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Calculation of X-ray signals from Károlyházy hazy space-time

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Károlyházy's hazy space-time model, invented for breaking down macroscopic interferences, employs wave-like gravity disturbances. In that case, electric charges would radiate permanently. Here we discuss the observational consequences of the radiation. We find that such radiation is excluded by common experimental situations.

1. Introduction

In a series of papers [1–3], Károlyházy et al. discussed the idea that space-time haziness puts an eventual limit on quantum coherence of massive systems. The following fluctuation has been introduced for the metric tensor,

$$g_{00}(\boldsymbol{x}, t) = 1 + \gamma(\boldsymbol{x}, t) , \tag{1}$$

with the Fourier expansion

$$\gamma(\boldsymbol{x}, t) = \sum_{\boldsymbol{k}} \{c_{\boldsymbol{k}} \exp[\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{x} - \omega t)] + \mathrm{c.c.}\} , \tag{2}$$

where $\omega = ck$. For the other components of the metric tensor no definite suggestion was made; the knowledge of g_{00} is usually sufficient to describe nonrelativistic dynamics of masses. For technical simplicity, we have taken unity for the volume. The complex coefficients $\{c_{\boldsymbol{k}}\}$ are independent random variables of zero mean. The stochastic averages of squared moduli satisfy the following relations,

$$\begin{aligned} \langle |c_{\boldsymbol{k}}|^2 \rangle &= \Lambda^{4/3} k^{-5/3} , \quad k < 2\pi/\lambda_{\mathrm{cut}} , \\ &= 0 , \qquad \text{otherwise} , \end{aligned} \tag{3}$$

where $\Lambda = \sqrt{G\hbar/c^3} \approx 10^{-33}$ cm denotes the Planck length and λ_{cut} is the cutoff parameter originally set to 10^{-12}–10^{-13} cm [1–3]. Without a cutoff length the theory would be divergent.

In refs. [1–3], the nonrelativistic Schrödinger equation was considered on the random space-time (1). The effect of γ perturbing the metric tensor component g_{00} is equivalent to introducing the potential

$$V(\boldsymbol{x}, t) = \tfrac{1}{2} Mc^2 \tilde{\gamma}(\boldsymbol{x}, t) , \tag{4}$$

into the Schrödinger equation. The tilde stands for averaging over the particle's volume. According to the proposal of refs. [1–3], the wave function generally obeys the Schrödinger equation with potential (4) but, from time to time, instantaneous reduction processes interrupt the ordinary dynamic evolution.

In the present paper we concentrate on the periods of dynamic evolution between instantaneous reductions. We will calculate the electromagnetic radiation which is due to the electric charge of the particles, performing a forced oscillation influenced by potential (4). We find that the radiation would be surprisingly intensive and may be moderate only if the cutoff parameter λ_{cut} is critically high. This result may strengthen previous warnings [4,5] that eqs. (1)–(3) considerably overestimate the conceivable fluctuations of the space-time metric. The effect calculated here seems to be a direct and inevitable consequence of the Károlyházy model.

2. Dipole radiation of oscillating charged particles

In this section we calculate the electromagnetic ra-

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diation of a particle of charge e, performing oscillations forced by the fluctuations of the hazy space-time (1).

We start from the dipole formula [6] for the radiation intensity,

$$I_\omega = \frac{4e^2}{3c^3} |\ddot{\boldsymbol{x}}_\omega|^2 , \tag{5}$$

where $\ddot{\boldsymbol{x}}_\omega$ is the Fourier transform of the acceleration of the charged particle. The dipole approximation holds when the radiating charged source is much smaller than the wavelength λ. In our considerations the sources are the electrons and nuclei, hence eq. (5) remains valid well above $\lambda \simeq 10^{-13}$ cm. (For atomic matter the electron shell as well as the whole neutral structure has an extension of $\sim 10^{-8}$ cm. For larger wavelengths the system reacts as globally neutral.)

It is known [6] that the dipole radiation (5) can equally well be calculated from the classical acceleration of the particle, so, for the present purpose, we shall use the classical Newton equation of motion instead of the Schrödinger equation,

$$\ddot{\boldsymbol{x}}(t) = -\frac{1}{M} \nabla V(\boldsymbol{x}(t), t) + \text{other forces} . \tag{6}$$

To calculate the Fourier components of both sides, we make the following simplifying assumptions: (i) the amplitude of the forced oscillation is small compared to the wavelength λ of the driving field (4), verified later, (ii) the other forces influencing the particle, as compared to the gravitational driving force on the r.h.s. of eq. (6), are ignored. Then, from eqs. (2), (4) and (6), one obtains

$$\ddot{\boldsymbol{x}}_\omega = \tfrac{1}{2} c^2 (-\mathrm{i}\boldsymbol{k}) c_{\boldsymbol{k}} \exp(\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{x}) . \tag{7}$$

Substituting this result into eq. (5) and taking the stochastic average according to eq. (3) one gets

$$\langle I_\omega \rangle = \frac{4e^2}{3c^3} \langle |\ddot{\boldsymbol{x}}_\omega|^2 \rangle = \tfrac{4}{3} e^2 c \Lambda^{4/3} k^{1/3} . \tag{8}$$

There will be no radiation below the wavelength λ_{cut} of the spectrum of the driving force (4).

To calculate the spectral intensity of the radiation, invoke the well known rule

$$\sum_{\boldsymbol{k}} \to 4\pi \int \mathrm{d}\lambda\, \lambda^{-4} . \tag{9}$$

So from eq. (8) we obtain the final expression for the spectral intensity of the dipole radiation,

$$\left\langle \frac{\mathrm{d}I}{\mathrm{d}\lambda} \right\rangle = \tfrac{16}{3} (2\pi)^{1/3} \pi e^2 c \Lambda^{4/3} \lambda^{-13/3} , \quad \lambda > \lambda_{\text{cut}} ,$$
$$= 0 , \qquad \text{otherwise} . \tag{10}$$

Consequently, the total intensity can be estimated as follows,

$$\langle I \rangle = \int_{\lambda_{\text{cut}}}^{\infty} \mathrm{d}I \approx e^2 c \Lambda^{4/3} \lambda_{\text{cut}}^{-10/3} , \tag{11}$$

where a constant factor of order unity is ignored.

We have to justify assumptions (i) and (ii). From eq. (7) we obtain the Fourier transform of the particle's elongation,

$$\boldsymbol{x}_\omega = \tfrac{1}{2} c^2 \frac{\mathrm{i}\boldsymbol{k}}{\omega^2} c_{\boldsymbol{k}} \exp(\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{x}) . \tag{12}$$

By using the above expression together with eq. (3), the range of the squared amplitude of the forced oscillation is

$$\langle |\Delta \boldsymbol{x}|^2 \rangle \equiv \sum_{\boldsymbol{k}} \langle |\boldsymbol{x}_\omega|^2 \rangle \approx \Lambda^{4/3} \lambda_{\text{cut}}^{2/3} . \tag{13}$$

For the only reasonable cutoff values $\lambda_{\text{cut}} = 10^{-5}$–$10^{-13}$ cm, the average oscillation amplitude will be about 10^{-24}–10^{-26} cm. This extremely small amplitude directly justifies assumption (i). As for (ii), when the particle is not free, the forced oscillations, due to their extremely small amplitudes, will simply be superposed onto the nonrelativistic motion of the particles. Up to this, extremely good, approximation, the dipole radiation of the forced oscillations will not be affected by binding (or other) interactions. If in eq. (6) *other forces* act, they will cause, e.g., thermal radiation, which will be incoherently superposed onto the radiation (10).

Consequently, the calculated radiation formula (10) itself can be extended to interacting or even bound charged particles. Usually they will radiate decoherently, each according to eq. (10), provided the wavelength λ is much smaller than the separation of the charged particles. (An interesting exception is the radiation of nuclei bound in ideal crystals where the driving forces are strongly correlated even at wavelengths much smaller than the lattice constant.)

3. Discussion

For calculating the resulting radiation, one has to multiply the intensity (11) with the density of charges present, and integrate over the volume of the source. We count only the charges which are free or bound in a system larger than λ_{cut}. First consider the range $10^{-13} \leqslant \lambda_{cut} \leqslant 10^{-8}$ cm. Then all charged particles of atomic and even condensed matter would contribute decoherently to the radiation since the average separation of charges (electrons, nuclei) is larger than λ_{cut}. According to eq. (11), some 10^{23} charged particles of a mole (e.g. several grams) of any condensed matter would produce radiation with an overall intensity of $\sim 10^{10}$ erg/s if $\lambda_{cut} = 10^{-12}$ cm or, still a considerable value of ~ 1 erg/s if $\lambda_{cut} = 10^{-9}$ cm. In the spectrum the short-wavelength end $\lambda \approx \lambda_{cut}$ would dominate, so this radiation would mean hard γ- or X-rays: $\sim 10^{15}$ γ-photons if $\lambda_{cut} = 10^{-12}$ cm or $\sim 10^{8}$ Röntgen photons if $\lambda_{cut} = 10^{-9}$ cm, per each mole.

Such a number of hard photons is a dangerous radiation from e.g. lead used for shielding against γ-ray radiation, which would have been discovered long ago. Therefore certainly $\lambda_{cut} > 10^{-8}$ cm.

A great number of charged particles separated by a distance larger than the above distance can be most typically found in plasmas. Consider a gas at 1 atm, heated up above 3000 K. Then it is in the ionized plasma state and the average charge separation is approximately 10^{-6} cm. Then for $\lambda_{cut} \approx 10^{-6}$ cm from one mole (e.g. ca. $\frac{1}{4}$ m^3) of hot gas the radiation would be 10^{-10} erg/s, i.e. ~ 10 photons per second, each of energy ~ 100 eV.

This intensity is low; however at 3000 K the peak of the plasma thermal radiation is in the near infrared, while the 100 eV photons are somewhere between UV and X-rays. Their calculated intensity is by some 100 (!) orders of magnitude higher than the intensity of the thermal photons of the same wavelength.

Such nonthermal hard UV radiation should have been detected by detectors long ago, and it has not been. So $\lambda_{cut} > 10^{-6}$ cm. From the very essence of the model of Károlyházy et al. [1–3] follow that the cutoff parameter λ_{cut} should not be macroscopic, see, e.g., ref. [7]. Hence the remaining range is, e.g., $10^{-6} < \lambda_{cut} < 10^{-5}$ cm. Here it seems that the inevitable electromagnetic radiation would not necessarily result in trivially drastic effects. (Namely, for the plasma experiment, one mole of dilute plasma with 10^{-5} cm average ion separation would occupy a container of ca. 250 m^3 while the photon flux would be ca. one photon of 10 eV in a minute.)

So the fact that drastic UV radiation from very familiar kinds of matter around us and in laboratories is generally not detected leaves for the cutoff length necessary in the Károlyházy model [1–3] a narrow range,

$$10^{-6} < \lambda_{cut} < 10^{-5}\,\text{cm}\,.$$

Unfortunately this range seems to be excluded by cosmological considerations listed by us in a previous paper [5].

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