Comment on "Source of vacuum electromagnetic zero-point energy"

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An error is pointed out in the calculation by Puthoff [Phys. Rev. A **40**, 4857 (1990)]. The result obtained is consistent with the interpretation of the zero-point field as dynamically generated by the motion of charged particles, but does not supply any explanation for the cosmic large-number coincidences.

The purpose of this Comment is to clarify what the correct implications of the calculations made by Puthoff [1] are. I start putting the problem in perspective.

The hypothesis of an electromagnetic radiation with energy $\frac{1}{2}\hbar\omega$ per normal mode, present even at the absolute zero of temperature, goes back to Planck in his second blackbody formula [2]. A short time after, Nernst proposed that such zero-point radiation could provide an explanation for the stability of atoms [3]. With the discovery of quantum mechanics in the 1920s, the zero-point radiation reappeared in a more firm basis as a straightforward consequence of field quantization. However, it lost the status of a real field to become a "virtual" or purely mathematical construction. Nevertheless, as time elapsed, the reality of the zero-point field has been increasingly accepted by the community in order to understand phenomena such as the Casimir effect or the squeezed states of light. In parallel, a few people have attempted to arrive at a (nonorthodox) understanding of quantum mechanics starting from Nernst's idea, rediscovered by Braffort *et al.* in the 1950s, by Marshall in the early 1960s, and by other people later, and developed since then under the name of stochastic (or random) electrodynamics [4]. The hypothesis that the zero-point field causes the quantum fluctuations and it is, on the other hand, created by these fluctuations in a self-consistent manner is the basis of stochastic electrodynamics, as expressed several times in the past [5]. The Puthoff calculation shows that this hypothesis is compatible with the cosmological standard model.

The essential content of the second and third (unnumbered) sections of the commented paper is the study of the classical scattering of electromagnetic radiation by a free charged point particle; that is, Thomson scattering. The calculation could have been considerably shortened by realizing that the scattering does not change either the spectrum or the isotropy of the radiation, which are rather trivial consequences of the isotropy of the radiation incoming in the particle plus the fact that Thomson scattering does not change the frequency of the radiation (in contrast with Compton scattering, for example). Then, the final result of the third section [formula (20)] could be written in terms of the Thomson cross section $\sigma=(8\pi/3)(e^2/mc^2)^2$ as

$$\rho_i=\rho_0\sigma/(4\pi r^2), \quad \rho_0=\hbar\omega^3/(2\pi^2c^3) . \tag{1}$$

In the fourth section, the author tries to relate the zero-point field with cosmology, but the calculation is wrong. His starting equation (24) can be written, using (1), as

$$\rho=\int \rho_i\eta 4\pi r^2\,dr=\int \sigma\rho_0\eta\,dr=\int \sigma\rho_0\eta c\,dt . \tag{2}$$

It can be shown that ρ_0 may be taken out of the integral, as the author does, and we get, for the relevant parameter γ, the result

$$\gamma=\rho/\rho_0=\int \sigma\eta(t)c\,dt , \tag{3}$$

which is just the (Thomson) optical depth for scattering of radiation by electrons, $\eta(t)$ being the number density of electrons in the universe at time t. The integral (3) is straightforward and we obtain the standard result [6]

$$\begin{aligned}\gamma&=\tfrac{2}{3}\sigma\eta_0 cH_0^{-1}[(1+z)^{3/2}-1]\\&\cong 0.02[(1+z)^{3/2}-1] ,\end{aligned} \tag{4}$$

in terms of the redshift z, H_0 being Hubble's constant and η_0 the number density of electrons at the present epoch. The optical depth diverges with $z\to\infty$, in contrast with the finite result obtained by Puthoff, the error in his calculation being due to incorrect cancellations of the z dependence in the factors of the integral (2).

The result obtained, Eq. (4), means that the zero-point radiation reaching us experienced last scattering from sources that range local sources out of about $z=13$, and has been scattered infinitely many times in the past. [Of course, most electrons in the universe are not free at present, but bound in hydrogen atoms. Therefore, the Thomson scattering formula and Eq. (4) are only valid for frequencies above, say, near ultraviolet. In particular, microwave radiation, either zero-point or thermal, has not been scattered since $z\cong 1000$.] In my opinion, this is more satisfactory for an interpretation of the zero-point field as dynamically generated by the motion of charged particles than previous Puthoff's result of a single scattering during the whole life of the universe. In my opinion, however, the result (4) does not supply a convincing explanation for the large-number coincidences mentioned at the end of the commented paper. The result merely shows again the relation between the large-number coincidences and the value of the Thomson optical depth [6].

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[1] H. E. Puthoff, Phys. Rev. A **40**, 4857 (1989).
[2] M. Planck, *Theory of Heat Radiation* (Dover, New York, 1959), English translation of *Vorlesungen uber die Theorie der Warmestrahlung.*
[3] W. Nerst, Verh. Dtsch. Phys. Ges. **18**, 83 (1916).
[4] See reviews of stochastic electrodynamics by L. de la Peña, in *Proceedings of the Latin American School of Physics, Cali, Colombia, 1982,* edited by B. Gómez *et al.* (World Scientific, Singapore, 1983); T. H. Boyer, Phys. Rev. D **11**, 790 (1975).
[5] See, e.g., E. Santos, An. Fis. (Madrid) **9**, 317 (1968); E. Santos, in *Open Questions in Quantum Physics,* edited by G. Tarozzi and A. van der Merwe (Reidel, Dordrecht, 1985), p. 283.
[6] Ya. B. Zel'dovich and I. D. Novikov, *The Structure and Evolution of the Universe* (University of Chicago, Chicago, 1983), p. 74.