plasma may be formed in small volumes (the volume of a delta-electron track, mode-focusing volumes, and hot points in the focus of a laser, etc.), and must be taken into account when the effects are estimated. Cascade multiphoton ionization and the propagation of the front of multiphoton ionization are also possible.

An intense light field can also change the specific ionization of fast particles, adding its own quanta to the momentum of the field of a particle moving past the atoms, and producing bursts of multiphoton ionization at the instant when the particle crosses the maxima of the light-wave field; this marks the specific ionization of the track, with a spatial period $L = \pi v/(\omega - \vec{k}\cdot\vec{v})$, from which it is possible to estimate the particle velocity; since the velocity of an ultrarelativistic particle is close to the velocity of light in the gas, the period $L_{max} = \lambda/2(1 - \beta')$ may greatly exceed the wavelength of the light and can be readily observed. This method differs from marking the track by bursts of microwave breakdown [4] not only because we are using in our case multiphoton ionization for the marking, rather than breakdown, but also because the changeover to light with a short wavelength makes it possible to measure the velocities of ultrarelativistic particles in small regions of the medium.

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STATIONARY RELATIVISTIC GAS IN COSMIC OBJECTS AND γ BACKGROUND IN THE 1 - 20 MeV REGION

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As is well known [1], the spectrum of the x-ray and γ-ray background at 40 keV < hν < 1 MeV and the points at hν ∿ 30 MeV [2] and 100 MeV [3] are in good agreement with the power law $I_\nu \sim \nu^{-1.2}$. Recent measurements have revealed an increase of the background radiation in the region 1 < hν < 6 MeV [4]. In this paper this fact is interpreted as a superposition of the summary radiation from discrete sources of bremsstrahlung γ rays on the general power-law spectrum of the background.

Attempts were made earlier to explain the observed effect as the result of the γ activity of the nuclei Ni^{56} and Co^{56}, which are possibly synthesized in supernova explosions in galaxies [5], or else as the γ quanta produced in π^0-meson decays during the expansion period of the universe, corresponding to a red shift z ∿ 70 - 100 [6]. In the second variant it is assumed that the π^0 mesons are produced in collisions between the cosmic-ray protons and the intergalactic gas. Both interpretations contradict the latest experimental data. The first predicts a cutoff of the spectrum at 3.26 MeV, which is not observed [7], and the background intensity expected according to the latter at hν ∿ 30 and 100 MeV exceeds the observed value [2, 3].

There are a number of grounds for the hypothesis advanced in this article (that the background is due to bremsstrahlung radiation of relativistic plasma in the sources). First, heating as a result of the induced Compton effect of the low-frequency radiation leads to relativistic temperatures of all the electrons near powerful sources of infrared (quasars, nuclei of galaxies) and radio emission [8]. It is possible that heating by shock waves, by alternating magnetic fields, etc., also leads to relativistic electron temperatures. Second, calculation of the equilibrium concentration of the positrons in a stationary optically-thin relativistic plasma has shown that at an electron temperature $kT \simeq 20$ MeV (or at a medium energy in the absence of a Maxwellian distribution), catastrophic pair production sets in [9], an increase takes place in the energy loss to bremsstrahlung and synchrotron, in the case of the Compton effect of low-frequency radiation, etc. The density of the electron-positron pairs is then determined only by the rate of energy release from the source, and the temperature becomes stabilized at the 20-MeV level.

The conclusion drawn in [9] can be easily understood. The positron concentration under stationary conditions is determined by the equilibrium between two processes: pair production

$$e^- + p,\quad e^-, e^+ \rightarrow e^- + p, e^-, e^+ + e^+ + e^-$$

and annihilation

$$e^+ + e^- \rightarrow 2\gamma\,.$$

The cross section of the first process far from threshold is practically independent of the energy, and that of the second process decreases rapidly, $\sigma \sim 1/E^2$. At $E \sim 20$ MeV, the cross section of the first process becomes larger than the cross section of the second, the number of positrons becomes close to the number of electrons, and pair production on the positrons and on the newly-produced electrons becomes important, i.e., the number of pairs increases rapidly.

The conclusions are not affected by the assumption that the energy distribution is Maxwellian; all that matters is that the average electron energy is high. Usually one considers a second case, when fast particles are injected in the given region of space; these particles leave the region and simultaneously lose energy. Our estimates pertain only to a plasma with a lifetime larger than the time of equilibrium establishment. Observations of a plasma with an electron temperature (or an effective energy) much higher than critical indicate that the plasma stays in such a state for a short time.

The existence of relativistic plasma in the interior and in the vicinity of quasars, nuclei of galaxies of radio sources, and other powerful sources of low-frequency radiation should transform them into sources of γ radiation with a characteristic spectrum. In astrophysics one usually considers power-law spectra of hard radiation, resulting from the inverse Compton effect on the low-frequency radiation or synchrotron emission in the magnetic field of relativistic electrons having a power-law spectrum and constituting a negligible fraction of all the electrons in the objects. Regions in which all the electrons are heated to relativistic temperatures and have a Maxwellian distribution emit bremsstrahlung γ quanta with a spectrum given by $I_\nu = \mathrm{const} \cdot \exp(-h\nu/kT_e)$, i.e., when $h\nu \ll kT_e$ the intensity is practically independent of the quantum energy, and when $h\nu \gg kT_e$ it decreases exponentially. The results of the present article, which point to the presence of an upper temperature limit $kT_e = 20$ MeV for the stationary relativistic plasma (its lifetime should exceed the positron-production time), impose conditions also on the spectrum of the discussed γ sources, which should be cut off exponentially at $h\nu \sim 20$ MeV. It is interesting that positron production leads to an increase of the degree of emission and intensity of the γ radiation. The upper luminosity limit is determined only by the power of the source of heating. Annihilation of the positrons and electrons as a result of their high energy cannot lead to emission of a γ line with $h\nu \sim 0.511$ MeV, and since the positron production rate is a process weaker by a factor of 137 than bremsstrahlung, the annihilation does not influence the γ intensity in the continuous spectrum. Since quasars and powerful radio sources undergo a strong cosmological evolution in analogy with the situation with the background in the radio band, it can be assumed that the main contribution to the background is made by sources emitting at a red shift $z \sim 2$. In this case, the exponential cutoff occurs at $h\nu \sim 7$ MeV. We note that the total energy density of the background radiation in the 1 - 6 MeV region amounts to only 3×10^{-5} eV/cm^3, which is smaller by three or four orders of magnitude than the energy density of the background radiation in the infrared band [10]. We see therefore that the consumption of a small fraction of the total infrared-radiation source power in the heating of the electrons to relativistic temperatures can fully account for the observed distortions of the γ background.

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ORIGIN OF THE X-RADIATION OF THE METAGALAXY

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There is no unified point of view at present concerning the origin of the metagalactic x-radiation. Felten and Morrison [1] considered the possibility that the sources of relativistic electrons responsible for the diffuse x-ray background are powerful radio galaxies with a spectral index $\alpha = 0.7 - 0.8$. Longair and Syunyaev [2] criticized this point of view, for within the framework of this model it is difficult to explain the observed form of the x-ray spectrum, and in particular the kink of the spectrum in the energy region 20 - 40 keV. This difficulty led Brecher and Morrison [3] to another hypothesis concerning the origin of the background x-rays. They showed that the form of the observed x-ray spectrum agrees well with the spectrum of the electrons of our galaxy. They therefore believe that the leakage electrons from normal galaxies produce the x-radiation by Compton scattering from the relict radiation. It is necessary in this case to choose a leakage time $\tau = 10^6$ years. Within the framework of this model, however, it is difficult to explain the experimental value of the flux of x-radiation, for this requires that the total