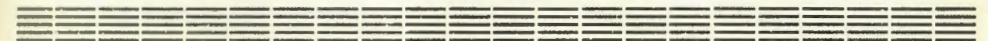


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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ
YEREVAN PHYSICS INSTITUTE



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COSMIC RAY POSITRONS CONNECTED WITH
DIFFUSE GALACTIC GAMMA-RAYS OF HIGH
AND VERY HIGH ENERGIES



ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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ПОЗИТРОНЫ В СОСТАВЕ КОСМИЧЕСКИХ ЛУЧЕЙ, СВЯЗАННЫЕ С
ДИФФУЗНЫМ ГАЛАКТИЧЕСКИМ ГАММА-ИЗЛУЧЕНИЕМ ВЫСОКИХ
И СВЕРХВЫСОКИХ ЭНЕРГИЙ

Предлагается модель, согласно которой наблюдаемые в составе космических лучей позитроны высоких энергий ($E \geq 10$ ГэВ) своим происхождением обязаны взаимодействию гамма-квантов с оптическим и ультрафиолетовым излучением непосредственно вблизи локальных источников, ответственных за диффузное космическое гамма-излучение с $E_\gamma \approx 10^{15}$ эВ. В рамках данной модели удается объяснить как наблюдаемое резкое возрастание отношения позитронов к электронам $r_+(E) = e^+ / (e^+ + e^-)$ в составе КЛ в области $E \geq 10$ ГэВ, так и спектры электронов в области энергий $E \leq 10^{12}$ эВ.

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1. Introduction

Recently, in cosmic rays (CR) a gamma-ray flux at energies $E \geq 10^{15}$ eV has been observed on the level $J_\gamma / J_{CR} \approx 10^{-3}$ [1,2], which is two orders of magnitude greater than the relevant ratio in a small energy range $E \leq 1$ GeV. The peculiarity of this result becomes evident when comparing the energy release in gamma- and cosmic rays, i.e.

$$\kappa = \frac{W_{cr}}{W_\gamma} \approx \frac{J_{CR} (\geq 5 \cdot 10^{15} \text{ eV})}{J_\gamma (\geq a \cdot 5 \cdot 10^{15} \text{ eV})} \frac{L/C}{t_{CR}} \quad (1)$$

Here $L \approx 1$ kpc is the typical size of CR capture region (the thickness of the galactic disk), $t_{CR} \approx 10^5$ yr is the supposed CR confinement time at $E \geq 10^{15}$ eV [3]. It is also assumed that the gamma-rays are of a secondary origin, i.e. they are produced in the interactions of accelerated CR with ambient medium, and the factor $a \approx 0,1$ corresponds to the mean fraction of the parent CR initial energy transmitted to the gamma-rays created. Substituting the values of $J_{CR} (\geq 5 \cdot 10^{15} \text{ eV}) \approx 10^{-11} \text{ cm}^{-2} \text{ s}^{-1} \text{ ster}^{-1}$ and $J_\gamma (\geq 5 \cdot 10^{14} \text{ eV}) \approx 5 \cdot 10^{-13} \text{ cm}^{-2} \text{ s}^{-1} \text{ ster}^{-1}$ into Eq.(1), one obtains $\kappa \approx 1$. This means that the protons pass a distance of the order of their free path. For example, if gamma-rays are produced due to interactions of accelerated protons with matter, then they should pass through 100 g/cm^2 of it. Therefore, the ultrahigh energy gamma-radiation observed in CR cannot be produced in interstellar medium and,

in fact, should result from the superposition of gamma-radiation of unresolved discrete sources. That is why we shall further use the word "diffuse" in quotes.

What is the nature of these sources? It follows from the analysis of gamma-ray absorption in the microwave background radiation (MBR) field, that they are produced in a region of $R \leq 10$ kpc, i.e. in the Galaxy. Would the sources be homogeneously distributed in the Galaxy, then a pronounced disk anisotropy of gamma-ray flux should be expected. However, the Akeno data indicate that the observed "diffuse" flux is connected with the extensive air showers (EAS) coming mainly from high galactic latitudes, and only partially is related to the EAS coming from different directions of the galactic plane. Therefore, the size scale of the production region should not exceed the thickness of the galactic disk ($R \leq 0.5$ kpc). Then the probable sources of ultrahigh energy gamma-rays seem to be connected with the intensive star formation regions, and most probably, with the close vicinity of hot OB stars of Gould Belt [4]. Note that at present these objects are widely discussed as sources of high-energy gamma-rays ($E_\gamma \geq 100$ MeV) [5,6].

The detailed information on the diffuse component of gamma-radiation in the energy range $E_\gamma \geq 100$ MeV is obtained on the satellites SAS-2 [7] and COS B [8]. An essential fraction of this emission is unambiguously related to the galactic disk emission (due to interaction of CR with interstellar medium), whereas the origin of the so-called isotropic component remains quite open so far. It may be of an

extragalactic origin as well as may be (at least partially) of a local origin, being connected with a region of the size $R \leq 1$ kpc. Hence, the observed value of the flux of isotropic component, $J_\gamma(\geq 100 \text{ MeV}) \approx 10^{-5}$ ph/cm² s ster [7], may be used as the upper limit for the flux of gamma-rays with energy $E_\gamma \geq 100$ MeV, which are genetically connected with the "diffuse" ultrahigh energy gamma radiation. Further on we shall call this component (extending from 10^8 eV up to 10^{15} eV) a local gamma-ray component (LGC) assuming the typical size of the production region to be less than several hundreds of pc. Then, suggesting the power-law spectrum of gamma-rays in this energy range and using the data of SAS-2 [7] and Akeno [2], we find the upper limit to the index α of the differential spectrum:

$$\alpha = 1 + \frac{\ln J_\gamma(\geq 10^8 \text{ eV}) / J_\gamma(\geq 10^{15} \text{ eV})}{7 \ln 10} = 2.1 \quad (2)$$

If the gamma-rays result from the interactions of protons with ambient matter (production mechanisms related to the electron component of CR seem to be negligible at these energies due to intensive synchrotron and Compton energy losses), then the power-law index α_p of proton spectrum should be the same as the index of gamma-ray spectrum. Taking into account that the index α_p of CR within the sources is discussed to be in the interval $\alpha_p \approx 2.1 + 2.3$ [9,10], we may conclude that the gamma-ray spectral index cannot be much

less than the upper limit $\alpha=2.1$.

It should be noted that the spectrum of gamma-rays escaping from the source may be essentially distorted due to interactions with ambient media. In the case under consideration, where the star formation regions are thought to be responsible for LGC, the interactions of gamma-rays with optical and ultraviolet radiations of young stars seem to be most important (Sec.IV). Obviously, this may lead to the initial gamma-ray spectrum distortion, particularly in the energy range 10^{10} - 10^{14} eV. Therefore, the investigation of gamma-ray spectra at these energies will provide valuable information concerning the gamma-ray production and absorption mechanisms as well as the physical conditions inside the sources.

Exploration of LGC in this energy range may play a more important role as to the fundamental problems of the origin of CR. The present paper is devoted to one of these problems, namely, that of an anomalously high content of high-energy positrons ($E \geq 10$ GeV) in primary CR.

In a number of recent independent experiments [11-13] a sharp increase of the content of positrons in CR at energies $E \geq 10$ GeV has been observed. Such a behaviour of $r_+(E) = z e^+ / (e^- + e^+)$ is not explained in frames of standard models assuming the secondary origin of positrons to be due to interactions of CR with interstellar medium (e.g., ref. [14]). Presumably, new ideas and approaches are needed to interpret this effect.

Which are the questions to be answered?

1. The positron flux at energies $E \geq 10$ GeV arises suddenly; at least the ratio $r_+ = z e^+ / (e^- + e^+)$, increases up to $r_+ = 0.2$ at $E = 14 \pm 20$ GeV, being $r_+ \leq 0.05$ at $E \approx 3$ GeV [12].

2. Such a sharp increase of the flux of the new component of positrons should be further saturated not to contradict to the absolute flux of CR electrons at $E \approx 1$ TeV¹.

In the present paper we propose a model which makes it possible to understand and explain the observed peculiarities of both the ratio $r_+(E)$ and the total electron spectrum. The basic idea of the model consists in the assumption that prior to escaping from the source the gamma-rays responsible for LGC interact (at least partially) with the surrounding optical and ultraviolet radiation producing e^+e^- pairs.

2. Interaction of LGC with Optical Radiation in the Source

Let the observed LGC is produced in N discrete sources. For simplicity we assume, that these sources are approximately of the same power and are homogeneously distributed in a region with a characteristic size R_0 (≤ 1 kpc). Note that in this case the precise value of N is not critical, and the most important parameter is the gamma-ray production rate $Q_\gamma(E_\gamma)$ (in units of photons/cm³ s ster eV).

¹It should be noted that such contradiction may arise in the model of Harding and Ramaty [15], where the e^+e^- production in pulsars is discussed, if the cut-off in the e^+e^- spectrum of a pulsar at $E \approx 1$ TeV is not supposed.

i.e. observed differential flux $J_\gamma(E_\gamma)$ is related to $Q_\gamma(E_\gamma)$ as

$$J_\gamma(E_\gamma) = \int_0^{R_0} \frac{Q_\gamma(E_\gamma)}{4\pi R^2} R^2 dR d\Omega, \quad (3)$$

or in case of homogeneous distribution of sources

$$Q_\gamma(E_\gamma) = \frac{4\pi}{R_0} J_\gamma(E_\gamma) \quad (4)$$

Assuming a power-law dependence for $J_\gamma(E_\gamma) \propto E_\gamma^{-2.1}$ and using the observed values of the integral flux $J_\gamma(>E_\gamma)$ at $E_\gamma = 100$ MeV ($\approx 10^{-5}$ ph/cm²s ster [7]) and $E_\gamma = 10^{15}$ eV ($\approx 3 \cdot 10^{-13}$ ph/cm² s ster [2]), we obtain:

$$Q_\gamma(E_\gamma) = Q_0 (E_\gamma / 10^{15} \text{ eV})^{-2.1} \quad (5)$$

$$Q_0 = 1.38 \cdot 10^{-48} \frac{1 \text{ kpc}}{R_0} \left(\frac{1}{\text{cm}^3 \cdot \text{s} \cdot \text{ster} \cdot \text{eV}} \right)$$

Now suppose, that prior to leaving the source (sources) gamma-rays interact with the ambient low-frequency photons with mean energy ϵ_0 , and consider the case of an optically thin target. The pair production spectrum $Q_+(E)$ in the general case has been studied in ref.[16]. In the particular case of a power-law distribution of gamma-rays, the production spectrum $Q_+(E)$ has the following characteristic shape: starting from the threshold energy $E_* = m^2 c^4 / 4\epsilon_0$ of the particles produced, the spectrum sharply rises reaching the maximum at $E \approx (2-4)E_*$, and then at $E \gg E_*$ it decreases as

$Q_+(E) \propto E^{-(\alpha+1)} \ln(E/E_*)$. For further calculations the following analytical approximation for the pair production spectra per interaction will be used:

$$q_e(E) dE = f(\alpha) \frac{e^{-1/(\alpha-1)}}{E_* \cdot x \cdot (1+0.07 x^\alpha / \ln x)} dE, \quad (6)$$

where $x = E/E_* \geq 1$, and $f(\alpha) = 1.11(1 - 1.44\alpha + 1.06\alpha^2)$. For $\alpha \approx 3$ this approximation provides an accuracy better than 20% (note that the accuracy at $\alpha \approx 2$ is about 5%).

The spectrum (6) corresponds to creation of 2 electrons (e^+ and e^-) per 1 gamma-quantum, i.e. $\int q_e(E) dE = 2$.

To obtain the electron production spectrum $Q_e(E) = 2Q_+(E)$, we should determine the number of interactions of gamma-rays averaged over the volume $V_0 (R \leq R_0) = \frac{4}{3}\pi R_0^3$. Note that the total number of gamma-rays (produced in the volume V_0 in unit time) capable to interact with the field photons is then equal to $N_\gamma = V_0 \cdot Q_\gamma(>\tilde{E}_\gamma)$, where $\tilde{E}_\gamma = (m_0 c^2)^2 / \epsilon_0 = 4E_*$ is the threshold energy of pair production at photon-photon collisions, and $Q_\gamma(>\tilde{E}_\gamma) = \int_{\tilde{E}_\gamma}^{\infty} Q(E_\gamma) dE_\gamma$. Hence, the total number of e^+e^- pairs produced per ls is equal to $\dot{N}_+ = \tau_{\gamma\gamma} \dot{N}_\gamma(>\tilde{E}_\gamma) = \tau_{\gamma\gamma} V_0 Q_\gamma(>\tilde{E}_\gamma)$, where $\tau_{\gamma\gamma} = l n_{\text{opt}} \sigma_{\gamma\gamma}$ is the optical depth accumulated by a gamma-quantum with energy $E_\gamma > \tilde{E}_\gamma$ when travelling the distance l inside the source. For the power-law spectra of gamma-rays $Q_\gamma(E_\gamma) \propto E_\gamma^{-\alpha}$ the averaged pair-production cross-section

$$\bar{\sigma}_{\gamma\gamma}(\alpha) = \int \sigma_{\gamma\gamma}(E_\gamma) Q_\gamma(E_\gamma) dE_\gamma / Q_\gamma(>\tilde{E}_\gamma) \quad (7)$$

is a weak function of α . The numerical calculations show

that $\bar{\sigma}_{\gamma\gamma} = 0.85 \cdot 10^{-25} \text{ cm}^2$ at $\alpha=1.5$; $\bar{\sigma}_{\gamma\gamma} = 0.91 \cdot 10^{-25} \text{ cm}^2$ at $\alpha=2$; and $\bar{\sigma}_{\gamma\gamma} = 0.83 \cdot 10^{-25} \text{ cm}^2$ at $\alpha=2.5$.

Dividing \dot{N}_+ to the volume V_0 , we obtain the mean number of interactions in the unit volume per unit time.² So, the production rate for secondary electrons can be written as:

$$Q_e(E) = \tau_{\gamma\gamma} Q_{\gamma}(>E_{\gamma}) q_e(E) \quad (8)$$

where $q_e(E)$ is defined from Eq.(6). The production rate $Q_e(E)$ being known, one may determine the equilibrium electron spectrum $n(E)$ in the interstellar medium using the familiar stationary diffusion equation

$$\frac{d}{dE} [P(E) \cdot n(E)] - \frac{n(E)}{t(E)} + Q_e(E) = 0. \quad (9)$$

Here $P(E)$ is the electron energy loss rate, $t(E)$ is the CR electron confinement time in the interstellar medium. Following ref.[14] we will use the dependence $t(E) \propto E^{-\delta}$ with the index δ in the interval $0 \leq \delta \leq 0.55$ ($E \geq 10 \text{ GeV}$):

$$t(E) = t_0 (E/10 \text{ GeV})^{-\delta}; \quad t_0 \approx 10^7 \text{ years} \quad (10)$$

In the electron energy range of interest the energy loss rate $P(E)$ is predominantly due to synchrotron radiation and

²Note that though the γ -rays interact with optical and UV photons in the vicinity of discrete sources, the consideration of characteristic production rates averaged over the volume V_0 (wherein the sources are supposed to be homogeneously distributed) seems convenient.

inverse Compton scatterings:

$$P(E) = \frac{4}{3} \sigma_T c \left[W_B + W_{\text{opt}} + W_{\text{MBR}} \right] \left[\frac{E}{m_0 c^2} \right]^2 \quad (11)$$

where W_B , W_{MBR} and W_{opt} are the energy densities of magnetic field, microwave background radiation, and optical radiation in the interstellar medium, respectively. It should be noted, however, that this expression for $P(E)$ is correct for electron energies $E \ll 100 \text{ GeV}$, since at energies $E \geq 100 \text{ GeV}$ the condition of a Thomson scattering of electrons on optical photons does not hold, and the energy losses in the optical photon field are essentially weakened. Since in the interstellar medium $W_{\text{opt}} \leq W_B + W_{\text{MBR}}$, the neglect of this effect may lead to a noticeable error (up to a factor of 2). For present calculations we have taken $W_B = 0.4 \text{ eV/cm}^3$; $W_{\text{MBR}} = 0.25 \text{ eV/cm}^3$ and $W_{\text{opt}} = 0.45 \text{ eV/cm}^3$.

Using Eq.(8), the general solution of Eq.(9) can be written as:

$$N(E) = \tau_{\gamma\gamma} F(E), \quad (12)$$

where

$$F(E) = \frac{Q_{\gamma}(>E_{\gamma})}{P(E)} \int_E^{\infty} q_e(x) \exp \left[- \int_E^x \frac{dy}{t(y)P(y)} \right] dx \quad (13)$$

Note that the expected differential flux of electrons is

$$I_0(E) = \frac{c}{4\pi} N(E). \quad (14)$$

The spectra of electrons and positrons calculated in the frames of the suggested model for the values of the parameter $\delta=0, 0.4, 0.5$ are presented in Fig.1a ($\epsilon_0=10$ eV) and Fig.1b ($\epsilon_0=30$ eV). The spectrum $J_0(E)$ calculated without account of "damping" of radiative energy losses of electrons in optical photon field (due to Klein-Nishina cross-section) is shown in Fig.1b by a dashed line. All the other curves are obtained with this effect being taken into account, and are normalized so as to provide the ratio $r_+ \equiv e^+/(e^-+e^+) = 0.2$ observed at $E=17$ GeV [12]. As it follows from these curves, the values of $\delta \geq 0.55$ lead to inconsistency of the calculated spectra with the total electron flux detected at $E_\gamma \geq 100$ GeV. This is the consequence of a more intense leakage of electrons from the confinement region at higher δ , which requires too high production rates of e^+e^- pairs at energies $E \approx 1$ TeV to provide the observed positron flux at $E=17$ GeV. At the same time, in case of $\delta \leq 0.4$ the observed spectral fluxes of electrons and positrons can be satisfied in the frames of the proposed model for both values of $\epsilon_0=10$ eV and $\epsilon_0=30$ eV of optical photon mean energies. Note that it is difficult to obtain a good agreement with experimental data if the photon energy ϵ_0 is both well above or well below the energy interval 10 eV $\leq \epsilon_0 \leq 30$ eV.

As was noted above, the spectra in Figs 1a,b are obtained so as to satisfy the value of the ratio $r_+=0.2$ observed at $E=17$ GeV. The gamma-ray production spectrum and the optical photon energy being given, the only free parameter defining the absolute value of electron and

positron fluxes expected is the characteristic optical depth $\tau_{\gamma\gamma}$ of the source. For the ratio $r_+(E)$ we have

$$r_+(E) = \frac{c \tau_{\gamma\gamma} F(E)}{8\pi I_\Sigma(E)} \quad (15)$$

where $F(E)$ is given by Eq.(13), $I_\Sigma(E)$ is the observed differential flux of electrons (e^- and e^+). Taking advantage of this relation and using the data observed for $r_+(E)$ and $I_\Sigma(E)$ at $E=17$ GeV, we find the $\tau_{\gamma\gamma}$ needed. It is seen from the numerical results presented in the Table, that the required values of $\tau_{\gamma\gamma}$ vary within $0.1 < \tau_{\gamma\gamma} < 1$.

Table

ϵ_0 (eV)	$\tau_{\gamma\gamma}$		
	$\delta=0$	$\delta=0.4$	$\delta=0.55$
10	0.29	0.54	-
30	0.17	0.60	1.5

Let us now estimate the characteristic size l of the source, assuming the blackbody (gray) nature of the optical radiation. In this case the field photon density is determined by the temperature T_γ and the "gray" radiation parameter $\kappa \leq 1$. For the average pair production cross-section $\bar{\tau}_{\gamma\gamma} = 0.9 \cdot 10^{-25} \text{ cm}^2$ one obtains:

$$l \approx 1.5 \cdot 10^{10} \left(\frac{3 \cdot 10^4}{T_\gamma} \right)^3 \frac{\tau_{\gamma\gamma}}{0.3} \kappa^{-1} \text{ cm} \quad (16)$$

Note that a similar estimate for the characteristic

source size can be obtained also in the case when the optical photon source is a thin spherical layer with a curvature radius about l . This is explained by the fact that the photon density outside the source decreases as $\propto (R/l)^{-2}$, so the number of optical photons encountered by gamma-rays outside the source (practically within the distances $R \leq 2+3 l$) along the line of sight is of the same order as the one inside the homogeneous spherical source (e.g., see [17]).

It worths while noting that the obtained estimate for l as well as the required values of the radiation temperature $T_r \geq 3 \cdot 10^4$ K (the mean photon energy $\epsilon_0 \approx 3 kT_r \geq 10$ eV) correspond to the typical values of these parameters in hot young stars (e.g. Wolf-Rayet or OB stars.)

The discussion of the possible models of gamma-ray production in these objects is out of the frames of this paper. Here we'd like only note that, according to contemporary ideas, an essential fraction of the diffuse gamma-radiation, namely, the gamma-radiation from the Gould Belt, is produced in the active star formation regions, particularly in OB associations.

3. Conclusion

The anomalously high content of positrons in CR at energies $E \geq 10$ GeV is in an apparent contradiction with the standard models suggesting the positron production due to interactions of CR with the interstellar matter. Here we propose a model according to which the positrons are produced

in discrete sources due to interactions of high-energy gamma-rays with the optical (and/or UV) radiation. This model allows one to satisfactorily explain the observed sharp increase of the ratio $r_+(E) = e^+ / (e^+ + e^-)$ without any contradiction with the total differential spectrum of electrons and positrons detected. The model requirements to the power of the sources are quite acceptable. In particular, assuming that the observed diffuse gamma-radiation of ultrahigh energies is due to superposition of gamma-rays from unresolved discrete galactic sources within the radius $R \leq 1$ kpc, we conclude that the necessary optical depth of a typical source with respect to photon-photon interaction will vary within $0.1 < \tau_{\gamma\gamma} < 1$. These values of $\tau_{\gamma\gamma}$ can be readily provided in the vicinity of hot young stars which seem to be possible candidates for the sources of LGC.

Obviously, for further verification of the model proposed, the measurements of the differential spectra of both electrons and positrons at energies $E \geq 100$ GeV will be very informative. Such measurements are planned in the future experiment with "ASTROMAG" [18].

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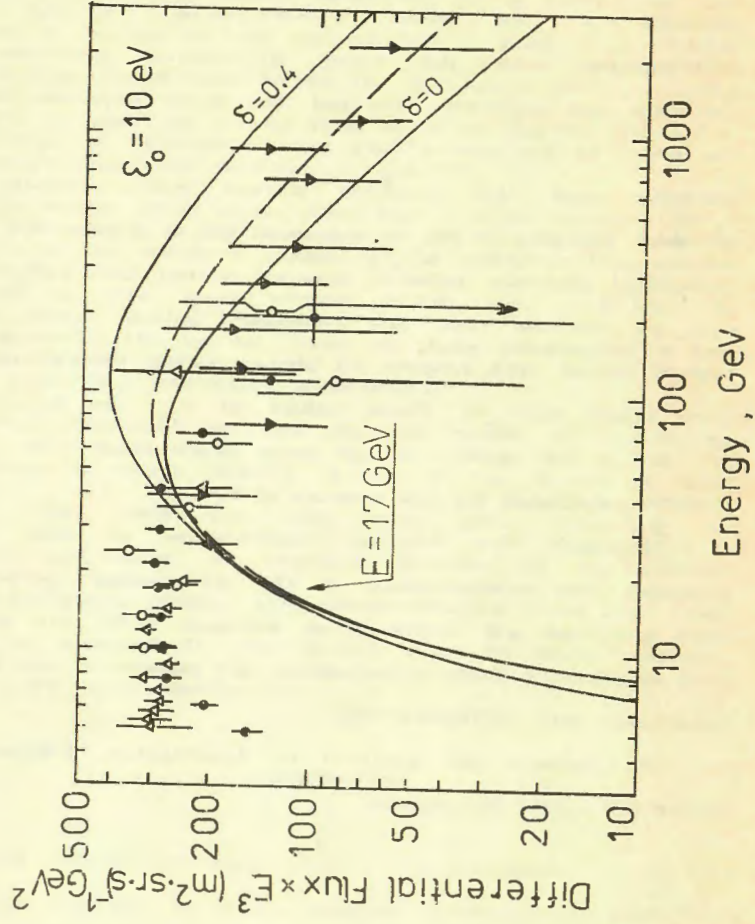


Fig. 1a

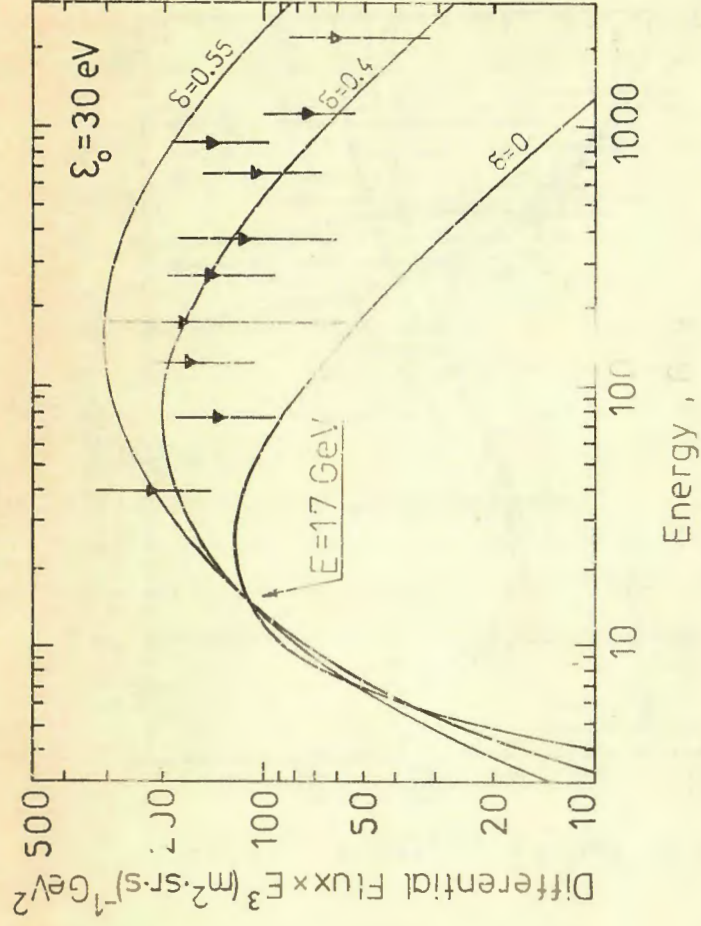


Fig. 1b

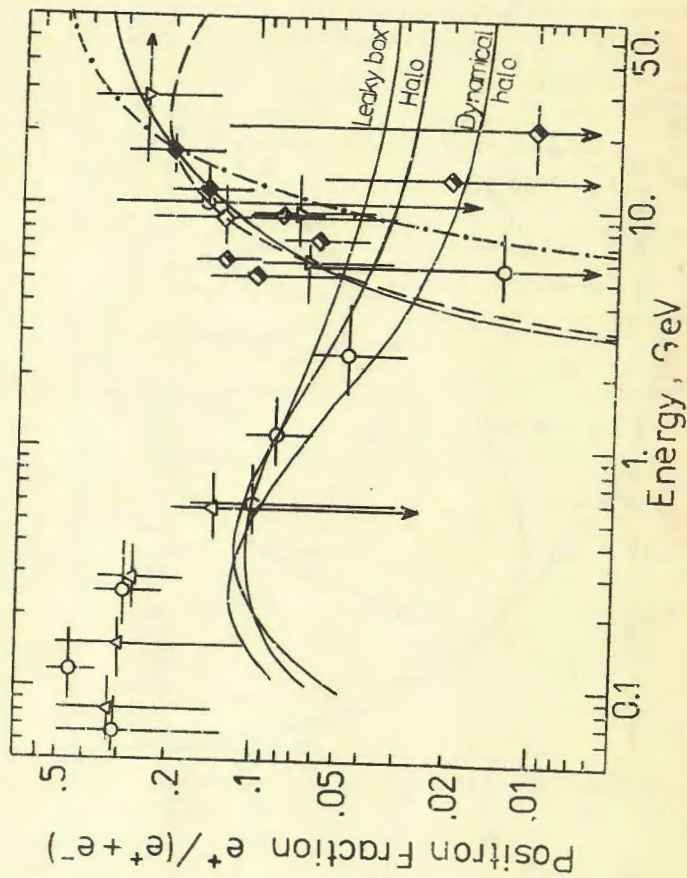


Fig.2

Figure Captions

Fig.1 Equilibrium differential spectra of electrons (e^+ and e^-), calculated in frames of the model normalized so as to satisfy the observed ratio $e^+/(e^+e^-) \approx 0.2$ at $E=17$ GeV.

a) $\epsilon_0 = 10$ eV; $\delta = 0$ and $\delta = 0.4$. The dashed line corresponds to the electron spectrum for $\delta = 0.4$ calculated ignoring the relativistic corrections to the Compton scattering cross-section. b) $\epsilon_0 = 30$ eV; $\delta = 0$, $\delta = 0.4$ and $\delta = 0.55$. The experimental data are taken from the compilation in ref.[18].

Fig.2. The expected ratio of $e^+/(e^+e^-)$.

$\delta = 0.4$, $\epsilon_0 = 30$ eV (solid line); $\delta = 0$, $\epsilon_0 = 30$ eV (dashed line); $\delta = 0.4$, $\epsilon_0 = 10$ eV (dash-dotted line).

The experimental data are taken from compilation in ref.[18].

References

1. Никольский С.И., Стаменов И.Н., Ушев С.Э. Состав космического излучения при энергиях $\approx 10^{15}$ эВ и выше. - ЖЭТФ, 1984, т. 87, с.18.
2. Kifune T., Hara T., Matsubara Y., et al., Diffuse gamma rays in PeV energies.- Preprint, 1987.
3. Hillas A.M. Is the Cygnus X-3 a monoenergetic 10^{17} eV accelerator? - Nature, 1985, vol. 318, p.642.
4. Агаронян Ф.А., Мамиджян Э.А., Никольский С.И., Тукиш Э.И. Первичное гамма-излучение с энергия 10^{14} - 10^{16} эВ и возможные источники космических лучей в Галактике. - Астрофизика, 1985, т. 23, с.55.
5. Montmerle T. On gamma-ray sources, supernova remnants, OB associations, and the origin of cosmic rays.-Astrophys.J., 1979, vol.231, p.95.
6. Casse M., Paul J.A. Local gamma-rays and cosmic ray acceleration by supersonic stellar winds.- Astrophys.J., 1980, vol.237, p.263.
7. Fichtel C., Simpson G.A., Thompson D.J. Diffuse gamma radiation.-Astrophys.J., 1978, vol.222, p.833.
8. Bignami G.F., Barbareschi L., Bloeman JB et al. COS B observations of gamma-ray emission from local galactic features - 17-th ICRC, Paris, 1981, vol.1, p.182.
9. Березинский В.С. и др. Астрофизика космических лучей. - М. Наука, 1984.
10. Silberberg R., Tsao C.H., Shapiro M.M., Letaw J.R. Models for Cosmic Ray Propagation at Energies 10^3 - 10^{14} ev. -18-th ICRC, Bangalore, 1983, vol.2, p.179.
11. Buffington A., Orth C.D., Smooth G.F. Measurement of primary cosmic ray electrons and positrons from 4 to 50 GeV.- Astrophys.J., 1975, vol.199, p.669.
12. Müller D., Tang J. An observation of cosmic ray positrons from 10-20 GeV.- 19-th ICRC, LA Jolla, 1985, vol.2,p.378.
13. Golden R.L., Mauger B.G., Horan S. Observation of cosmic ray positrons from 5 to 25 GeV.- 19-th ICRC La Jolla, 1985, vol.2,p.374.
14. Protheroe R.J. On the Nature of the cosmic ray positron spectrum. Astrophys. J. 1982, vol.254, p.391.
15. Harding A.K., Ramaty R. The pulsar contribution to galactic cosmic ray positrons.- 20-th ICRC, Moscow, 1987, vol.2,p.92.
16. Агаронян Ф.А., Атоян А.М., Нагапетян А. Фоторождение электрон-позитронных пар в компактных рентгеновских источниках. -Астрофизика, 1983, т.19, с.323.
17. Zdziarski A.A., Absorption of gamma-rays in the 5 March 1979 gamma-ray burst source.- Astron.Astrophys., 1984, vol.134,p.301.
18. Ormes J.F., Israel M., Wiedenbeck M., Mewaldt T. The particle Astrophysics Magnet Facility, - Interim Report, 1986, NASA, Code 661, Greenbelt, MD, 10771. U.S.A.

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ПОЗИТРОНЫ В СОСТАВЕ КОСМИЧЕСКИХ ЛУЧЕЙ, СВЯЗАННЫЕ С ДИФфуЗНЫМ
ГАЛАКТИЧЕСКИМ ГАММА-ИЗЛУЧЕНИЕМ ВЫСОКИХ И СВЕРХВЫСОКИХ
ЭНЕРГИИ

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