Comments and Addenda

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Photon-tachyon interactions and the isotropic photon flux

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The possibility of photon-tachyon interactions has been considered and the isotropic photon flux in the universe has been analyzed to place limits on this interaction. The results extend the stringent limits available for tachyon-bradyon interactions for small tachyon liberty masses. The excess of high-energy photons in the isotropic flux has also been interpreted in terms of photon-tachyon interactions.

In the last decade there has been considerable speculation on the possible existence of tachyons.[1,2] Although a recent result could be interpreted in terms of tachyons existing in cosmic-ray showers,[3] a reanalysis of the experimental arrangement has shown a systematic error in the system that was not allowed for.[4] When a correction is made for this the results are only marginally significant. Several groups have repeated the experiment and obtained negative results.[4-8] Other experiments have placed lower limits on the existence of tachyons and on the probabilities of particles decaying via tachyon emission.[9-13] However, even though there is no convincing experimental evidence available for the existence of tachyons, it is interesting to speculate on the possible consequences which can result if they do occur in nature.

If tachyons do exist it is kinematically possible for a photon to absorb a tachyon. After absorption the photon energy is E' and is related to the original photon energy E by

$$E'=\frac{-\mu^2}{2(\cos\theta-1)E}\ . \tag{1}$$

θ is the angle between the directions of the photons and μ is the liberty mass of the tachyon. From Eq. (1) it is evident that $E'>E$ for any θ if $\mu\geq 2E$.

It is possible to place limits on photon-tachyon interactions by considering the isotropic photon flux in the universe. The isotropic photon flux is dominated by a contribution from ~10^{13} photons $\text{cm}^{-2}\,\text{sec}^{-1}$ of ~10^{-3} eV photons associated with blackbody radiation.[14] If we assume that the low-energy photon flux was established early in the history of the universe, perhaps 10^{10} years ago, we can place limits on the photon-tachyon interaction by assuming that all the higher-energy isotropic photon flux is produced by absorption of tachyons by the 10^{-3}-eV photons. Possible E' values range from $\mu^2/4E$ to ∞. However, if isotropy is assumed, 87% of the interactions are such that θ ranges from 30° to 150°. This will result in a relatively narrow range of (0.27 to 3.73) μ^2/E for E'. $n(E')$, the number of photons after the interaction per cm^2 per sec, with an energy close to E, and $n(E)$, the number of photons before the absorption per cm^2 per sec, with an energy close to E, is given by

$$n(E')=\frac{n(E)\,T}{\tau}\ , \tag{2}$$

where T is the time period in which this process occurs and τ is the mean lifetime for a photon before it undergoes a tachyon absorption.

If we assume that the photon-tachyon interaction is a first-order process, the mean lifetime will be given by $\tau\sim f/g^2N$, where g is the photon-tachyon coupling constant with dimensions of inverse length (L^{-1}) and in units $\hbar=c=1$, f is a kinematic-

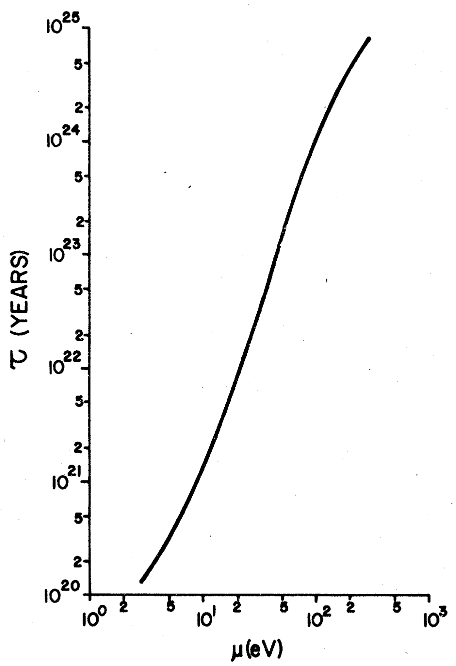

FIG. 1. The mean lifetime τ for photons as a function of the liberty mass μ of the absorbed tachyon.

ally dependent factor of dimensions L^{-3}, and N is the mean tachyon flux per unit energy interval in the period T.

In our case, if we assume T is about the age of the universe, we have

$$n(E') \sim \frac{10^{13} \times 10^{10}}{\tau \text{ (years)}} \quad .$$

For an isotropic system the μ values of the absorbed tachyon will be about $(2EE')^{1/2}$. $n(E')$ is known[14,15] and τ values derived from this for various μ values are shown in Fig. 1. The limits on τ are much higher than can be obtained from conventional laboratory investigations.

We have also made an estimate of f in the case where the photon field A_λ is coupled to the tachyon field ϕ via a first-order scalar interaction. This is described by a Lagrangian $L_I = g A_\lambda A_\lambda \phi$. Although this is not an isotropic system, the difference between the effects of this extra complication on the final results as compared with a simpler approach in which isotropy is assumed is not substantial, and we present an analysis based on an isotropic system. This is reasonable as the real, detailed photon-tachyon interaction is unknown, and any calculation of f depends on the form of the assumed interaction.

The x- and γ-ray regions of the isotropic photon flux spectrum have been investigated extensively

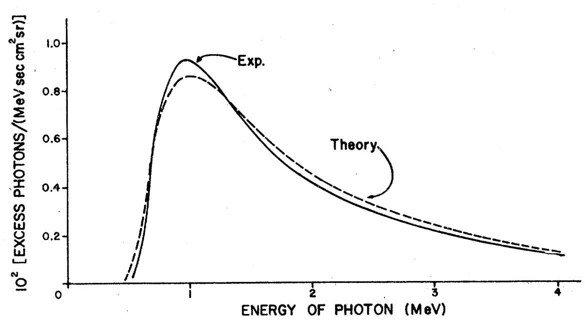

FIG. 2. The predicted spectrum of the excess photon flux for photons absorbing tachyons with a liberty mass of 55 eV is shown as a dashed line. The experimental data from Apollo 15 are shown as a continuous line.

in recent years and the spectra in these energy regions have been found to have an approximate inverse-square energy dependence.[15] However, an excess of photons over this general trend has been observed at energies above 0.5 MeV. This photon excess has excited considerable interest and several attempts have been made to explain this. Some of these are discussed in a review by Stecker[15]; other explanations have been offered by Clayton and Silk[16] and by Leventhal.[17] Despite these ingenious attempts at a theoretical explanation, the nature of the excess photon flux must still be regarded as an open question.

We suggest that the excess photon flux can be produced by the photons absorbing tachyons. The predicted photon flux distribution is shown in Fig. 2 along with the experimental data[18] from Apollo 15 for the excess photon flux. While there have been several different analyses of the experimental data on the excess photon flux, our data have been taken from the analysis of Leventhal[17]; we have also assumed a photon energy distribution based on Planck's law for a temperature of 2.7 K. The experimental results and the theoretical distribution imply a τ value of about 10^{24} years and a tachyon liberty mass of 55 eV. As the experimental data have uncertainties of 30%, our predicted distribution is in excellent agreement over a wide range of photon energies.

It is interesting to note that Narlikar and Sudarshan[19] have analyzed the problem of tachyons existing inside a cosmological framework. They conclude, assuming models based on an indefinitely expanding universe, and assuming tachyons were produced in a primordial explosion, that only very-low-mass tachyons could exist for any appreciable time on a cosmological time scale. Tachyons with μ values in the range we assumed would only have existed for short values of T (~10^2 years for $\mu \sim$ eV). In this case, from the kinematical conditions of Eq. (1) and conservation principles, it can be shown that τ would be of the same order as T.

However, tachyons are unusual and hypothetical particles and, assuming they exist, their behavior is unknown. It is therefore quite possible that the assumptions of Narlikar and Sudarshan are invalid. If we disregard these considerations our results can be regarded as extending the limits available for tachyon-bradyon interactions for tachyons with small liberty masses.

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