EVALUATION OF PARAMETERS FOR PARTICLES ACCELERATION BY THE ZERO-POINT FIELD OF QUANTUM ELECTRODYNAMICS

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1. Preliminaries. That particles may be accelerated by vacuum effects in quantum field theory has been repeatedly proposed in the last few years[1-10]. A natural upshot of this is a mechanism for cosmic rays (CR) primaries acceleration[2-3,7-12]. We have been concerned with a mechanism for acceleration by the zero-point field (ZPF) when the ZPF is taken in a realistic sense (in opposition to a virtual field)[2,3,7,8,11,12]. Originally the idea was developed within a semiclassical context[2,3]. We used the classical Einstein-Hopf model (EHM) to show that free isolated electromagnetically interacting particles performed a random walk in phase space and more importantly in momentum space when submitted to the perennial action of the so called classical electromagnetic ZPF.[1] The Einstein-Hopf drag force provided the counteracting dissipation which vanished because of the ZPF Lorentz-invariance. The model could be applied to polarizable particles like protons and nucleii. For monopolar particles like electrons it could be shown that there would be a quenching of the acceleration due to a time dilation effect associated to the ultrarelativistic oscillation of the center of charge of the particle around the center of mass. This was reminiscent of zitterbewegung but in the context not of an intrinsic but of a vacuum effect.[6] Energy spectra of the accelerated particles could be derived assuming several presumably extant dissipation mechanisms in intergalactic space (IGS) like interparticle collisions, bremsstrahlung, inverse-Compton collisions and cosmic expansion (CE) [2,3,7]. IGS particle densities were taken at 10^{-5}- 10^{-7} cm^{-3}. The cut-off in the energy spectrum imposed by CE could be avoided if there was enough magnetic confinement within the magnetic cavities of superclusters so that particles would not be adiabatically cooled [7] by CE.

2. Quantum Version of the Einstein-Hopf Model. In order to check if the ZPF acceleration, originally predicted semiclassically, also occurs within ordinary Quantum Electrodynamics (QED), one should develop a quantum version of the EHM[8,12]. The original EHM considered a linear dipolar oscillator, constrained to vibrate parallel to the z-axis, mounted on a particle restricted to move unidimensionally along the x-axis[13,14]. Such a model was only good for discussing matters of principle[1,13,14]. We had to extend the model to three dimensions in the vibrations and three dimensions in the translations[2]. The linearity assumption could be relaxed[15]. Recently we have developed a quantum version[8,12] of the EHM by means of the Abraham-Lorentz operator equation proposed by Moniz and Sharp[16] in their nonrelataivistic approach to QED. Among several desirable features this approach has the advantage of being nonperturbative in its approximations, a real advantage when dealing with the divergent energy spectrum of the ZPF.

3. Acceleration in the Time Symmetric Zero-Point Field. With the quantum model above we show that if the ZPF is represented as a time symmetric background random field, there is acceleration[12]. The time symmetry of the ZPF suggests itself naturally if one is willing to preserve the time constancy of Planck's constant $\hbar$ in an expanding Universe where the ZPF is a background field tied to particles, i.e., if the ZPF is not a free field but if it is generated by the motion of charges in the Universe as is usually assumed in Stochastic Electrodynamics[17]. So, one constructs the ZPF by superimposing half-advanced

and half-retarded plane wave operators as follows from simple second quantization of Wheeler and Feynman's radiant absorver theory[18]. The resulting average translational energy growth per proton is given by[12,8]

$$\left\langle \frac{dE}{dt} \right\rangle = \frac{15\alpha}{4\pi^3} \int_0^\infty d\omega \left(\frac{\hbar\omega}{Mc^2} \right)^2 \left(\Gamma_M \omega \right) \left(\hbar\omega \right) |g|^2 \qquad (1)$$

where α is the fine structure cosntant, e and M are the proton charge and mass respectively, $\Gamma_M = 2e^2 / 3Mc^3$ is the associated Abraham-Lorentz time parameter, and

with

$$g \equiv \left[\delta + i\sigma \right]^{-1} \qquad (2)$$

$$\delta \equiv \frac{m}{M} \left[\left(\left(\frac{\omega}{\omega} \right)^2 - \frac{m}{M} \right)^{-1} - 1 \right] . \qquad (3)$$

$$\sigma \equiv \left(\frac{\Gamma_m \omega}{3} \right) \sum_{s=0}^{\infty} \frac{(8s+9)}{(s+1)(2s+3)} \frac{(4s+1)!!}{(2s)!} \left(\frac{\omega}{\omega_c} \right)^{2s} \qquad (4)$$

where $\Gamma_m = \Gamma_M (M/m)$, m is the equivalent mass of the entity that oscillates inside the proton[19]. The summation results from going to the point particle limit[16] and $\omega_c = mc^2/\hbar$ is the corresponding Compton frequency. In practice one may take mc^2 to be approximately equal to a few MeV (H. Leutwyler, personal communication), and in principle m cannot be smaller than the quark's rest mass[19].

4. No Acceleration in the Time-Asymmetric Zero-Point Field. If the ZPF is represented as a time asymmetric (retarded) expansion of plane waves, it can be rigorously shown[12] at least up to the first iteration in the quantum EHM, that no acceleration takes place and $< dE/dt > = 0$. This result is to be expected if internal thermodynamic consistency of QED is demanded but one has to pay the price of not having a clear origin for the ZPF and of giving up interesting vacuum effects.

5. Evaluation of Parameters. When a Fokker-Planck equation is established for a dilute (10^{-5} - 10^{-7} cm^{-3})gas of protons under the influence of the ZPF plus a thermal background it can be numerically shown[12] that the ensueing very long relaxation time (much longer than the age of the Universe) implies that the mechanism of Section 3 works efficiently up to inelastic inverse Compton collisions energies (10^{18} eV, pair production) implying that other dissipation mechanisms like those mentioned above should be invoked to establish the energy spectrum of particles. The correspondance between the semiclassical $< dE/dt >$ and the quantum $< dE/dt >$ of Section 3 is quantitatively very good. All the previously proposed preliminary propagation models[2,7] may then easily be adapted to the quantum case[12]. Numerical evaluation of $< dE/dt >$ has been performed for a wide range of values of m/M (or ω_c). The fitting of the model to times consistent to expected CR propagation times taking care of the mentioned Greisen-Zatsepin effect is easily done for a rather wide margin of values of ω_c (or m/M)[20]. Unfortunately there is a paucity of data and of theoretical numerically tractable results on the proton polarizability response at the ultrahigh ZPF induced excitations frequencies that are expected[21,7].

6. SUMMARY. The acceleration mechanism was originally established semiclassically using the EHM in a classical stochastic version of the ZPF[2,3,6,7,11]. The acceleration was an

upshot of the Lorentz-invariance of the ZPF spectral energy density. By a quantum version of the EHM we have shown within QED that acceleration occurs for the time-symmetric version of the ZPF[7,12] but not for the time-asymmetric (retarded) version[12]. We hope this opens the way to an important new class of candidates for sources of acceleration of particles in the IGS, namely vacuum effects in quantum field theory.

7. Postcript. This postcript is written for the theoretically minded reader. We have performed the second quantization of the one half-advanced plus one half-retarded radiation in the Wheeler-Feynman absorver theory.[18] No attempt however has been made at a full quantization of an action at a distance theory which because of troublesome boundary conditions is not easily quantizable as is well known[22].

8. Acknowledgements. This work was sponsored by the Resource Center for Sciences and Engineering at the UPR in Rio Piedras. The author acknowledges the sponsorship of Professors M. Gòmez, J. Arce de Sanabia and J.F. Nieves.

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