# *ON THE ABSORPTION OF GAMMA RAYS IN INTERGALACTIC SPACE*

P. GOLDREICH and P. MORRISON

Center for Radiophysics and Chemical Research, Cornell University, Ithaca, N.Y.

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Nikishov's calculations[1] on the absorption of high energy gamma rays in the universe are extended to collisions of photons of very high energy ($10^{18}-10^{20}$ eV) with radio waves. It is shown that these collisions can appreciably attenuate the gamma-ray flux over distances comparable to the reciprocal of the Hubble constant.

NIKISHOV[1] has shown that gamma rays with energy of the order of $10^{12}$ eV are incapable of covering distances on the order of the reciprocal of the Hubble constant, since the scattering of similar high-energy photons by optical photons occurs at a c.m.s. energy sufficient for the production of real electron-positron pairs, with appreciable cross section. We consider this interesting idea to be of importance to many astronomical and cosmological problems, and without involving any new considerations we have extended Nikishov's calculations to some cases which he does not consider.

Although the optical photons make the largest contribution to the flux of electromagnetic energy from outer space, an important role is also played in metagalactic processes by photons corresponding to oscillations in the meter band (we note, incidentally, that it is possible to obtain a sufficiently reliable estimate of the number of such photons). This is connected with the fact that even radio waves can cause conversion of gamma rays of suitable energy into electron-positron pairs, since the necessary cms energy can be obtained for arbitrary radiophoton energy, provided the photon participating in the reaction has sufficiently high energy.

The arguments presented below are based only on the Lorentz transformations and on the most general premises of quantum electrodynamics, which, we hope, remain valid at extremely high energies.

Inasmuch as the pair production cross section decreases sharply with decreasing cms energy, the energies $E_1$ and $E_2$ of the photons participating in the reactions with pair production should satisfy the condition

$$E_1E_2 \sim m^2c^4,$$

where m —electron rest mass.

We have estimated the density of the radiophotons in the metagalaxy using the results of radioastronomic observations in the region of the galactic pole[2]. The principal error is due here to the separation of the contribution of the galactic "corona" to the total radiation background. Following Shklovskiĭ[2], we have assumed that at high galactic latitudes the galactic "corona" is responsible for about 75% of the sky brightness.

It is interesting to note that although the observations in the centimeter band point to the existence of a "window" in the spectrum of the $10^{16}-10^{18}$ eV gamma rays, the lack of data in the infrared region does not permit determination of the mean path of the gamma rays with energies $10^{13}-10^{16}$ eV. There are likewise no radioastronomical data for wavelengths longer than 300 meters, so that the mean path of gamma rays with more than $10^{20}$ eV energy is likewise unknown.

The authors have considered, in addition, the possible pair production due to the interaction between high-energy gamma rays and the magnetic field of the metagalaxy. If we assume the latter to be $10^{-6}$ G, then the process indicated becomes appreciable only at energies in excess of $10^{24}$ eV[3].

Denoting by P(E) the probability per unit path length of pair production by a photon of energy E, we can supplement Nikishov's table[1] with the following data:

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|---|---|---|---|---|---|
| $10^{-20}$ $E$, eV: | 0.01 | 0.1 | 0.3 | 0.5 | 1.0 |
| $10^{27}$ $P$, cm$^{-1}$: | 0.45 | 2.5 | 3.6 | 4.1 | 4.7 |

[1] A. I. Nikishov, JETP **41**, 549 (1961), Soviet Phys. JETP **14**, 393 (1962).

[2] I. S. Shklovskiĭ, Kosmicheskoe radioizluchenie (Cosmic Radio Emission), Gostekhizdat, 1956.

[3] H. R. Reiss, J. Math. Phys. **3**, 59 (1962).

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