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Vacuum Correlations, Detector Efficiency Fluctuations and Classical Dynamic Violations of CH-Inequality

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Abstract

We study in this paper the possible influence of vacuum fluctuations on photo detection and its background noise in Bell tests. We analyze its consequences on the standard statistical analysis of data showing that it is not fulfilled anymore the conventional hypothesis of a Poisson like probability density distribution of single photodetection events. We assume that vacuum fluctuations are due to real and measurable fluctuating fields, as recently confirmed experimentally, and that their non null correlations outside the light cone contribute to photon coincidence rates making them time dependent. We introduce a generalized Bell like correlation function which contains a new term due to supposed vacuum induced photon counting events. We deduce then a generalization of CH-inequality which takes in account the effect of these vacuum electric fields on detector efficiency. We predict an apparatus temperature fluctuations during photon detection which we suggest could be observed by looking for colored noise thermal emission of the photodetectors, generalizing the standard white noise prediction of C.S.L. models on wave function collapse postulate. We discuss an experimental test of this prediction, based on the idea of inducing a thermal wave on the whole quantum detectors, aimed to observe time dependent deviations from standard stationary statistical predictions of Quantum Mechanics.

Keywords

Electric Vacuum Correlations, Dark Counts, Detector Efficiency Fluctuations, Detector Thermal Emission, Temperature Dependent CH-Inequality

1. Introduction

During the last forty years, there has been an intense debate on quantum non locality and incompleteness of Quantum Mechanics, caused by the discovery of Bell like inequalities and their presumed violations in E.P.R.-Bell tests for classical hidden variable models. They consisted of the measurement on two independent detectors of the spin polarization correlation of two entangled electrons or photons emitted by a source; the single outcomes of an experiment are described by a stationary stochastic variable $A(\lambda, a)$, for example the spin polarization observable, which depends only on the values of the filter axis a and on the hidden variable λ, fixed in the past, during the emission process of entangled pairs in the source; the expected value of the outcome was assumed by Bell to be described by the ensemble average given by the integral

$$E(A) = \int A(\lambda, a) \rho(\lambda) \mathrm{d}\lambda, \quad (1)$$

with $\rho(\lambda)$ the stationary statistical distribution; in a similar way it is introduced a correlation function between two observables A and B in each quantum detector, with zero mean, given by

$$E(AB) = \int A(\lambda, a) B(\lambda, b) \mathrm{d}\lambda \quad (2)$$

where the product of the observables AB was introduced by Bell assuming that locality, and therefore, detectors outcomes were independent. Bell tests assumed this statistical hypothesis of locality and were conceived initially to look for perfect anticorrelations of rotational invariant singlet states of paired particles emitted by laser sources

$$A(\lambda, a) = -B(\lambda, b), \text{ if } a = b, \quad (3)$$

that is parallel polarizer axis, and with the hypothesis of dichotomic value of the spin polarization observable

$$|A(\lambda, a)| = |B(\lambda, b)| = 1 \quad (4)$$

This framework, assuming that the polarizer is inserted ahead of each detector makes collapse instantaneously the polarization state of the incident photon depends on the validity of the controversial postulate of wavefunction collapse of the Copenhagen interpretation and on the hypothesis of photon indivisibility (which conflicts with the classical Malus law assumed to be true for every polarizer). We think that this hypothesis, together with that one that spin correlations are generated just by the source are not necessary in every hidden variable local model which, once abandoned, as we did, might allow to generalize Bell theorem and to overcome the debate between who believes on quantum non locality, supported by experimental successful violations of Bell like inequalities, and the followers of Einstein local realism.

The discussion, between the supporters of this two opposite approaches to Quantum Mechanics (that continued notwithstanding the Nobel price assigned last year to Clauser and Horn for the discovery of their inequality) is inadequate, since both do not consider the role of quantum electromagnetic vacuum and vacuum spin currents [1] [2] as infinite dimensional contextual hidden variable affecting detector thermal noise, dark counts and therefore the correlated functions extrapolated by photodetection events. The hypothesis that quantum vacuum might have an active role in explaining detected spin correlations did not attract the attention of the researchers which tried recently to develop an alternative explanation of Bell like tests taking in account contextual hidden variables [3] [4] [5]. One important aspect of these researches, for the followers of this approach, is a causal explanation of the emergence of statistical data of photon coincidence rates on which are based every modern Bell tests supposed to be loophole free [6] [7].

Notwithstanding the very definite claims contained in this paper on the realization of loophole free Bell tests and their conclusion on the impossibility to complete Quantum Mechanics by local deterministic models there are still a lot of authors that disagree with these opinions [8] [9] [10] [11] [12] [13]. In particular these papers are considered to have proved the statistical point of view of the Copenhagen interpretation against the followers of classical models, as Einstein and Debroglie. On the contrary there is still a big research area to investigate, we think, concerning the role of dark energy vacuum fluctuations and out of equilibrium thermal emission processes for explaining in a realistic and causal way the emergence of a quasi stationary statistics from the quantum physics.

We will try in this paper to show with a deterministic local model how to bypass Bell like inequalities, discussing a new loophole, which we call "vacuum correlation loophole", which is present, as far as we know, in every free loophole E.P.R.-Bell like experiments. Over more in the last two years have appeared some papers which generalize C.H.S.H inequalities [9] [11] which pave the way to future definite experimental disproval of Bell theorem with experiments realized with classical electromagnetic fields or hydrodynamic waves, as recently showed [14] [15] [16].

We think that these E.P.R.-Bell tests, showing violation of Bell like inequalities with classical fields, strongly support the search of general deterministic models explaining the emergence of the statistics of the quantum world, independently from the discussion on entanglement and non-locality (called by Einstein "spooky action at distance").

Our paper, following ideas suggested by Santos [17], and the hypothesis of a hidden dark vacuum state, which, we conceive as a real dynamic medium which induces detector spontaneous virtual photons emission and causes the postulated wavefunction collapse. We assume that the vacuum state is in a squeezed polarized state and its fluctuating polarized electric fields induces statistical correlations between the detectors making inadequate the standard removal of dark photons counting rates conventionally used in Bell tests. In particular we will exploit the modern experimental evidence of quantum fluctuations [18] [19] [20], based on the hypothesis of a excited squeezed vacuum state to show the inadequacy of the concept of single photon and its presumed indivisibility, always assumed in the standard interpretation of the photodetector clicks, implying or the passage of the whole photon after the beam splitter or the absorption.

This hypothesis, although incompatible either with Maxwell theory that with

Heisenberg energy relations, is at the base, we think, of the fallacious identification of one click event with one photon arrival; we criticize it and show how local hidden variable models are compatible with experimental evidences, as recently suggested in an interesting paper on the correlation function of N independent photons [14].

We propose a new framework to photon coincidence rates, conceiving dark counts not as accidental events; on the contrary we assume that they are caused by vacuum pair production and they look like a noise effect due to the superposition of the photon source signal with the time dependent zero point field fluctuations of the hidden excited quantum vacuum state.

We deduce a generalized non stationary CH-inequality [21] which depends explicitly on the Planck constant and which might be tested on future experiments searching time dependent violations of ensemble statistical prediction of Quantum Mechanics, as recently analyzed for the special case of Bell like inequalities.

We propose a new test of them based on the hypothesis that quantum detection efficiency oscillates and that there is a time delay between the entangled pairs emitted by the laser source and those created from the induced polarized vacuum, which might show for a very little time interval violations of CH-inequalities during the period in which the laser source has been switched off.

We remark that all recent supposed free loophole Bell tests [6] [7], as remarked very clearly by Hnilo [13], even if free from well known loopholes, are still based on the implicit assumption that detector efficiency is a fixed well known parameter whose high level is exploited to test the zero hypothesis of a classical violation of Bell inequalities (and its estimates are used to calculate the statistical confirmed predicted quantum coincidence counting rates).

We note that this assumption entails that the experimental data of single photon detection is equivalent statistically for a big number N registered events to be an ergodic stochastic process described by a Poisson like distribution.

Anyway this conclusion is no more valid if the previous N number is considered to be an unknown unobservable parameter (that is a real hidden variable associated to the laser source of entangled pairs), which, due to vacuum polarizations, depends on time in each different setting of a specific experimental run. This problem was implicitly present in the first paper on CH inequality [21], when it was defined the probability of single photodetection and coincidence events

$$p_1(a)=\frac{N_1(a)}{N};\quad p_2(b)=\frac{N_2(b)}{N};\quad p_{12}(a,b)=\frac{N_{12}(a,b)}{N} \tag{5}$$

and correctly remarked by the authors, that Bell -C.H.S.H. inequalities were not directly testable due to the impossibility to know and measure in a non invasive way N. In the previous paper Clauser and Horn, were forced to bypass this problem and deduce their inequality to introduce the hypothesis of no enhancement, which was then generalized in all modern free loophole tests as the fair sample hypothesis. The previous probabilities were considered by Bell and his followers, as average values on the ensemble space of hidden variables

$$p_1(a)=\int p_1(\lambda,a)\rho(\lambda)\mathrm{d}\lambda \tag{6}$$

and analogous relation for the probability of detection in the second apparatus; he, as Clauser and Horn, implemented the locality hypothesis assuming that the statistical independences between the detectors outcomes was given by the relation

$$p_{12}(\lambda,a,b)=p_1(\lambda,a)p_2(\lambda,b) \tag{7}$$

We remark that this statistical assumption of statistical independences is compatible with our novel proposal based on an explanation of detected spin correlations of entangled photons as a byproduct of environment induced vacuum electric field correlations [18].

Our realistic and local approach predicts dynamic deviations from quantum mechanics stationary expectation values which could be revealed in experiments with two independent laser sources with time dependent intensity $I(t)$; in fact the variable signals makes photodetection a non ergodic stochastic process since the fluctuating vacuum photon number $\Delta N(t)$ implies that the empirical definition of the probability of a single photon detection in (5) should be generalized

$$p_1(a)=\frac{N_1(a)}{N}-\frac{\Delta N_{vac}(a)}{N} \tag{8}$$

which, we will show, will allow to generalize C.H. inequality, taking in account vacuum correlations induced by measurement processes. If we assume then a vacuum incident signal

$$\Delta I_{vacuum}(t)\cong\frac{\Delta N(t)h\omega}{\tau} \tag{9}$$

It is no more reasonable to assume, as usually made, that quantum detector efficiency is constant and polarizers angle independent. Therefore from (9) we must abandon the conventional hypothesis that single photon detection in a finite time interval can be described by the stationary Poisson probability distribution and that detected correlations, being so little, are not caused by entangled pairs generated by the source.

On the contrary we assume that they are generated by a non linear photo detection process which induces vacuum spin correlations between the two detectors.

We introduce, as proposed by some authors, the hypothesis that the detector efficiency might fluctuate during the experimental run [9] [10], making the photodetection a non ergodic process. Therefore the measured single photon detection doesn't accomplish the Poissonian statistics used in the standard Mandel theory of photocounts and must be generalized in the following non linear way [12].

$$P_A(\alpha,t,\tau)_{measured}=\frac{1}{\tau}\int_t^{t+\tau}\rho(t)P_A(\alpha,t)\mathrm{d}t=1-\exp\left(-\frac{\int_t^{t+\tau}\eta(t)I(t)\mathrm{d}t}{I_0}\right) \tag{10}$$

The last integral implements time dependent Bell like inequalities violations, except when laser intensity signal is very little, as it is in standard modern Bell tests; in fact in this common case we recover the standard linear detection model conventionally adopted in every experiment

$$P_A(\alpha, t, \tau)_{measured} \sim \eta \frac{I}{I_0} \sim \frac{\Delta N}{N_A} \tag{11}$$

where I_0 is the stationary intensity of the input signal (presumed to be bigger than the fixed background noise level to produce a click), and N_A is the measured number of photodetction in station A, during the time interval τ of the experimental run. We remark that our proposal deviates from a recent similar objection to Bell like tests (13) since we interpret the photon count probability in the integrand as a byproduct of vacuum induced signal fluctuations generated during the measurement process (which is usually interpreted as background thermal noise). We reformulate the (11), taking in account (10), making it dependent on the contextual hidden variable given by the fluctuating detector efficiency

$$P_A(\alpha, \eta(t), \tau)_{measured} = \frac{\Delta I_{noise}(t, \tau)}{I_0} \tag{12}$$

We will show in the next paragraph, assuming that vacuum polarization makes time dependent quantum detector dielectric constant, that is possible to deduce a generalized CH-inequality consistent with data sets of loophole free Bell tests.

We will suggest to interpret in the following paragraph the predicted classical violations of Bell like inequalities, as byproduct of a hidden quasi stationary vacuum polarization wave exchanged by the two detectors in analogy with some ideas exposed in a previous paper of the author and by Fleury [22] [23]. We will then expose a new tentative model aimed to explain, more generally, the emergence of the statistical predictions of Quantum Mechanics from out equilibrium thermodynamic phenomena associated to a non linear and path dependent measurement process [12].

We hope that our proposal will be useful, more generally, to extend the old debate between Einstein and Bohr on incompleteness of quantum wavefunctions belonging to Hilberts state space to the bound and quasi bound state of Nuclear Physics; we think, in fact, that the observed long range interactions between spinning ions and nucleons need new dynamic models with path dependent hidden variables not considered in Bell theorem, overcoming the well known debate generated from it on local realism and quantum non-locality

2. Model

In this paragraph we will expose a new definition of the experimental testable correlation functions used in Bell like inequalities due to a perturbing effect of quantum energy fluctuations on photon coincidence rates estimated in Bell like tests; in fact, if we assume, as recently investigated theoretically and experimentally [19] [20], that there are detectable correlations of vacuum electric fields

$$\overline{E(r,t)E(r',t')} \neq 0 \text{, (for outside light cones space time events)} \tag{13}$$

We have to reject standard statistical framework used in presumed free loophole tests; in fact all the recent experiments which show violations of Bell like inequalities are based on the fallacious assumptions if (13) is true that source emission rate of entangled pairs and probability of single photodetection are constant in time and are not path dependent. Differently from the well known stochastic electrodynamics theory, called S.E.D. [24], we assume that vacuum instabilities associated to virtual photon pair production exchanged by the two detectors and polarizers are real polarization waves [9] [20] [22], associated to vacuum dielectric perturbation which couples to the quantum detectors in a path dependent way inducing the emergent statistical phenomena of wavefunction collapse.

We start by observing analyzing the effect of Heisenberg energy-time inequalities

$$\Delta E \Delta t \cong \frac{h}{4\pi}. \tag{14}$$

On detectors event registration, in fact it implies for conventional photodetector time window of about 10 nanoseconds and apparatus unitary volume dimension, an energy fluctuations, which is of the same order of magnitude estimated for dark energy density [17]

$$\rho_{dark} \sim 10^{-26}\,\frac{\mathrm{J}}{\mathrm{m}^3}, \tag{15}$$

We will develop in a forthcoming paper the speculative idea that the information exchanged between the two detectors is due to a dark energy wave associated to detector thermal wave spontaneous emission by

$$\frac{\mathrm{d}\rho_{dark}}{\mathrm{d}t} V_{det} = C \frac{\mathrm{d}T_{det}(x,t)}{\mathrm{d}t} \tag{16}$$

This suggestion is, we think, the real physical process explaining correlations of spin polarized photon pairs observed in Bell like tests as a byproduct of vacuum dependent detector energy thresholds and their associated detector non stationary noise thermal field. We note then that due to (9) and (11) each of the two entangled photon emitted by the source used in Bell tests will become a packet of multiple photon with fluctuating number $\Delta N(t)$ depending of the time interval on which is observed, making less clear the experimental distinction between correlations of imperfect entangled states of two photons and that one of a classical variable electromagnetic incident signal (on this implicit hypothesis of photon indivisibility is based the standard framework of Bell inequalities with dichotomic variables of spin polarization), in fact, rewriting the previous equation we can explicit the vacuum induced photon number fluctuations, usually disregarded in the previously cited recent experiments on Bell tests

$$\Delta N(t, t+\tau)\omega_0 \sim \frac{1}{2\tau} \tag{17}$$

where the last time interval is the detector standard time window.

We remind, as already explained in the introduction, that modern loophole free tests are based on the implicit conventional assumption of a Poisson like distribution of measured photo detections; anyway it is no more necessary this hypothesis for alternative causal models of measurement process based on time dependent contextual hidden variables associated to induced detector thermal emission which implements path memory dynamics, since the photocounts process is no more ergodic.

We propose to consider this fluctuation number as the source of the dark counts registered then in quantum detectors associated to a vacuum induced thermal power noise signal proportional, at first order, to the detector efficiency fluctuation

$$\Delta\eta w_{in} \propto \Delta w_{vacuum} \sim \Delta N h \frac{\omega_0}{\tau} \tag{18}$$

with w_{in} the power of the signal entering the detector, a fraction of it will be absorbed and will cause detector thermal fluctuations.

We will see that this relation can be used to generalize the CH-like inequality for vacuum dependent local hidden variables models. These ΔN are dark counts that we conceive as real time dependent events and which must not be subtracted, as usually made in standard derivation of Bell like inequalities; on the contrary in our vacuum dependent hidden variable model they must be added since they are caused by the interference effect due to the superposition of the electric field of the signal entering each detector and that one of the vacuum noise field. This vacuum dependent background noise enhancement can be estimated, at first order in the vacuum perturbed dielectric constant, by the following relation

$$w(t) = \frac{\Delta\varepsilon(t)}{\varepsilon_0} w_{in} \propto \frac{\Delta\varepsilon(t)}{\varepsilon_0 \tau} N_0, \tag{19}$$

where $w(t)$ is the detected fraction of the power input signal due to photon losses, N_0 is the unobservable number of entangled photon pair emitted at a constant rate during the detector time window τ from the laser source; we note that the power w_{in} of (19) can be interpreted as a hidden parameter which controls the perturbed dielectric constant due to the apparatus induced vacuum polarization.

We predict from (14) and (15) that the order of the detector energy fluctuations induced by the polarized vacuum can be approximated by

$$\Delta E_0(t) \cong k\Delta T_0 \cong 10^{-26}\ \text{J} \tag{20}$$

whose order of magnitude gives an estimate of temperature fluctuations of the order of millikelvin, compatible with recent available experimental set up [25] [26]. These detector threshold energy fluctuations can be interpreted as due to the work done by hidden path dependent vacuum friction forces, similar to those investigated recently by Barnett [27], and we suggest could be detected as thermal waves emitted by the apparatus during the photodetection (a prediction that is discussed in forthcoming paper of the author); in fact, in a time scale of the order of detector time window, the detectors will exchange an electromagnetic radiation associated to the decay of this excited quantum vacuum state, whose energy fluctuations are given(disregarding detector mass fluctuations and volume deformations), by

$$\Delta E_0(t) = C\Delta T = \int_t^{t+\tau} e(T(t))\, w(t)\, \mathrm{d}t \cong e(T_0)\Delta w_{em}(t) \tag{21}$$

with C the constant volume heat capacity of the detectors, $e(T(t))$ is detector perturbed thermal emissivity, $w(t)$ is the total thermal power absorbed by the detector, Δw_{em} is thermal power emitted by the detector and τ is the time interval of the emission process. We note, as previously explained, that either the energy fluctuations of (20) and (21) could be both be interpreted as generalized time dependent contextual hidden variables which might violates Bell like inequalities, since they violate the ergodic hypothesis, implicitly assumed in every data statistical analysis used in Bell like tests [13].

We can estimate the dielectric wave perturbation introduced in (19) by generalizing a relation proposed in a recent paper, which explores violation of Bell inequalities in vacuum [28], inserting in it the thermal radiation due to detector photon emission of (21)

$$\Delta E_0(t,\tau) = C\Delta T \sim e(T_0)\Delta w_{em} \sim E_0 \exp\left(-\frac{2McL}{h\Delta n}\right), \tag{22}$$

with L the average detector linear dimension. This formula allows to estimate the predicted detector hidden thermal emission once it is measured the fluctuation of detector index of refraction Δn; on the contrary if we look at the second member with the ΔT unknown it allows to determine its dependence on the detector perturbed index of refraction Δn. We can deduce an estimate of the associated hidden temperature variation assuming a linear relation between them given by

$$\frac{\Delta n}{\Delta T} = \alpha(\omega_0, \Omega(t)) \tag{23}$$

with α a constant typical of each photo detector, that depends on the photon angular pulsation ω_0 of the laser source and; we note that the dependence on the relative angular rotation $\Omega(t)$ between the detector and the Earth angular rotation takes in account the rotation induced control of photon correlations discovered by Faccio *et al.* [29]. Inserting (23) in (22) we get the following transcendent equation.

$$C\Delta T = \Delta E_0 = E_0 \exp\left(-\frac{2McL}{h\alpha\Delta T}\right), \tag{24}$$

We note that the due to exponential function the temperature variation goes to zero when the Planck constant goes to zero, that is a quantum effect due to vacuum induced thermal emission.

This relation can be rewritten posing as variable x the temperature variation ΔT in the simpler manner

$$Ax = \exp(Bx), \tag{25}$$

with

$$A = \frac{C}{E_0}, \quad B = \frac{\alpha h}{4\pi McL} \tag{26}$$

whose first order approximated solution can be obtained by developing the exponential in power series of x, which, taking just the linear term gives

$$x(h) = \Delta T(h) \sim \frac{1}{A - B(h)} \tag{27}$$

the temperature oscillation variable, which when the Planck constant is zero gives the physical reasonable estimate $x \cong \frac{E_0}{C}$; the example now considered is the simplest conventional case since in standard Bell experimental set up the detectors are at rest with respect to Earth rotation, which breaking rotational invariance, makes invalid the hypothesis of Fock vacuum photon state used in Bell tests. We introduce the more general functional dependence because we think inertial effects induces dark vacuum state, as in the Unruh effect, whose vacuum electric field correlations could explain experimental violations of Bell like inequalities compatible with Einstein local realism approach. We suggest that the relation (22) and (23) could be tested in future Bell like experiments with photodetectors on rotating platform, analogous to those, previously cited, proving rotation induced entanglement [29].

We remark that is this energy fluctuations and its associated vacuum power will give an added vacuum dependent term which we will use to generalize C.H. inequality, interpreting dark counts as delayed coincidence events and not as usually assumed in Bell tests, as stochastic accidental events.

We deduce from (18) and (19) a new definition of detector efficiency fluctuations which makes it dependent on the assumed vacuum perturbed dielectric constant, and from (15) on the detector temperature fluctuations ΔT

$$\Delta\eta(t) = \frac{\Delta\varepsilon(t)}{\varepsilon_0}\frac{\tau}{\tau_0} = \Delta n^2 \frac{\tau}{\tau_0}, \tag{28}$$

with τ_0 the photon pulse duration emitted by the source; this relation makes explicit our interpretation that Bell inequalities are violated due photon correlations caused by the vacuum polarization stationary wave generated by the two quantum detectors (and, more generally, by the excited polarizers), In fact our interpretation of Bell like tests are based on the following testable assumption of vacuum induced detector correlations, generalizing those proposed recently by Hnilo and collaborators [10].

$$\frac{\mathrm{d}}{\mathrm{d}t}\eta_A(t)\frac{\mathrm{d}}{\mathrm{d}t}\eta_B\left(t+\frac{d}{c}\right)\le 0 \tag{29}$$

with d the distance between the detectors, that can be rewritten from (21) as an inequality concerning correlations of the detector time derivative of relative dielectric constant. This relation will be exploited to propose at the end of the paragraph a novel test of quantum predictions and classical hidden variable models based on time dependent Bell like correlation function.

We can, taking in account our generalized definition of single photon probability detection given by (8), deduce a generalized CH-inequality which must be satisfied by our vacuum dependent hidden variable model, without assuming the no enhancement hypothesis nor the fair sample hypothesis

$$S_{gen}(t)=S_{C.H}+\Delta S_{vac}(t,h)=S_{C.H.}+\frac{\Delta R_1(a,t)+\Delta R_2(b,t)}{R_0}\ge 0\,, \tag{30}$$

where the vacuum perturbed temperature dependent counting rates are given by

$$\Delta R_1(a,T_1(t))=\frac{\Delta N_{vac}(a,T_1(t))}{N\tau} \tag{31}$$

and analogous for the other detector coincidence rate, and

$$S_{.C.H}=\frac{R(a,b)-R(a,b')+R(a',b)+R(a',b')-R_1(a')-R_2(b)}{R_0} \tag{32}$$

where the C-H. inequality has been rewritten as ratio of coincident rates rather than detection probabilities; the four coincident rates R are the measured photon coincidence rates with both polarizers present, R_0 is with no polarizer present, and the last two are the vacuum perturbed ones, with only one polarizer present. We assume, as already discussed in the introduction, that vacuum polarization cause a non Poisson like stochastic process during photo absorption making the last two detector counting rates constant rates acquire a fluctuation ΔR defined identifying them with the detector efficiency fluctuations of (18)

$$\Delta R_{1,2}=R_0\Delta\eta_{1,2}(\Delta T_{1,2},h) \tag{33}$$

Therefore the new temperature dependent term in the vacuum correlation function can be rewritten as

$$\Delta S_{vac}(t,h)=\Delta\eta_1(h,\Delta T_1(t))+\Delta\eta_2(h,\Delta T_2(t)) \tag{34}$$

and from (27), (22) and (23) goes to zero when either the Planck constant h or the detector temperature fluctuations ΔT goes to zero. We note that well known Bell like inequalities do not depend on Planck constant so it not so clear their link with Quantum Mechanics formalism, apart from the use of eigenstates of the Pauli spin polarization operator [14]; on the contrary our proposed vacuum correlation function of (34) explicitly depends on Planck constant and implements classical violations of CH-generalized inequality compatible with the well known value of the correlation function reported in the celebrated Aspect experiment [30] $S = 0.126$, if it satisfied the reasonable estimate that the relative dielectric variation is

$$\frac{\Delta\varepsilon}{\varepsilon_0} \sim 0.1. \tag{35}$$

We remark that as recently observed in experiments on quantum electric field correlations, the Aspect result can be reproduced assuming a vacuum dark photons counting rates on each detector estimated to be of about six over one thousands per second and photon average incident flux N entering the detector of one over ten per second

$$\Delta S_{vac} \cong 2\frac{\Delta R}{R_0} \cong 2\frac{\Delta N_{vac}}{N} \sim 2\times 6\times 10^{-3} \div 10^{-1} \sim 0.12 \tag{36}$$

compatible with presumed quantum violations discussed in recent claimed free loophole tests. Since the photon statistical correlation in (34), is caused by hidden detector photothermal emission we propose to test this quantum thermodynamic effect by introducing a variable thermal stress on the whole quantum apparatus (both the photodetectors and the polarizers filters), making time dependent the temperatures of the two detectors, as predicted by (27).

In particular we expect that with a little time delay of the order of ten time windows, that is about *100ns*, notwithstanding the switch off of the temperature control laser intensity, there will continue to be non-null coincidence photon counting rates such that the associated correlation function of (30) will satisfy an out of equilibrium thermodynamic inequality given by

$$\frac{\mathrm{d}S_{gen}\left(T_1+T_2\right)}{\mathrm{d}t} \le 0, \tag{37}$$

that, looks like the familiar thermodynamic second law, implies an oscillatory decay regime towards an equilibrium value, if the detector has temperature wave oscillations. We note that an interesting thermodynamic interpretation of Bell inequality violations can be suggested if we substitute to the entropy the opposite of the correlation function S. In fact the correlation function decay implied by (37),during the experimental run of Bell tests can be conceived as a kind of vacuum entropy growth associated to vacuum correlations induced by photodetection and, contrary to the standard approach, not caused by entangled photon pairs generated by a laser source

We remark that this approach might be applied to reformulate a very interesting proposal of generalized C.H.S.H inequalities published this year [11]

$$S \le 4 - 2\Delta \tag{38}$$

once we suppose the Δ term of the previous formula, and therefore the different experimental set up quadruples, to be dependent on the fluctuating detector index Δn, introduced in (23); in this way the previous inequality can be shown to be equivalent with a similar inequality obtained by the author [9] having the same upper and lower bounds

$$S' \le 2\left|1+f\left(n\right)\right|^2 \le 4 \tag{39}$$

with *f(n)* a function which can be shown to be dependent on the fluctuating detector efficiency; this relation, together with (38), makes $\Delta(n)$ explicitly dependent on a temperature dependent detector index of refraction

$$\Delta\left(n\right) = 2 - \left|1+f\left(n\right)\right|^2 \tag{40}$$

We remark that our new definition of the coincident counts correlation function is a generalization, as already written, of the previous cited relation, which allows time dependent fast deviations from Quantum Mechanics predictions [10], consistent, in each experimental run, with a path dependent $\Delta(t)$ in (38), which is different in every set up of a Bell like test.

We think that the out of equilibrium thermodynamic approach pursued in our proposal, implementing the vacuum induced colored background noise, is the essential element missing up todays to interpret experiments on Bell like inequalities as supporting causal local models, based on a new "vacuum correlation loophole". We hope that our tentative proposal will stimulate to elaborate new vacuum dependent models of photodetection, assuming, as recently, investigated that quantum detector process is caused by a non-linear interaction with the hidden polarized vacuum; more generally we propose that the quantum measurement during the interval τ of particle or photo absorption can be described by a non linear path dependent relation

$$\boldsymbol{D} = \frac{1}{\tau}\int_0^\tau \varepsilon\left(t, t-t'\right)\boldsymbol{E}\left(t'\right)\mathrm{d}t' = \overline{\varepsilon_{ij}}\boldsymbol{E} \tag{41}$$

where the dielectric tensor in the last member could be give an electromagnetic interpretation of the abstract operators acting on the Hilbert space of the quantum states, used to describe observables in Quantum Mechanics. Therefore we could conceive every photodetector as an effective excited anisotropic media which induces vacuum spin correlations [2], due to the emission of a spinning electromagnetic wave, a consequence of classical Maxwell theory recently investigated [31].

We remark that the detector induced non relativistic vacuum polarization implied by (41) could be interpreted as caused by a gauge breaking wave exchanged between the detectors and the excited quantum vacuum; a similar proposal concerning vacuum longitudinal gauge breaking waves has been suggested recently by Hively, called by him extended gauge free electromagnetic wave [32], that we interpret as a scalar wave associated to the vacuum dark energy density estimated in (15)

$$\rho_{dark} = \left(\frac{\frac{\mathrm{d}\varphi}{c^2\mathrm{d}t} + div\boldsymbol{A}}{\sqrt{2\mu}}\right)^2 \tag{42}$$

On our opinion, in fact, what makes Quantum Mechanics still an incomplete theory notwithstanding its great predictive successes is the lack of a causal model of the quantum measurement process We suggest that the dielectric permittivity tensor introduced in (41) will allow to explain why and when happen click registration by generalized path dependent contextual tensorial hidden variables (an idea which will be explored in a future paper).

We remark, in fact, that the aim of our model was to show that new vacuum dependent hidden variable fields may violate generalized Bell like inequalities, as the C.H. inequality of Equation (30), in accordance with experimental data recent free loophole Bell tests. We hope, finally, to have proved with our proposal that quantum nonlocality is no more experimentally and theoretically justified, and that Einstein local realism is still a valid approach to explain quantum phenomena.

3. Conclusions

We propose in this work a new approach to violate by means of local hidden variable fields CH-like inequalities.

We assume that measured photon coincidence counts measured in E.P.R.-Bell like tests are not due to entangled photon pairs but due to out of light cones vacuum field correlations, induced by the quantum detectors during the measurement process.

We introduce a temperature dependent photon correlation function S which we show allows to deduce a generalized CH-inequality in accordance with well known data of Aspect experiments and with some recent free loophole Bell tests.

We predict a not stationary background noise associated with detectors' temperature fluctuations during the photon absorption process. These phenomena, we suggest, could be observed either thermally stressing for short periods the quantum detectors or by switching them off with very fast pulses and measuring time delayed non null coincidence counts.

We interpret this classical violation of Bell like inequalities as caused by out of equilibrium thermal emissions during the detector photo absorption making the measurement process a not ergodic stochastic process

We compare then our proposal with recently published similar ones concerning time dependent hidden deviations from Quantum Mechanics which, we hope, could give new support to Einstein's efforts to find a local realistic theory which completes it and explain deterministically single event outcomes.

We hope, that the out of equilibrium thermodynamic framework introduced in this work, could shed new lights, more generally, on the time symmetry violation and gauge breaking interaction between a detector and a quantum particle during the measurement process causing the emergent wave function collapse.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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