

# Quantum electrodynamics based on self-fields: On the origin of thermal radiation detected by an accelerating observer

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We continue with our series of papers concerning a self-field approach to quantum electrodynamics that is not second quantized. We use the theory here to show that a (detector with a uniform acceleration  $a$  will respond to its own self-field as if immersed in a thermal photon bath at temperature  $T_a = \hbar a / 2\pi k c$ ). This is the celebrated Unruh effect, and it is closely related to the emission of Hawking radiation from the event horizon of a black hole. Our approach is novel in that the radiation field is classical and not quantized; the vacuum field being identically zero with no zero-point energy. From our point of view, all radiative effects are accounted for when the self-field of the detector and (not the hypothetical zero-point field of the vacuum, acts back on the detector in a quantum-electrodynamic analog of the classical phenomenon of radiation reaction.) When (the detector is accelerating, its transformed self-field induces a different back reaction than when it is moving inertially. This process gives rise to the appearance of a photon bath, but the photons are not real in the sense that the space surrounding the accelerating detector is truly empty of radiation, a fact that is verified by the null response of an inertially moving detector in the same vicinity. The thermal photons are in this sense fictitious, and they have no independent existence outside the detector.

## I. INTRODUCTION

In the wake of the discovery by Hawking of the apparent thermal emission from the event horizon of a black hole,<sup>1</sup> there came a related calculation by Unruh<sup>2</sup> that indicated that a uniformly accelerating particle detector would perceive a thermal bath of photons. If an idealized point detector is accelerating at a rate  $a$ , then the photon spectral distribution is Planckian at a temperature  $T_a = \hbar a / 2\pi k c$ , (where  $k$  is the Boltzmann constant) This thermal radiation is not picked up by an inertially moving detector, and the vacuum expectation of the normal ordered stress energy tensor  $T_{\mu\nu}$  is identically zero in both the inertial and accelerated or unprimed and primed frames,<sup>3</sup>  $\langle 0|:T_{\mu\nu}:|0\rangle = \langle 0|:T'_{\mu\nu}:|0\rangle = 0$ . In what sense then can one say that these thermal photons are physically real if they do not alter the above expectation values?<sup>3</sup> Davies argues that these results are indicative of a breakdown of (the traditional quantum field theoretical notion of a particle when space-time is curved.<sup>3</sup>) The present authors contend that the problem is not with the concept of particle but rather with the quantum field treatment of the vacuum field. Boyer has given an account of the Unruh effect in the framework of stochastic electrodynamics, which lends credence to the viewpoint that the acceleration somehow turns the virtual quanta of the Minkowski vacuum into real quanta.<sup>4</sup> In stochastic electrodynamics (the zero-point field is taken to be a very real thing, responsible for many quantum-electrodynamical phenomena.) The idea is that a classical vacuum with a spectrum proportional to  $\frac{1}{2}\hbar\omega$  per normal mode is permissible on the grounds of Lorentz invariance. If one chooses the proportionality constant appropriately, one recovers a classical vacuum field that is nearly identical to that predicted by the second quantization procedure in field theory) Boyer then shows that under acceleration, the zero-point term is deformed into a

zero-point plus Planckian spectrum at the Unruh temperature  $T_a = \hbar a / 2\pi k c$ . The transformation is

$$\hbar\omega \rightarrow \hbar\omega \left[ \frac{1}{2} + \frac{1}{e^{\hbar\omega/kT_a} - 1} \right], \quad (1)$$

where we will from now on set  $\hbar = c = a = 1$ .

But are these thermal photons really real? Indeed, one may ask if even the virtual Minkowski photons with the spectrum of  $\frac{1}{2}\hbar\omega$  have any real existence apart from (the detector that appears to register them, say, as the apparent "trigger" for spontaneous emission.) In stochastic electrodynamics the choice of a nonzero proportionality constant for the spectrum proportional to  $\frac{1}{2}\hbar\omega$  is permissible, but not required. The other obvious choice is to set the spectrum of the vacuum identically equal to zero as is done in classical electrodynamics. Where then would radiative effects such as spontaneous emission and the Lamb shift originate if not driven by the vacuum fluctuations, as is usually assumed in quantum electrodynamics (QED)? In classical electrodynamics there are two perfectly respectable phenomena which should correspond to the classical limit of spontaneous emission and the Lamb shift in atoms; they are line breadth and level shift in the energy, for instance, of a harmonically bound charge.<sup>5</sup> These radiative corrections to the otherwise unperturbed motion of the charge arise (not from any interaction with a zero-point field) — {the classical vacuum field is identically zero} — but rather from the radiation reaction on the charge from its own self-field. (The scale of the electromagnetic field fluctuations is set by the constant  $\hbar c$ ) so in the classical limit of  $\hbar \rightarrow 0$ , one would expect spontaneous emission and the Lamb shift to vanish and to have no classical analog since the causative agent, the zero-point field, has vanished. This is clearly not the case in that we are actually left with the classical line breadth and level shift of an oscillating charge. Barut