ВАК 2024 MODERN ASTRONOMY:
FROM THE EARLY UNIVERSE TO EXOPLANETS AND BLACK HOLES
300 years Russian Academy of Sciences

Spectrum of positrons produced due to interaction of gamma-ray background photons with soft background photons

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Abstract. The interaction of the cosmological gamma-ray background photons with soft cosmological background with producing electron-positron pairs is considered. It is shown that the majority of positrons are produced with energies of 10 Gev – 1 TeV. However, the interaction of “X-ray” cosmological background photons may produce the positrons with energies of 10–100 keV.

Keywords: cosmology: cosmic background radiation; positrons

DOI: 10.26119/VAK2024.015

1 Introduction

The cosmological background radiation (CBR) is near isotropic homogeneous radiation which fills the Universe (Hill et al. 2018). The various components of background radiation have various origin. The main component of CBR is the microwave background radiation (CMB) which is a relic of the epoch of recombination which occurs in the early Universe at redshift $z \sim 10^3$ (Hill et al. 2018). The second important component of CBR is optical and infrared extragalactic background light (EBL) which mainly consists of radiation of stars (Franceschini et al. 2008; Cooray 2016). The cosmological ultraviolet background radiation (CUB) mainly consists of the light radiated by hot young stars and nebulas (Hill et al. 2018). The cosmological X-ray background radiation (CXB) is mainly produced by accretion in galactic nuclei (Ajello et al. 2008). The cosmological gamma-ray background radiation (CGB) had been mainly radiated by AGN and supernovas (Ackermann et al. 2015). The main source of perturbation of CBR photons spectrum is the scattering on intracluster gas (Grebenev & Sunyaev 2020). In addition to the scattering on intracluster gas, CRB photons may also interact with each other producing electron-positron pairs (Gould & Schreder 1967) which also may give a small input into its spectra perturbation. Moreover, it is possible that the produced positrons may give some input into annihilation line (Nizamov & Pshirkov 2023).

2 Model

In this paper we consider the interaction of two photons with electron-positron pair production. The positron production spectra is calculated in the same way as in Popov et al. (2023). We consider only the interaction of CGB photons with EBL, CUB and CXB photons. Also, we consider the interaction of CXB photons with each other. We use the simplified model and assume that spectra profiles do not depend on redshift z and coincide with profile of corresponding spectra observed at $z = 0$. The CGB spectrum is taken from Ackermann et al. (2015), CXB and EBL spectra are taken from Ajello et al. (2008) and from Franceschini et al. (2008) correspondingly. In case of CUB spectrum we use the upper limit of CUB photon density taken from Hill et al. (2018). We assume that photon density depends on z and is proportional to star formation rate (SFR) at this redshift. To calculate the SFR we use its approximation, taken from Behroozi et al. (2013):

$$S(z) = \frac{C}{10^{A\,(z-z_0)} + 10^{B\,(z-z_0)}}, \tag{1}$$

where $S(z)$ is SFR at redshift z, $z_0 = 1.243$, $A = -0.997$, $B = 0.248$ and $C = 0.180\, M_\odot\, \mathrm{year}^{-1}\, \mathrm{Mpc}^{-3}$ in comoving frame (Behroozi et al. 2013). The used spectra at $z = 0$ are shown in Fig. 1. The power law extrapolation of CXB spectrum upto CUB and CGB spectra is shown by dashed lines.

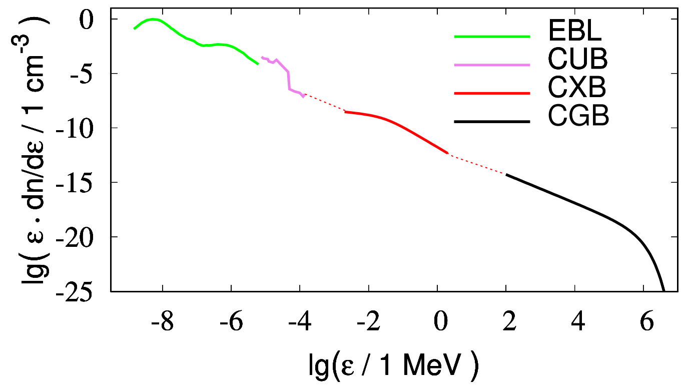

Fig. 1. The used spectra of background radiation are shown. The ε is photon energy in MeV and $\frac{dn}{d\varepsilon}$ is photons number per 1 cm^3 in 1 MeV energy interval.

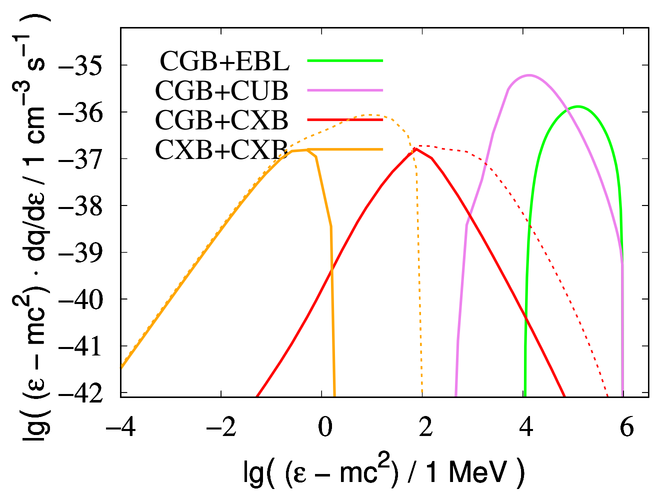

Fig. 2. The calculated positrons spectrum at $z = 1.5$ is shown. The ε is positron energy in MeV, mc^2 is positron rest energy in MeV and the $\frac{dq}{d\varepsilon}$ is positron production rate in units $1\text{cm}^{-3}\,1\text{s}^{-1}\,1\text{MeV}^{-1}$.

3 Results

The calculated positron spectrum at $z = 1.5$ is shown in Fig. 2. Dashed lines correspond to extrapolated CXB spectra. Majority of positrons are produced with energies of 10 Gev – 1 TeV. Such positrons almost do not annihilate due to the interaction with intracluster gas and slowly accumulate in space between galaxies (Nizamov & Pshirkov 2024). However, the interaction CXB photons with itself may produce the positrons with small energies of $10 - 100$ keV. Life time of such positrons may be estimated as $(1 - 3) \cdot 10^9$ years, so it may give input into annihilation line (Nizamov & Pshirkov 2023).

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