

[16] Zareski David, Unification of physics theories by the ether elasticity theory, *Global J. Sci. Frontier Res., A Physics and Space Science* **14** (6) (2014).
[17] Bo. Lehnert, A way to revised quantum electrodynamics, *Prog.Phys.* **2** (2012), http://www.ptep-online.com.
[18] Bo. Lehnert, Higgs-Like particle due to revised quantum electrodynamics, *Prog. Phys.* **3** (2013), http://www.ptep-online.com.
[19] Bo. Lehnert, Potentialities of revised quantum electrodynamics. *Prog. Phys.* **4** (2013), http://www.ptep-online.com.
[20] Bo. Lehnert, Mass—radius relations of Z and Higgs-like bosons, *Prog. Phys.* **10** (1) (2014), http://www.ptep-online.com.
[21] Lopez, Adrian E. Rubio and Fernando C. Lombardo, Quantum Electrodynamics of inhomogeneous anisotropic media, EPJ 2015, also in arxiv:1411.7758 [hep-th].
[22] J.E. Hirsch, Electrodynamics of superconductors, 2003, arXiv:cond-mat/0312619 [cond-mat.str-el.].
[23] J.E. Hirsch, Correcting 100 years of misunderstanding: electric fields in superconductors, hole superconductivity, and the Meissner effect, 2012, arXiv: 1202.1851 [cond-mat.supr-con].
[24] Mario Liu, Hydrodynamics theory of electromagnetic fields in continuous media, *Phys. Rev. Lett*. **70** (23) (1993).
[25] C.J. de Matos and M. Tajmar, Gravitomagnetic London moment and the graviton mass inside a superconductor, 2006, arXiv:gr-qc/0602591.
[26] Victor Christianto, Florentin Smarandache and Yunita Umniyati, A derivation of Maxwell–Proca equations in chiral medium, and implications to galaxy handedness, *Prespacetime J*, 2018, Submitted.
[27] Victor Christianto, A Review of Schrödinger equation and classical wave equation, *Prespacetime J.*, May 2014. URL: www.prespacetime.com. Also available at: http://vixra.org/abs/1404.0020.
[28] Victor Christianto, A derivation of GravitoelectroMagnetic Proca equations in fractional space, *Prespacetime J.*, May 2014, URL: www.prespacetime.com.
[29] Victor Christianto, An outline of cosmology based on interpretation of the Johannine prologue, *Bull. Soc. Math. Services and Standards* (BSMASS), Sept. 2014, URL: www.scipress.com.
[30] Victor Christianto and Biruduganti Rahul, A derivation of Proca equations on cantor sets: a local fractional approach, *Bull. Math. Sci. Appl.* (BMSA), Nov. 2014, URL: www.bmsa.us.
[31] S.I. Kruglov, "Square root" of the Proca equation: Spin-3/2 field equation, 2004, arXiv:hep-th/0405088.
[32] M. Dressel, Electrodynamics of Metallic Superconductors, *Adv. Cond. Matt. Phys*, 2013, Article ID 104379, http://dx.doi.org/10.1155/2013/104379.
[33] Nuray Candemir, Murat Tanish, Kudret Ozdas and Suleyman Demir, Hyperbolic Octonionic Proca–Maxwell equations, *Z. Naturforsch* **63a** (2008) 15–18, URL: http://www.znaturforsch.com/s63a/s63a0015.pdf.
[34] D.D. Ryutov, D. Budker and V.V. Flambaum, A hypothetical effect of the Maxwell–Proca electromagnetic stresses on galaxy rotation curves, arXiv: 1708.09514 (2017).
[35] W. Sproessig and E. Venturino, An alternative approach for solving Maxwell equations, Part ofAlgorithms For Approximation IV, *Proc. Int. Symposium*, 2001.
[36] Carlos V. Gonzalez et al., An enhanced vector diagram of Maxwell's equations for chiral media, *Rev.Fac. Ing. Univ. Antioquia*, No. 62, Marzo, 2012, pp. 137–144.
[37] Sergey M. Grudsky et al., On a quaternionic Maxwell equation for the time-dependent electromagnetic ?eld in a chiral medium, arXiv: math-ph/0309062 (2003).
[38] Leonid G. Kreidik and George P. Shpenkov, Important results of analyzing foundations of quantum mechanics, *Galilean Electrodynamics and QED-EAST* **13** (2) (2002) 23–30, URL: http://shpenkov.janmax.com/QM-Analysis.pdf.
[39] J. Longo Michael, Detection of a dipole in the handedness of spiral galaxies with redshifts $z$ ~0.04, *Phys. Lett.* B **699** (2011).
[40] Shamir. Color Lior, Differences between clockwise and counterclockwise spiral galaxies, *Galaxies* **1** (2013) 210–215, doi:10.3390/galaxies1030210; also (a) Lior Shamir, Large-scale photometric asymmetry in galaxy spin patterns, *Publications of the Astronomical Society of Australia* (PASA), doi: 10.1017/pas.2018.xxx. arXiv: 1703.07889.
[41] R.M. Kiehn, Chirality and helicity in terms of topological spin and topological torsion, Arxiv: physics/0101101v1 (2001).
[42] F. Qin et al., Superconductivity in chiral nanotube, *Nature communication*, Feb 2017, DOI: 10.1038/ncomms14465.
[43] H.-H. Kung et al., Chiral spin mode on the surface of a topological insulator, *Phys. Rev. Lett*. **119** (2017) 136802.
[44] Irene d'Amico et al., Chirality and intrinsic dissipation of spin modes in two-dimensional electron liquids, Arxiv: 1808.15266 (2018).

[45] Shahrzad Karimi et al., Spin precession and spin waves in a chiral electron gas: beyond Larmor's theorem, Arxiv: 1612.04314 also (a) Karimi, Shahrzad, Ullrich, Carsten A., D'Amico, Irene, orcid.org/0000-0002-4794-1348 et al. (2018), Spin-helix Larmor mode, *Scientific Reports.* 3470, ISSN 2045-232.

[46] Liang-Cheng Tu, Test of U(1) local gauge invariance of Proca electrodynamics, *Phys. Lett.* A **352** (2006).

[47] L. Mills Randell, The hydrogen atom revisited, *I.J. Hydrogen Energy* **25** (2000) 1171–1183.

[48] Norman Dombey, The hydrino and other unlikely states, *Phys. Lett. A* **360** (2006) 62–65.

[49] Jan Naudts, On the hydrino state of the relativistic hydrogen atom, Arxiv: physics/0507193.

[50] Antonino Oscar Di Tommaso and Giorgio Vassallo, Electron Structure, Ultra-dense Hydrogen and Low Energy Nuclear Reactions, arXiv: 1809.0575 (2018.