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A Realistic Interpretation of Quantum Wavefunctions as Temperature Dependent Vacuum Polarization Waves

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Abstract

We discuss in this paper a novel interpretation of Born rule as an approximated thermodynamic law which emerges from the interaction of a quantum system with a non-stationary thermal bath associated to vacuum fluctuations induced by external environment radiation. In particular we assume that vacuum polarization is a real non relativistic phenomena caused by hidden vacuum charge oscillations which diffuses heat energy in a dispersive and dissipative dielectric medium with a temperature dependent speed of propagation. We propose a model which couples vacuum wavefunctions to vacuum charge fluctuations and we deduce a temperature dependent running fine structure constant function proportional, at first approximation, to the squared of the effective electron charge and compatible with known experimental data. We interpret the vacuum symmetry breaking energy fluctuations induced in scattering experiments of particle physics and in laser assisted nuclear reactions as thermal quasi-monochromatic beams produced by the decay of hidden non equilibrium massive photons propagating with a variable light speed. We suggest, exploiting an old analogy between plasmons and pseudo Goldstone bosons, to interpret heat diffusion of this non relativistic polarized vacuum as a real De Broglie electromagnetic scalar wave associated to the radiation emitted by the hidden massive photons with acceleration proportional to vacuum Unruh like temperature. We predict a temperature dependent deviation from Coulomb law and a generalized dispersive law of these hidden unstable photons that could be revealed as not stationary coloured noise in experiments on anomalous heat diffusions associated to the decay of unstable accelerated pairs produced in nuclear physics experiments. We discuss then how our proposal of a temperature dependent non relativistic vacuum polarization might be applied to deduce a dynamic generalization of Born rule based on a realistic interpretation of quantum wavefunctions as averaged electromagnetic waves of hidden massive photons. Finally we suggest to test our time asymmetric model looking for very fast oscillating polarization thermal waves emitted during the not instantaneous wavefunction collapse and revealed as not stationary bulk heating effects in experiments on accelerated conductors and nanoconductors.

Keywords

Non Relativistic Vacuum Pilot Wave, Hidden Temperature Dependent Vacuum Index, Hidden Unstable Massive Photons, Space Time Dependent Vacuum Temperature Oscillations, Temperature Dependent Running Fine Structure Constant, Vacuum Temperature Induced Wave Collapse, Generalized Born Rule

1. Introduction

In this work we will discuss our novel thermodynamic approach to the statistics of quantum physics suggesting that its apparent chaos is caused by hidden vacuum charge density oscillations associated to electromagnetic longitudinal scalar pilot waves conceiving interacting charged particles as open unstable systems. Our proposal will interpret quantum statistics as a consequence of non relativistic vacuum energy fluctuations associated to a hidden space time dependent vacuum temperature $T(x,t)$ induced by every measurement process and environment background interaction; in particular we will explore the possibility that quantum wavefunctions might be associated by the Born rule to hidden electromagnetic radiation emission and absorption of hidden massive unstable photons (a topic which attracted a lot of attention [1] [2] [3]), which might be revealed as a non relativistic De Broglie vacuum polarization wave which pilots the dynamic and cinematic of chaotic atomic and nuclear phenomena. This realistic approach to quantum fluctuations will be developed exploiting some analogies between vacuum electric impedance, vacuum electric conductivity and vacuum heat which will implement a novel temperature dependent model of quantum electrodynamics not encompassed by perturbative finite temperature quantum fields theories so far conceived.

On the contrary our idea of thermodynamic origin of vacuum electromagnetic instabilities and its correlation with Born rule, even if might be correlated to the recent experimental and theoretical search of relic nonequilibrium massive photons [4] has, as far as we know, just some analogies with a recent interesting proposal [5].

This model is based on a stochastic reformulation of Quantum Mechanics and therefore shares with our the insight that quantum physics has its foundations in hidden electromagnetic processes; anyway, differently from it, we propose a deterministic time asymmetric and non relativistic model based on a temperature dependent generalization of De Broglie matter wave hypothesis [6], reinterpreted as a Klein-Gordon like longitudinal vacuum wave of hidden unstable Proca-Stückelberg massive photons [7]. Our main goals are to illustrate by our tentative classical model a frame to describe the irreversible nature of quantum measurement and a way to overcome the paradoxical wave particle dualism. We wish that this approach might explain by the hidden unstable electromagnetic vacuum the emergence of the statistical Born rule underpinning the irreducible indeterminism conventionally associated to quantum physics. In particular our proposal assumes a possible thermodynamic origin of the vacuum energy fluctuations and conceives that they can be interpreted as a kind of spontaneous absorption processes of accelerated charged particles interacting with a hidden cloud of longitudinal massive photons.

We will then exploit this vacuum thermal pilot wave to suggest an explanation of the irreversible wavefunction collapse, which it is assumed as a postulate in every standard theory of quantum measurement processes (even in scattering processes in accelerator experiments).

This last issue motivated in the twenties of the past century the great controversy between Einstein, who believed on the possibility to complete Quantum Mechanics with a deterministic model extending classical mechanics and Bohr, the father of the Copenhagen interpretation of Quantum Mechanics, who denied the existence of such realistic space time descriptions of microscopic particle dynamics and was convinced that single quantum events were intrinsically unpredictable. This great scientific controversy stimulated Einstein opinion that quantum theory was incomplete and made paradoxical predictions, as spooky actions at distance, which were described in the very influential paper [8], called E.P.R. model, and influenced the Schrodinger discovery of quantum entanglement [9]; unfortunately, we think, all the efforts and critiques to the standard approach did not consider the possible electromagnetic nature of the apparent chaotic quantum phenomena associated to charged accelerated and extended particles (as in decays phenomena of nuclear physics) and the need to complete Maxwell theory extending its Lorentz symmetry and gauge invariance symmetry (even De Broglie pioneer's works on wave mechanics assumed for accelerated interacting particles Lorentz invariance symmetry).

This debate between the fathers of Quantum Mechanics inspired then Bell to discover his Theorem [10], whose famous inequality paved the way to the subsequent Aspect's experiment [11] aimed to test the validity of the Copenhagen interpretation against the Einstein realistic approach (called by Bell "hidden variable models"). Even if recently there has been a revival of interest and papers against Bell Theorem and its loopholes [12] [13] [14] [15] [16], till now, the majority of physics believes that E.P.R. like experiments confirmed the Copenhagen interpretation, since the Bell ideal inequality was considered to be violated in laboratory experiments (we note that his theorem was deduced assuming constant light speed).

We think, on the contrary, that since the first struggle between the Bohr and his opponents it has been underestimated the role of light speed fluctuations and the associated environment induced electromagnetic vacuum energy fluctuations on the emergence of quantum statistics (which in the standard approach is explained by a cumbersome theory of the measurement process [17]).

In fact since the first papers of Planck on the non relativistic blackbody law and the specific heat of solid bodies [18] it appeared the new concept of vacuum zero point energy, and was applied few years later by Einstein to explain the theory of quantum jump transitions between Bohr stationary energy states, discovering the new phenomenon of atomic spectra instabilities caused by spontaneous emission; unfortunately was not explored the similar idea of spontaneous absorption process, since was not considered at that time possible the active role of vacuum and its pilot wave on the chaotic dynamic of quantum particles (although the idea of an active vacuum motivated twenty years later Bethe successful calculus of Lamb shift based on non relativistic radiative corrections to Hydrogen energies).

Curiously, when was developed the standard formalism of Quantum Mechanics (Q.M.) about ten years later, was rejected by the followers of the standard approach the possibility of a space time descriptions of quantum events because considered to be incompatible with Heisenberg relations; therefore the presumed impossibility to describe with a deterministic model the dynamics of quantum particles stimulated Born to introduce its probabilistic interpretation of Schrodinger quantum wavefunctions, abandoning the realistic approach proposed previously by De Broglie wave particle hypothesis. As far as we know, none of the great opponents of the Copenhagen interpretation, looked for an alternative electromagnetic formulation of Q.M. based on a classical non relativistic theory and on out of equilibrium thermodynamic approach to stochastic single events of interacting atoms or nuclei (which were described, anyway, in high energy physics and nuclear physics as stationary Markovian processes). In fact, we think, a deterministic theory of vacuum energy fluctuations could have explained the dynamics of atomic transitions, questioning the hypothesis of instantaneous specific single atom quantum jumps, although were already known experimentally the non relativistic lifetimes of excited atomic states.

Consequently alternative deterministic interpretations of quantum fluctuations were not considered by the opponents of the Copenhagen interpretation, abandoning the possibility to conceive Bohr stationary quantized spectra as ensemble averages of hidden time dependent atomic energies (whose electromagnetic oscillations induced the apparent stochastic quantum jumps). This approach made physicists think that every click in a detector of a particle or photons was an intrinsic chaotic event and detector count rates were unpredictable. On the contrary we think that, for example, that detector efficiency may fluctuate due to energy threshold fluctuations caused by hidden temperature dependent vacuum energy oscillations (induced by the measurement process or by environment radiations), making superfluous the controversial wavefunction collapse postulate. We note that this is still an important open problem of Quantum Mechanics that it is not cleared up by E.P.R. tests and is the motivation which inspired recent experiments on Continuous Spontaneous Localization models (C.S.L. models) [19].

This statistical paradigm, we think, made overestimate the role and the importance of entanglement of individual quantum pairs for identifying intrinsic properties of quantum systems (as recently suggested by experiments revealing the spin of classical acoustic waves [20]), abandoning the search of Born rule deviations from the Copenhagen interpretation of Q.M. (for example, we will discuss, the possible hidden time dependence of atomic energy shift), which could have been explained by electromagnetic dynamical deterministic models. We think that modern experiments on nuclear physics with lasers urge for new approaches which should investigate the nature and the origin of quantum diffusion processes as caused by temperature dependent Brownian processes of pair productions, in analogy with the pioneer work of Nelson [21] on stochastic reformulation of Q.M. and Boyer on stochastic electrodynamics [22] (although these authors didn't consider the possible role on quantum fluctuations of a temperature dependent vacuum dielectric constant and disregard vacuum friction forces) [23].

In our opinion, in fact, there are phenomena in atomic and nuclear physics which, as for example laser assisted Schwinger effect and laser assisted nuclear pair production [24], or temperature dependent nuclear quantum tunnelling, that show the inadequacy of the standard approach for describing single quantum events and makes necessary to investigate the conceptual foundations of quantum mechanics and electrodynamics (we remind that till now is missing a well-established non relativistic theory of classical electrodynamics and thermodynamics of radiation emissions of accelerated charged particles). More in particular we propose a deterministic frame to deduce a generalization of Born rule based on the introduction of a vacuum temperature function $T(x,t)$, the local hidden variable, assuming that the statistics of Quantum Mechanics is of thermodynamic origin and emerge from measurement and environment induced vacuum charge oscillations.

We will show in the heuristic model exposed in the following paragraph that the polarized vacuum diffuses non relativistic thermoelectric waves due to the decays of unstable hidden massive photons which we identify as De Broglie matter waves propagating in a real dissipative unstable medium; therefore we will base our approach to these vacuum decays processes nor on Lagrangian formalism (since it is impossible to use the least action principle for unstable quantum states) neither on relativistic quantum fields at finite temperature, since the radiation fields depend on the local variable given by vacuum temperature $T(x,t)$.

On the contrary we choose to introduce some naïve relations exploiting analogies between the thermodynamics of heat conduction, the Joule law, the

Ohm's first law, and that one of vacuum electric charge density diffusion (assuming a generalized Wiederman-Franz law), conceiving the polarized vacuum as a not relativistic excited plasma of accelerated photons and unstable electron-positron pairs; in fact it is well known in plasma physics that a complex dielectric constant $\epsilon(x,t)$, is associated to the heat dissipated Q by the electric field in the medium (constituted by accelerated electrons and ions) and that it is proportional to its squared average and to the frequency of the electromagnetic wave (a proportionality, the last one, similar to that one introduced by Einstein to explain the photoelectric effect).

We note, over more, that the classical Maxwell theory assumed electromagnetic waves propagate in a conductive ether and, notwithstanding the Michelson-Morley experiment, against its existence remains the problem to explain why the vacuum had an electric vacuum impedance different from zero given by the following experimentally confirmed value

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \frac{|\vec{E}|}{|\vec{H}|} \cong 376,730\ \Omega \tag{1}$$

We can go on with this speculative analogy of the vacuum as real dissipative dielectric medium assuming that classical electromagnetic waves have longitudinal massive modes associated to gauge breaking vacuum charge oscillations, as recently proposed [25]; these induced energy fluctuations that depends on a vacuum temperature function T, which diffuses heat of the electromagnetic vacuum field with a power energy p that is proportional to the squared of the electric field, given by an analogue of Joule law

$$p = Z_0^2 I_{vacuum} = Z_0^2 \frac{\mathrm{d}q(T)}{\mathrm{d}t}, \tag{2}$$

with $q(T)$ the oscillating effective charge of the polarized vacuum. The integral in a finite time interval of this vacuum power allows to define, by an analogue of Ohm's first law, the quasi-thermal energy dissipated by the polarized vacuum, equivalent to the radiation loss of an accelerated charge particle interacting with it

$$\Delta Q(T) = Z_0(T)\Delta I_{vacuum} = Z_0^2 \Delta q(T) = Z_0^2 \left(\frac{\mathrm{d}q}{\mathrm{d}T}\right)(\Delta T) = C_{vacuum}\Delta T, \tag{3}$$

where we introduce space time dependent non relativistic vacuum charge oscillations analogue to electron self charge renormalization of Quantum Electro Dynamics (Q.E.D.)

$$\Delta q(T) = e - q(T), \tag{4}$$

and the vacuum heat capacity given by

$$C_{vacuum} = \frac{\mathrm{d}(\Delta Q(T))}{\mathrm{d}T} = Z_0^2 \left(\frac{\mathrm{d}q}{\mathrm{d}T}\right), \tag{5}$$

which for little temperature variation is proportional to the vacuum charge variation.

We implement thermal stability of the dynamic vacuum by the condition that C_{vacuum} is zero and this implies, from (5), that we could deduce the values of stable electric charge as solutions of the equation

$$\frac{\mathrm{d}q}{\mathrm{d}T} = 0. \tag{6}$$

This condition can be written more generally when the vacuum impedance depends on the vacuum temperature function T

$$\frac{\delta(Zq)}{\delta T} = 0, \tag{7}$$

or when T is a known function, can be implemented by

$$\frac{\mathrm{d}p(T)}{\mathrm{d}T} = \frac{\mathrm{d}\big(Z(T)q(t)\big)}{\mathrm{d}T} = 0. \tag{8}$$

These electric charge oscillations, as previously explained, propagate electro-thermal energy density fluctuations that we will exploit to deduce our temperature dependent generalization of Born rule, conceiving particle detection probabilities as averages of out of equilibrium electric vacuum pressures (in analogy with Faraday hydrodynamic surface waves associated to walking droplets dynamics).

We note that this non relativistic thermodynamic approach to vacuum fluctuations implies that quantum particle when accelerated by external radiation have hidden time dependent charge and mass oscillations (which could be detected experimentally as not stationary coloured electromagnetic noise). Our proposal is therefore in contrast to the standard relativistic and gauge invariant approach of quantum electrodynamics which assumes implicitly charge invariance for accelerated particles. In fact vacuum polarization is explained in Q.E.D. as a stationary asymptotic stochastic process of particle charge screening caused by the chaotic creations of virtual pairs making unrealistic, we think, the underpinning assumption of vacuum stability, necessary to define asymptotic free states in scattering processes of high energy physics (described by transition amplitudes of the unitary S matrix, that is on the assumed extended validity of Born rule on asymptotic free Fock states).

On the contrary, we conceive every charged particle as an open system interacting with environment induced vacuum fluctuations whose polarization wave is a pilot wave that modifies vacuum electric impedance making it dependent on the Planck constant $\hbar$ and the fine structure constant α

$$Z_0 = 2\frac{\alpha h}{e^2}, \tag{9}$$

with e the electron charge and α given, as usual, by

$$\alpha = \frac{e^2}{4\pi c\hbar\varepsilon_0} \sim \frac{1}{137}, \tag{10}$$

and making, more generally, the squared of $\Delta q(T)$ proportional to the temperature dependent $\alpha(T)$.

The Equation (9) suggests a possible role of Planck constant on the emergence of classical Maxwell vacuum, and justifies, we think, some recent papers investigating whether relativistic quantum vacuum might explain the origin of light speed and classical optics [26] [27].

We assume in our model that environment assisted temperature dependent non relativistic radiative corrections (self mass and electron charge oscillations) induces the apparent chaotic and irreversible wavefunction collapses; therefore vacuum heat diffusion is not directly associated to standard transfer of kinetic energy to stable matter particles but to this vacuum charge propagation due to the polarized vacuum non conserved currents $\vec{J}$ which induce, we predict, a temperature dependent Coulomb's law deviation [2] [3]

$$\Delta V(T) \propto \frac{1}{r^{1+\frac{\Delta q(T)}{e}}} \propto \vec{J} \cdot \vec{A} \tag{11}$$

with $\vec{A}$ the vector electromagnetic potential which implements temperature dependent radiative corrections to atomic energy shifts (as those investigated in plasma physics).

In fact differently from relativistic perturbative Q.E.D. approach the running fine structure constant is, as recently proposed [28] space time dependent and doesn't depend on the asymptotic free particle impulses but on the gauge breaking hidden variable $T(x,t)$ which implements a time asymmetric process of vacuum fluctuations with finite time vacuum entropy variation, that using (3), is given by

$$\Delta S(T) = -\frac{\Delta Q(T)}{T} \propto -Z^2 \frac{\Delta q(T)}{T} \tag{12}$$

where the minus sign stands for the heat transfer to the particle and whose minima can be associated to the stable energy fluctuations of the degenerate vacuum ground states described by asymptotic Fock states.

This vacuum entropy allows to define a generalized Born rule dependent on alpha fine structure constant $\alpha(T)$, from (10)

$$p_{Born}(T) \propto \mathrm{e}^{\frac{-C_{vacuum}\Delta q(T)}{kT}} \propto \mathrm{e}^{-\frac{C_{vacuum}e^2\alpha(T)^2}{kT}} \tag{13}$$

whose explicit dependence of α on the function T will be found in the next paragraph and will allow for quasi monochromatic thermal waves to rewrite (13) as

$$p_{Born}(T) \propto \varphi^2(T) \tag{14}$$

where $\varphi(T)$ is the gauge breaking vacuum electric scalar field (that we identify with the thermal vacuum wave) that we will associate in the following paragraph to hidden unstable massive photons [1].

Therefore we conceive the dynamic vacuum as a real dissipative dielectric medium, as originally proposed by Weisskopf and Pauli in 1934 [29] with a gauge breaking vacuum electric density currents J, whose divergence is proportional to the time derivative of the Born probability.

We assume that the electric density oscillations defined in (8) propagates with variable light speed velocity and we will interpret them as De Broglie matter waves similar to classical pressure waves, in analogy with an approach suggested in a recent paper [30]. We note that the De Broglie hypothesis and the associated wave-particle dualism was the main motivation which inspired Schrodinger to discover his celebrated equation, which being a diffusive one typical of thermal processes, could not implement De Broglie wave hypothesis interpreting electron wavefunctions as real electromagnetic fields (unless one might be interested on an irreversible generalization of Faraday law) satisfying D'Alembert wave equation; our aim in this work is to implement this classical electromagnetic fields approach to quantum wavefunctions, trying to overcome this paradoxical wave-corpuscular dualism assuming that the statistics of quantum phenomena is due to hidden vacuum charge density oscillations (which implies that the divergence of the vacuum electric field is not zero).

In fact this contradiction of Quantum Mechanics, making it an incomplete theory for Einstein, Schrodinger and De Broglie, was not accepted neither by Bohm [31], since he believed in real spatiotemporal description of quantum particles and elaborated an alternative mechanics theory, called then Bohm-De Broglie theory; his non dissipative and non relativistic pointlike model of quantum particles showed that the famous Von Neumann "No go theorem" had a counterexample and therefore was fallacious and stimulated, few years later, Bell research on local hidden variables and the foundations of quantum mechanics. Our proposal is similar to a recent proposal called vacuum texture theory [32], since it implements a new realistic interpretation of quantum wavefunctions (interpreting them as real De Broglie thermal waves), but differently from it assumes time dependent temperature fluctuations as those experimentally observed in laser physics [33]; we will suppose that they induce time dependent energy shifts in accelerated quantum particles that might be revealed in experiments as thermal noise and might be useful to justify the Born rule by our generalization of De Broglie-Bohm Quantum theory (as recently suggested in [34]).

2. Theoretical Model

The non relativistic model that we are going to illustrate, as already explained in the previous paragraph, conceives quantum wavefunctions as temperature dependent averages of thermal waves associated to unstable non relativistic vacuum energy fluctuations which satisfies time asymmetric Klein-Gordon like equation with variable propagation speed (that is a generalized non linear telegraphist equation). Therefore we want to show with our naïve model that Quantum Mechanics randomness is caused by this time asymmetric deterministic process of vacuum charge oscillations whose coupling with the energy threshold of a quantum detector induces the irreversible finite time wavefunction collapse associated to longitudinal massive photon radiation emission; we propose to conceive quantum fluctuations not as an intrinsic property of single systems but a contextual effect caused by the hidden path memory interaction between the detector and the polarized vacuum. We note that our new approach to quantum statistics is similar, as already discussed, to the Brownian interpretation of Quantum Mechanics proposed by Nelson in 1966 [21]; anyway, differently from this author, we believe that probabilistic interpretation of Born of Q.M. and its statistical predictions are just good approximations of hidden deterministic energy fluctuations of real thermoelectric vacuum waves (whose statistical properties are just due to temperature dependent variable speed of propagation).

We believe, as recently proposed [35], that Q.M. is an approximated theory valid on time scale much bigger than femtosecond and that quantum vacuum is a real dynamic medium whose fast energy fluctuations might be revealed as non relativistic on this little time scale, investigating finite time productions of fermions pairs and resonances produced by frequency and amplitude modulated electromagnetic laser fields. We will show, as described in the previous paragraph and recently experimentally observed [36], that laser induced vacuum polarization depends on a vacuum temperature field which is a space time generalization of Planck vacuum zero temperature energy. This hypothesis implies a modification to the standard energy relativistic formula of Einstein for the particle rest energy

$$E = m_0 c^2 - kT \tag{15}$$

with T the vacuum temperature function satisfying an analogue equipartition principle for the space time dependent Planckian vacuum zero energy kT

$$kT = \frac{1}{2} \bar{N}(T) m_X \left(\frac{c}{n}\right)^2 \tag{16}$$

with m_X the averaged rest mass of hidden longitudinal photon (which more generally will depend on their frequency as the vacuum index n) [2] [7] [25]. This relation allows to interpret non relativistic time asymmetric zero point energy fluctuations as averaged kinetic energy fluctuations of a dark gas of longitudinal non equilibrium massive photons which induces a violation of relativistic energy-momentum conservation law for quantum isolated particles (as recently investigated in nuclear reactions [1]). In fact relativistic quadrimpulse conservation law of a free particle becomes temperature dependent and the asymptotic free particles in and out Fock states of scattering theory can be assumed to satisfy at finite time a non relativistic relation (since their impulses depend on their accelerations at finite time), as those in the presence of external laser fields with vector electromagnetic potential $\vec{A}$.

$$E^2 - c^2 \vec{p}^2 - \left(m_0 c^2\right)^2 = \Delta E(T)^2 = \frac{\left(\Delta\left(q(T)\vec{A}\right)\right)^2}{2m_0} = \Delta V(T) - \Delta Q \tag{17}$$

m_0 is the particle rest mass, T the vacuum temperature, $\Delta V(T)$ defined in (11), ΔQ in (3) and the environment induced vacuum energy fluctuations, during the finite time interval of non relativistic pair creations defined by

$$\Delta E(T)=\int_0^{\frac{Mc^2}{\hbar}}\hbar\omega\rho(\omega,T)\,\mathrm{d}\omega \tag{18}$$

with $\rho(\omega,T)$ a density distribution which generalizes Planck law depending on the unknown space time dependent hidden variable T, analogue of the Z.P.F used in recent electrodynamic stochastic models [5] and M is a critical unknown frequency dependent photon mass, proportional to detector threshold energy, given by

$$M=m_X\bar{N}(T) \tag{19}$$

with m_X the average mass of the thermal hidden photon [1] and $\bar{N}(T)$ the average number of massive photon emitted on the whole solid angle 4π. We note that the interaction at finite time of the scattering processes might induce electromagnetic radiation emitted which violates the Lorentz symmetry; in fact once it is used the De Broglie relation for massive photon impulses in (11) we get

$$\hbar^2\left(\omega^2-c^2\vec{\boldsymbol{k}}^2\right)=\Delta E(T)^2 \tag{20}$$

we can deduce a generalized space time dependent dispersive law (which corresponds in Q.E.D. to the creation of gauge breaking massive longitudinal photons), which takes in account the temperature dependent longitudinal wave vector of the massive photon $\vec{\boldsymbol{k}}_L$

$$\omega=c\sqrt{\vec{\boldsymbol{k}}_T^2+\frac{\Delta E^2}{\hbar^2}}=c\sqrt{\vec{\boldsymbol{k}}_T^2+\vec{\boldsymbol{k}}_L^2}=\sqrt{\omega_T^2+\omega_L^2} \tag{21}$$

This equation is similar to that one used to describe plasma frequency energy shifts in the presence of external lasers (analogous to non relativistic radiative corrections to atomic energy spectra) and might suggest, therefore, an interpretation of the heat energy as proportional to the squared electromagnetic vector potential $\vec{\boldsymbol{A}}$ associated to emitted radiation of accelerated charged particles (an analogy with vacuum spontaneous absorption that will be explored in a work in progress paper).

These temperature dependent violations of photon dispersive law might be interpreted as thermal radiation emission similar to that one predicted by recent works on C.S.L. models [37]; we note that it might have been already observed as anomalous heat transfers in laser induced fusion reactions [38], since they involve an-elastic scattering and anomalous heat diffusion due to violations for the out states of the quadrimpulse conservation law. More generally we think that this framework predicts non stationary thermal noise that might be revealed in photon polarization experiments and might explain vacuum thermal induced decoherence of photon pair singlet states in E.P.R. experiments as a byproduct of massive photon decays.

In fact, we note, as recently suggested [39], that detector efficiency and, therefore photon count rates, might depend on this vacuum induced energy shift, making necessary a generalization of Bell theorem.

We want to illustrate our approach, which will be applied in the next paragraph to the temperature dependent fine structure constant, with a simple example to show how it can be deduced generalized Unruh effect [40].

We start assuming, as in (22), that relativistic quadrimpulse of an accelerated particle is violated and that vacuum temperature induces particle self energy variation in a finite time interval, similar to one introduced in some previous paper of one of the authors [41] [42],

$$\Delta E = \Delta m(T)c^2 - k\Delta T = m_0 \frac{c^2}{n(T)^2} - m_0 c^2 + \Delta U \tag{22}$$

with $U = -kT$ the vacuum potential (equal to the generalized Zero Point Radiation Field Z.P.F.), T the vacuum temperature, $n(T)$ the temperature dependent vacuum index (generally with values in the complex domain), m_0 the electron rest mass, and $\Delta m(T)$ the electromagnetic electron self mass due to finite time radiation emission or absorption of the accelerated electron (assuming, therefore spontaneous absorption processes from the unstable non relativistic polarized vacuum).

We can show that light speed variation during pair productions is proportional to variation of this vacuum potential defined in (23); in fact we can identify it with the radiation emitted or absorbed in a scattering process or by external vectorial electromagnetic potential field (as that one of a laser field) by the following relation

$$\Delta U = -m\Delta c^2 = -2mc\Delta c = -k\Delta T \tag{23}$$

with ΔU defined in (23) and the Δc light speed variation during the process of pair production.

We think that this definition might be applied to explain low energy scattering processes of quasi-bound nucleons as irreversible processes caused by deterministic path dependent electro-dynamic forces (not predicted by the time symmetric theory of Maxwell), that, asymptotically, will converges to standard transition amplitudes of Q.E.D.

We remark that this vacuum temperature can be conceived as a generalized Unruh temperature [40], associated to light speed acceleration which is induced by external radiation as lasers, in analogy with recent discussed laser analogue of Hawking temperature [43]; therefore our approach is very different from the one used in Q.E.D. renormalization since in this theory the running constants depend on numbers given by the impulse or the energy, not on space time dependent variables such as our vacuum temperature.

We will now introduce a gauge breaking scalar electric field E_0 associated to the virtual massive longitudinal photons (which separates the opposite attracting charges of the pair), in analogy with similar idea on dynamic vacuum fluctuations discussed recently [30] [44],

$$E_0 = -c_0 div\vec{A} = -\frac{1}{ec_0}\frac{\mathrm{d}(kT)}{\mathrm{d}t}, \tag{24}$$

which, using the n vacuum index dependent implies a generalized Lorentz gauge invariance condition (in idea similar to a recent proposal [28])

$$div\vec{A}+\frac{\mathrm{d}(n\varphi)}{c_0\mathrm{d}t}=0\,, \tag{25}$$

by which it can be deduced the following equation

$$-kT=en\varphi\,, \tag{26}$$

with φ the vacuum polarization wavefunction of the hidden massive photon satisfying a generalized Poisson equation, due to the longitudinal photon mass, which could be interpreted as a scalar Proca-Stuckelberg field [7] or a pseudo Goldstone bosons associated to the not zero divergence of the vacuum electric field (a similar idea was suggested recently in a paper of Lehnert on subatomic physics [25]).

We remark that the electromagnetic vectorial potential $\vec{\boldsymbol{A}}$ introduced in (17) satisfies a generalized Proca equation since it propagates radiation in a medium, the polarized vacuum, with a variable vacuum index n

$$\nabla^2\vec{A}-\frac{n^2}{c^2}\vec{A}-\left(\frac{m_\gamma c}{\hbar}\right)^2\vec{A}=\mu_0\vec{\boldsymbol{J}} \tag{27}$$

with the vacuum electric density non conserved current $\vec{\boldsymbol{J}}$ satisfying a generalized Ohm law. We note that the non conserved part of it is transformed, we suggest, in temperature dependent vacuum energy fluctuations and might be revealed as non stationary thermal noise emitted in measurement process and causing wavefunction non instantaneous collapse.

The Equation (28) makes reasonable to interpret vacuum temperature as a generalized De Broglie matter wave similar to a recent proposal [45], and may allow to conceive Schrodinger wavefunctions as ensemble averages of non relativistic Klein-Gordon like fields propagating in medium with variable index n

$$\psi_{Schrodinger}\propto-\overline{\left(\frac{kT}{n}\right)} \tag{28}$$

where the averages with respect to T is with the entropy probability of (13).

In the following we will illustrate our classical self consistent model of finite time pair production and vacuum polarization, inspired by the unsuccessful research program which employed the last twenty years of life of Einstein unified fields. Our approach is inspired theoretically by the analogy proposed by White [30] [44] between vacuum energy fluctuations and longitudinal acoustic waves and experimentally by the quantum tunnelling processes of finite time pair productions by laser assisted Schwinger effect [46] or more generally by the electromagnetic field of light nuclei [47].

In fact the first one suggested us to look at the vacuum energy fluctuations as temperature dependent acoustic pressure waves, while the second one to conceive virtual pair creations or photon pair annihilations as vacuum polarization processes at finite temperature of a dense hidden plasma, in analogy with similar idea explored some years ago [48]; non relativistic pair creations can be therefore conceived as a kind of time dependent decay process, as those typical of nuclear reactions with variable lifetimes (mediated by massive bosons similar to the massive photons describing off shell diffusion processes), and the photon decays as a kind of tunnelling process of an unstable charged particles and massive longitudinal photons [42] [49] [50].

We want to remark that the renormalized constant Z (not to be confused with the vacuum impedance discussed in the previous paragraph) used in Q.E.D. can be considered as a kind of divergent hidden variables that, this relativistic theory, once renormalized by the perturbative series based on Feynman integrals, gives the stationary cross sections of asymptotic free states on which are based the very well predictions tested in particle accelerator experiments (therefore is possible, as we suggest, that finite time quantum scattering and environment assisted vacuum polarization might be non relativistic processes described by a temperature dependent gauge breaking vacuum DeBroglie pilot wave).

We start to describe our model noting that the vacuum potential energy introduced in (4) of the previous paragraph is not stationary, differently from the relativistic vacuum zero point field Z.P.F. of S.E.D. [51] [22], is proportional to a finite time variation of vacuum temperature T, since it as the relation (14), which implements an energy memory of past asymptotic interactions of the electron with the polarized vacuum of hidden massive photons. We can define from the vacuum temperature dependent potential of (23), making the time derivative of it, the acceleration of electron-positron bound state as proportional to the vacuum temperature

$$\frac{\mathrm{d}(-kT)}{c_0\mathrm{d}t}=\frac{p}{c_0}=-eE_0=2(\Delta m)a \tag{29}$$

with E_0 is the scalar electric field defined in the previous paragraph, $a=\mathrm{d}c/\mathrm{d}t$ the light speed acceleration (that is the acceleration of hidden massive photons), and p is the vacuum heat power of (8).

This relation shows clearly that, if the vacuum temperature can be approximated by a monochromatic thermal wave, the vacuum temperature is proportional to light speed acceleration since

$$\frac{\mathrm{d}(-kT)}{c_0\mathrm{d}t}=-\frac{ik\omega T}{C}=2(\Delta m)a, \tag{30}$$

which implies

$$T=-\frac{2c_0\Delta ma}{k\omega}, \tag{31}$$

with

$$a=\frac{\mathrm{d}c}{\mathrm{d}T}\left(\frac{\mathrm{d}T}{\mathrm{d}t}\right)=-\frac{c_0}{n(T)^2}\left(\frac{\mathrm{d}n(T)}{\mathrm{d}t}\right). \tag{32}$$

This equation implements in this particular case a dynamic generalization of

Unruh temperature of accelerated massive photons which can be deduce simply by writing the work done in a very short time interval as equal to the temperature field

$$kT \cong \Delta m a c_0 \tau \cong \Delta m a c_0 \left(\frac{\hbar}{m c_0^2} \right), \tag{33}$$

which implies

$$T \cong \frac{\Delta m \hbar}{m_0 k c_0} \cong \frac{M \hbar}{m_0 k c_0}, \tag{34}$$

where M is the averaged hidden photon mass introduced in (19) and m_0 is the electron rest mass. We think, as discussed in the introduction, that (31) might be very useful to describe pair unstable bound states induced by laser modulated impulses, whose decays might be associated to the anomalous electromagnetic radiation of these hidden massive photons; we can identify ω as the pulsation of the resonant thermal radiation emitted by accelerated nuclei or ions [36] in anelastic scattering, such that the kinetic energy loss of the system (equal to the radiation emitted) can be estimated to be $\Delta K = L$, with L the work done by the scalar electric field to separate in the time τ (of the femtosecond order) the pair of opposite charged particles given by

$$L = k\Delta T \cong e E_0 c \tau \tag{35}$$

which clearly associates scalar electric field to vacuum temperature and, by (32), kinetic energy to light speed acceleration a. We think that, more generally, every finite time scattering process implements an analogue Unruh effect due to acceleration dependent energy loss, which have been so far disregarded due to the asymptotic time formalism of the S matrix formalism. Therefore finite time single quantum scattering events have been considered as unpredictable while, we suggest with our model, they can be conceived as byproducts of acceleration dependent pair productions of a polarized vacuum with non perturbative running fine running constant; we will exploit in particular in the following an analogy of hidden massive photons with massive pions and mesons of nuclear physics, giving a realistic finite time interpretation to virtual photons relativistic of Q.E.D.

In fact starting from (1) we define the scalar electric potential of the electron interacting with hidden massive of the polarized vacuum, as the solution of a time asymmetric generalization of Klein-Gordon equation, dependent on a vacuum index already discussed by one of the author in a previous paper [49] on nuclear reactions, which is the field analogue of (17)

$$\nabla^2 \phi - \frac{n^2}{c^2}\left(\ddot{\phi} - \frac{kT}{\hbar}\dot{\phi} \right) = \left(\frac{L_{pair}}{\hbar c} \right)^2 \phi = div\vec{\boldsymbol{E}} = \frac{\rho_{vacuum}}{\varepsilon_0} - \left(\frac{\hbar}{M c_0} \right)^2 \phi \tag{36}$$

where ϕ is the vacuum electric scalar field of the non relativistic polarized vacuum (interpreted as a pseudo Goldstone bosons), M the averaged photon mass of (19) and ρ the hidden vacuum electric density charge [25]; L_{pair} defined in second member is the work necessary to create a massive longitudinal photon with mass

$\Delta m(T)$ (equals to electron environment induced self mass), defined by the (22).

$$L_{pair} = \Delta m(T)c^2 - kT \tag{37}$$

a relation similar to that one introduced by Einstein the photoelectric effect, with $U = -kT$ the analogous of metal extraction work.

This equation contains as temperature dependent variables the vacuum index n, the electron self mass Δm which must be coupled in a self consistent way to allow to find temperature dependent scalar potential fields. At first we note that in the previous paragraph it was found an explicit relation, which with the new potential of (37) inserted in (28)

$$kT = -n(T)q(T)\phi \tag{38}$$

which allows to interpret the vacuum temperature as proportional to the scalar electric potential of the electron in the polarized medium of hidden massive photons.

We will then assume that the self mass previously introduced is, at first order in the fine structure constant, formally identical to the relativistic formula of the Q.E.D. [52] (whose validity depends only on the assumption that chiral symmetry is preserved), by substitution of the stationary impulse cut off with a temperature dependent one

$$\Delta m(T) = \frac{2M'}{4\pi}\alpha(T)\log\left(\frac{kT}{m_o c^2}\right), \tag{39}$$

with M an unknown photon mass introduced previously in (19), to be interpreted as inversely proportional to an effective mean free path of created pairs (more generally at second member of (39) there will be integral in T which could be approximated as a power series expansion in $\alpha(T)$, and therefore in T).

We can suppose therefore that even the vacuum index $n(T)$ can be developed as a power series in the fine structure constant (that is in the squared effective charge), or, equivalently, that the effective charge can have a power series expansion in T such to have that $n(T)$ converges to one when T goes to zero, inserting as first order approximation on the right of (9) the Coulomb potential for example (or the Yukawa for pair production in laser assisted nuclear reaction).

We then define, exploiting a similar relation introduced by Einstein on his celebrated work on light bending, the temperature dependent vacuum index $n(T)$ already investigated previously by one of author papers [49] [50] on nuclear reactions.

$$n(T) = 1 + \frac{q_0(T)\phi}{m_o c^2} \tag{40}$$

with, as usual the squared effective charge is proportional (at first order in $\alpha(T)$ but not in the Planck constant) to the temperature dependent running constant alpha

$$\frac{q_0(T)^2}{e^2} = A \cdot \alpha(T) \tag{41}$$

with e the observable electron charge, $\alpha(T)$ the temperature dependent fine structure constant (equals to a temperature dependent Z_3 renormalization constant of Q.E.D.) and A is a numerical factor dependent on the lepton (or even hadron) electric charge e (of course more generally the constant A will depend too on the variable T). The system of Equations (36)-(41) is the core of our proposal of a non perturbative non relativistic model of time asymmetric vacuum polarization (due to presence at first member of (36) of the inverse of Planck constant) but is an incomplete system of six equations in seven variables.

In fact it lacks a condition to determinate alpha dependence on T; as already explained an iterative method could be used to find approximate solutions inserting in (36), as scalar field of order zero in T, the Coulomb potential and then inserting the vacuum index in the first member of Equation (40), whose solution will be the first order approximation and then iterating.

Since it is a non linear system which cannot be approximated as power series in the Planck constant it is very difficult to find explicit solutions (and to show that this iterative method will give solutions which converge to physical meaningful ones), we will implement a self-consistent system of coupled equations assuming that the total work to be done to create a stable pair from vacuum can be rewritten by the same relation previously introduced (36), conceiving $-kT$ as a vacuum threshold energy which is a work to be done to separate the unstable quasibound pairs (which are the generalization of virtual pairs of Q.E.D.) and to make them accelerate and radiate, and its gradient as a kind of vacuum friction force [53], proportional to a gauge breaking scalar pressure field which takes apart the created charged pair [44].

We then introduce a thermodynamic like equilibrium condition to create quasistable pair of particles, imposing the following minimum condition on the hidden variable T (that is by minimizing the work to be done to produce a stable electron-positron pair)

$$Min_T L_{pair} = Min_T \left(\Delta mc^2 - kT\right), \tag{42}$$

which implies, using (28), the following differential equation in T and α (which can be complex as recently experimentally investigated [54])

$$\frac{D}{DT} L_{pair} = \frac{D}{DT}\left(Mc^2\alpha(T)\log\left(\frac{kT}{mc^2}\right) - kT\right) = 0 \tag{43}$$

with D the derivative with respect to the variable T (that can be complex), and $M = \frac{2M'}{4\pi}$, with M of (19) might be interpreted as renormalized constant proportional to the critical mass of hidden longitudinal photon associated to the gauge breaking scalar electric field of (24) (to be determined by experimental data).

The solution of (43) can be written as

$$Mc^2\alpha(T)\log\left(\frac{kT}{m_o c^2}\right) - kT = E_o \tag{44}$$

where the quantity E_o is a constant energy to be determined. After some algebra one obtains the fine structure parameter α as follows

$$\alpha(T)=\frac{E_o+kT}{Mc^2}\frac{1}{\log\left(\frac{kT}{m_oc^2}\right)}, \tag{45}$$

which is bounded only if $E_o=-m_oc^2$, so that

$$\alpha(T)=\frac{m_o}{M}\left(\frac{kT}{m_oc^2}-1\right)\frac{1}{\log\left(\frac{kT}{m_oc^2}\right)}=\frac{m_o}{M}\frac{x-1}{\log(x)} \tag{46}$$

where the dimensionless parameter is introduced as $x=\frac{kT}{m_oc^2}$.

The unknown hidden photon mass M of (19) can be calculated from (46) as

$$M=m_o\left(\frac{1}{\alpha}\right)\frac{x-1}{\log(x)} \tag{47}$$

under the hypothesis that the Cosmic Microwave Background Radiation observed at T_o = 2.725 K is somehow correlated to the electron-positron pair production in the vacuum, then one may evaluate the quantity $x_o=\frac{kT_o}{m_oc^2}=4.595\times10^{-10}$, where we assume the values m_o = 9.1093837 × 10^{-31} kg for the rest mass of electrons/positrons, c = 299,792,458 m/s for the light speed in the static classical vacuum, k = 1.3806 × 10^{-23} J/K for the Boltzmann constant. Finally by imposing the fine-structure constant $\alpha_o=\alpha(T_o)$ = 1/137.036 in (47) one obtains

$$M'=m_o\left(\frac{1}{\alpha_o}\right)\frac{x_o-1}{\log(x_o)}=6.3735\times m_o=5.806\times10^{-30}\text{ kg} \tag{48}$$

corresponding by the relation introduced in (19) to an estimated average photon mass m_γ of 10^{-40} kg if the average number with respect to frequency of massive photons at this temperature are

$$\frac{\bar{N}}{4\pi}\sim10^{10} \tag{49}$$

photon per unit solid angle.

This value seems reasonable since it is compatible with actual estimates deviations from Coulomb potential law of the order of $\Delta q\sim e\frac{\bar{N}}{4\pi}\sim10^{-10}$ introduced in (11).

By combining (46) and (48) one obtains

$$\alpha(T)=\alpha_o\frac{x-1}{x_o-1}\frac{1}{\log\left(\frac{x}{x_o}\right)}=\alpha_o\left(\frac{kT-m_oc^2}{kT_o-m_oc^2}\right)\frac{\log(T_o)}{\log(T)} \tag{50}$$

whose reciprocal function $1/\alpha$ has been plotted in **Figure 1**.

In fact for great impulses, making the running impulse go to infinity our model predicts solutions experimentally competitive with the standard one predicted by Q.E.D. [52] (but, being based on a non perturbative approach is without

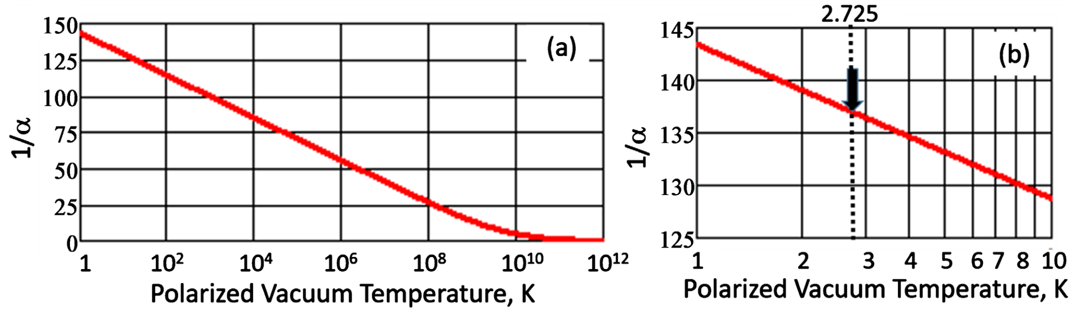

Figure 1. Reciprocal of the fine-structure constant ($1/\alpha$) vs polarized vacuum temperature as calculated from Equation (50): (a) wide temperature range from 1 K to 10^{12} K (log scale); (b) zoom in the temperature range from 1 K to 10 K (log scale). Note that for $T_o = 2.725$ K the inverse of the fine-structure constant is set to $1/\alpha_o = 137.036$ as pointed by the black arrow.

Landau poles)

$$\alpha\left(Q^2\right) = \frac{\alpha(0)}{1 - \frac{\alpha(0)}{3\pi}\ln\left(\frac{Q^2}{m^2}\right)} \tag{51}$$

with the static running fine structure constant dependent on the impulses Q of the asymptotic free scattered particles; if we assume that for great real valued electron impulses the vacuum De Broglie wave is approximated by a monochromatic thermal wave as in (28) and that the measured kinetic energy is caused by the work done by the scalar electric field of (23) it can be assumed to be valid the following approximation

$$\frac{Q^2}{2m_0} \propto \left(\frac{\mathrm{d}(-kT)}{c\mathrm{d}t}\right)\tau \propto \omega kT\tau \tag{52}$$

(that can be rewritten making explicit the dependence on light speed acceleration defined in (32)).

This relation can be experimentally meaningful even when the vacuum temperature is little (not of the Gev order) since it depends on the wave frequency ω of the asymptotic monochromatic vacuum thermal wave and the time interval τ of the interaction with the external field (which for a laser filed could be of the femtosecond order).

We note that the imaginary value of the running constant caused by a complex vacuum wave temperature might justify speculation about the violation of the Optical Theorem in LHC experiments [55]. Finally we wish to remark that from the approximate estimate of average frequency dependent massive photon and photon number and the relation (19) we expect a non stationary frequency dependent deviations of Coulomb law ([2] [3]) with vacuum charge oscillations of the order $\Delta q \cong 10^{-10}$ C which could be detected in modern Cavendish like experiments with actual voltage detector sensibility $\Delta V \cong 10^{-12}$ V.

As far as we know till now this kind of experiments looked only for static charge deviation of Coulomb law induced by fast oscillating capacitors while we think should deserve more attention new dynamic experiments on time dependent violation of this law.

3. Discussions and Perspectives

The theoretical model of a temperature dependent non relativistic finite time pair production and vacuum polarization exposed previously is very heuristic and incomplete since it lacks the conventional Lagrangian formalism of particle physics. Anyway, even if based on some ad hoc assumptions, it allows to deduce a non perturbative running constant and electron effective charge, whose fast oscillations propagates vacuum thermal energy with variable light speed dependent on a generalized Unruh like temperature *T(a)* associated to the radiation of accelerated particles. We can predict, as already explained in the first paragraph, that energy shifts of accelerated heavy ions could be observed in resonant coupling of nuclei with laser radiation [56]; over more we think that recently investigated coherence effect in low energy nuclear reactions [57] could be interpreted as the vacuum thermal wave of hidden massive photons emitted by accelerated electrons and nucleons.

In fact if we impose an equilibrium condition which corresponds to the stable asymptotic stationary in and out asymptotic states of the S matrix we can find a set of temperature equilibrium values and resonant laser frequencies given by the solutions of (50)

$$\Delta m\left(T_{eq}\right)c^2 - kT_{eq} = \hbar\omega_{laser} - 2mc^2 = L_{pair}\left(T\right) \tag{53}$$

(which in the relativistic Q.E.D. formalism should correspond to the peaks of asymptotic stationary cross sections); if the set of solutions of (40) is an infinite set of quantized values we could interpret the last member as atomic energy shifts (as the famous Lamb shift) or resonances which could be compared with those ones observed in accelerator experiments (and defined, in Q.E.D. by the quadrimpulse off shell condition [52]).

An other qualitative prediction of our model is a hidden time dependence in laser induced nuclear decay rates or laser assisted Schwinger effect [46], which can be estimated inserting the energy shift due to particle creation (17) in the Heisenberg relations conventionally used in nuclear physics [40]

$$\Gamma\left(T\right) = \frac{\hbar}{L_{pair}}, \tag{54}$$

making space time dependent the nuclear decays rates, with temporal deviations with the stationary ones, we expect, of the femtosecond time scale order (exploiting the proportionality with the acceleration of the previous paragraph, we expect an analogue strong dependence on nuclei accelerations of nuclear cross sections, tunnelling time and nuclear lifetimes). This relation is the energy bandwidth due to a radiation loss of a generic quantum system immersed in a thermal bath and could be adapted to reformulate the wavefunction collapse hypothesis of a quantum measurement as a finite time collapse time, with non conservation of energy as recently discussed [58]. We note that the problem of energy non conservation is strictly dependent on the radiation which is emitted during the measurement process and may give predictions competitive with those of C.S.L. models of spontaneous wavefunction localization [59]. In fact, once solved the equations of our model, the vacuum dependent decay rates of (40) may be compared with that ones observed in recent experiments aimed to falsifying those models, [36] (which, differently from our deterministic approach, are based on stochastic stationary models of an undefined thermal bath).

On theoretical point of view it is interesting to compare our approach with similar ones regarding quantum vacuum polarization [24] [60]; in fact their approach is based on the belief that vacuum polarization is a quantum process described correctly by Q.E.D. and their aim is to deduce classical light speed or atomic alpha constant from vacuum fluctuations, on the contrary our model tries to explain quantum vacuum a real dissipative dielectric medium whose energy instabilities are described by a heat diffusion process of a vacuum electric density defined by our self-consistent system of equations, which depends on the infinite dimensional hidden variable given by vacuum temperature (this implies that scalar vacuum polarization wavefunction describes an unstable vacuum ground state whose fluctuations are of thermodynamic origin). In fact the solutions of equation (41) gives the temperature equilibrium values which can be used to implement the main goal of this work, that is to give a realistic and dynamic interpretation and generalization of Born rule. Therefore the quantum fluctuations usually associated to every measurement process might be interpreted not as a random process due the wavefunction collapse (which is presumed, we remark, to be instantaneous) but as a deterministic (maybe path dependent) caused by temperature wave dependent radiation emission given by (41). We believe that this thermal radiation could be revealed looking for fast temperature oscillations in the detector temperature (contrary to the static ones predicted by C.S.L. models) and investigating the induced fast fluctuating energy shifts fluctuations.

Our realistic approach can be implemented assuming that Schrodinger wavefunctions are ensemble averages of the vacuum polarization thermal wavefunctions of (25), generalizing the relation (11) of the first paragraph, and that their energy fluctuations propagates longitudinal vacuum electric density waves ρ, analogous to acoustic pressure waves [30] [44], satisfying a generalized Poisson equation (similar to the first equation of Maxwell-Proca theory [60]);

$$div\vec{\boldsymbol{E}} = \frac{\rho(T)}{\varepsilon_0} - \left(\frac{Mc}{\hbar}\right)^2 \varphi\big(x,t,T(x,t)\big), \tag{55}$$

with M the hidden photon mass introduced in (19). This space time dependent vacuum electric charge density ρ [25], is proportional to the square of the averaged gauge breaking scalar electric field of (48) when the hidden variable T can be approximated as a monochromatic wave; in fact we can apply our generalized Born rule (13) to give a realistic interpretation of quantum vacuum wavefunctions as temperature dependent averages if the vacuum capacity satisfy

$$\frac{-C_{vacuum}\Delta q(T)}{kT} \propto \log\left(\frac{kT}{m_0c^2}\right)^2, \tag{56}$$

once we identify the quantum Schrodinger wavefunction of (28) with the vacuum scalar electric potential given by

$$\varphi(x,t,\Delta V) = \frac{r}{T(\Delta V)}\int_0^{T(\Delta V)}\left(\frac{kT}{n}\right)\mathrm{e}^{\frac{-\Delta Q}{kT}}\mathrm{d}T \tag{57}$$

with r a normalization constant and the temperature $T(\Delta V)$ defined by

$$T(\Delta V) = \frac{\Delta V}{k} \tag{58}$$

where in Q.E.D. ΔV corresponds to the Uehling potential due to non relativistic radiative correction to Coulomb potential; on the contrary, using (58), we could deduce this radiative correction to this static field from the asymptotic limit of the wavefunction solution of (36) obtaining an integral equation in the variable ΔV inserted in (57) (if this idea is correct we expect that the vector electric field of (55) satisfy a generalized diffusive telegraph equation dependent on the vacuum electric conductivity $\sigma(T)$.

We hope that our new proposal of a thermal gauge breaking origin of quantum statistics due to hidden non relativistic vacuum charge fluctuations will stimulate new debate on the dynamic origin of Born rule and the real meaning of quantum wavefunctions. We think that future search on the conceptual foundations of Q.M. will need to give new life to the pioneer work of Einstein, De Broglie and Schrodinger and will inspire new ideas on the thermal diffusion process beneath quantum statistics and vacuum fluctuation; we expect that a thermodynamic explanation of vacuum energy fluctuations will shed new lights on cause of the anomalous thermal diffusion processes in metals [61] [62], and anomalous efficiency of quantum heat engines, a topic, called recently quantum thermodynamics, which is attracting a lot of attention [63] [64] [65].

4. Conclusions

We discussed in this paper our realistic and deterministic approach to temperature dependent non relativistic vacuum polarization implemented by environment induced finite time pair productions and hidden massive photons and a tentative frame to describe non perturbative radiative corrections due to these thermal vacuum instabilities. We suggest in this work that the statistical predictions of quantum physics based on Born rule are just emergent approximated rules due to fast vacuum energy fluctuations caused by a hidden vacuum temperature oscillations. Therefore we illustrated our tentative model aimed to reformulate quantum wavefunctions as ensemble averages of electric scalar fields of the polarized vacuum.

We hope that our new approach based on a dynamic dissipative quantum vacuum will help to reformulate deterministically quantum mechanics and Q.E.D. as a theory of time asymmetric thermo-electrodynamics forces and fields.

The goal of this research program is to overcome wave function collapse paradigm of quantum measurement process by introducing vacuum thermal waves of relic non equilibrium massive photons and we suggest could explain quantum instantaneous jumps of atomic spectra as finite time transitions between thermodynamic equilibrium states; overmore we think that our proposal might be competitive, solved the equations of our model, with recent predictions of radiation emissions during wave collapse of C.S.L. models, since both try to reformulate wavefunction instantaneous collapse postulate as an emergent approximated effect of a hidden time asymmetric dynamic process (in our view to be explained by non equilibrium thermal waves emissions of the unstable electromagnetic polarized vacuum).

We hope that the suggested electrodynamic interpretation of quantum wavefunctions as temperature averaged polarization vacuum waves will give new life to the efforts of the last life research programs of Einstein, Schrodinger, De Broglie and Bohm on a realistic and classic interpretation of quantum wavefunctions; in fact we think they were too early abandoned from the physicist community because they mostly adhered to the Copenhagen interpretation. On the contrary we strongly believe that its revival and generalization may pave the way to a deterministic and classical non perturbative theory of non relativistic quantum electrodynamics. We think that non relativistic vacuum pilot waves models implements hidden dissipative electrodynamic forces which might allow to observe temperature dependent violations of Born rule in experiments; we, finally, suggest that these naïve dissipative pilot wave models could explain anomalous heat diffusion phenomena of accelerated conductors and might shed new light on the out of equilibrium thermodynamics of quantum heat engines.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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