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Consequences of the existence of the infrared background in addition to the microwave background for the future high energy γ-rays experiments

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Abstract

We show that the attenuation of the gamma ray flux from extragalactic sources due to the blackbody background in addition to the infrared background attenuation, bring to the necessity to lower as much as possible the threshold of the future high energy γ-rays detectors.

1 The blackbody background attenuation

It is well known that the gamma ray fluxes from high energy sources can loose photons from the interaction with the blackbody background through the process $\gamma\gamma \leftarrow e^+e^-$. The electrons then loose the source direction due to the interstellar magnetic field. The cross section of the process is [1]

$$\sigma_{\gamma\gamma} = \frac{\pi r_e^2}{2}(1-v^2)\left\{(3-v^4)\ln\left(\frac{1+v}{1-v}\right) - 2v(2-v^2)\right\}$$

where r_e is the classical radious of the electron and

$$v = \sqrt{1 - \frac{4m_e^2}{2\omega_1\omega_2(1-\cos\vartheta)}}$$

ω_1 e ω_2 are respectively the energies of the blackbody spectrum and the high energies gamma ray and ϑ is their angle of incidence.

Because the blackbody spectrum is isotropic, we can integrate in $d\Omega = 2\ \pi\ \sin\vartheta\ d\vartheta$ with the normalization $1/(4\pi)$, then the ratio between the flux I(L) at a distance L from the source and the initial flux I can be written as:

$$I/I_0 = exp(-k_\gamma \cdot L) \tag{1}$$

where k_γ is the absorption coefficent

$$k_\gamma = \frac{1}{2}\int_0^\infty \int_{\vartheta^*}^{\pi} \frac{dn_\gamma}{d\omega_1}\sigma_{\gamma\gamma}\sin\vartheta\, d\vartheta\, d\omega_1$$

and $dn_\gamma/d\omega_1$ is the Plank black body distribution

$$dn_\gamma/d\omega_1 = \frac{1}{\hbar^3\ c^3\ \pi^2}\frac{\omega_1^2}{\exp(\omega_1/kT)-1}$$

The minimum angle ϑ^* depends from the photon energy because the energy in the center of mass must be

$$\sqrt{2\omega_1\omega_2(1-\cos\vartheta)} \geq 2m_e$$

In fig.1 is shown I/I_0 obtained from eq.1 for kT=2.726 for three different distances

2 The Infrared radiation field

Observational determinations of the extragalactic infrared background are plagued by the difficulty of separating the true extragalactic component from Galactic radiation and instrumental background. The observational determinations are general upper limits which lie above theoretical estimates. Figure 2 shows reasonable upper and lower limit on the infrared background. The solid curve corresponds to the maximum contribution from normal galaxies [3] the dotted curve is the minimum contribution chosen to include the estimation of Tyson [4](cross points) and of Yoshii and Takahara [5](open circle). The observed upper limits are from IRAS experiment [6] and by [7]. With these limits one can calculate [2] the degree of absorption for objects at red shift of $z \sim 1$ and $z \sim 0.03$, the distance of Markarian 421, shown in Figures 3 and 4 . For a $z \sim 1$ object the possible transmission of 100 GeV photons is between 36 % (upper limit) and 67% (lower limit) at 500 GeV the transmission falls to less then 1%. In fig.5 it is shown the sum of the infrared and black-body background.

The previous argument indicates that the future ground experiments will greatly benefit by a threshold as low as possible. The region between 100 GeV and $1TeV$ is doubly interesting, first because it cannot be reached by satellite experiments and second because by measuring the change in the slope of the spectra from $1/E^2$, one can have an indirect measurement of the extragalactic infrared background.

To lower the threshold as much as possible two conditions must be fulfilled. One is to make an extensive air shower detector which is active on all the area covered, like in the Argo project, the other is to reduce the atmospheric thickness.

Figure 6 shows the number of electrons with energies > 1.5 MeV in a shower in function of the traversed radiation length in air for different primary energy and figure 7 shows the relation between the height and the radiation lenght traversed. It can be seen that, if one requires at least 300 electrons as trigger at 4000 m of altitudes (17 X_0) one can have a threshold of 200 GeV (perhaps less with some heavy converter in front of the detector for the conversion of the γ-rays).

References

[1] L.D.Landau and E.M.Lifshist, *Relativistic Quantum Theory*, Mir, Moscow, 1965

[2] F.Steker et al., *Ap.J.*, **390**, L49, (1992)

[3] F. Steker et al., *Ap.J.*, **214** , L51, (1992)

[4] J. Tyson,*The Galactic and Extragalactic Background Radiation*; ed.S.Bowyer and C.Leinert (Netherlands)

[5] Y. Yoshii and F. Takahara, *Ap.J.*, **326**, 1, (1988)

[6] F. Boulanger and M.Perault, *Ap.J.*, **330**, 964, (1988)

[7] R. Dube et al., *Ap.J.*, **232**, 333, (1979)

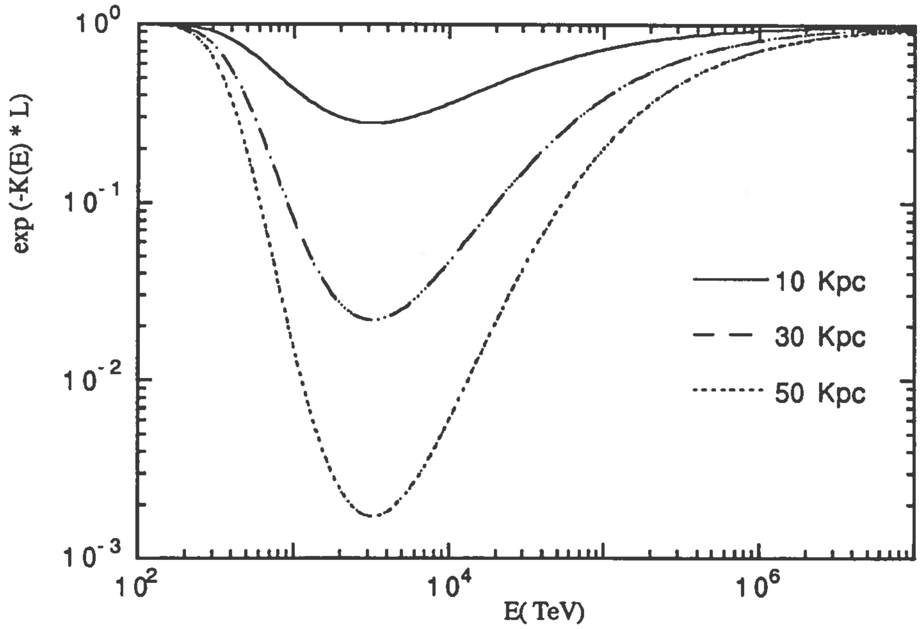

Figure 1: *The absorption of the γ-ray flux due to the black-body background.*

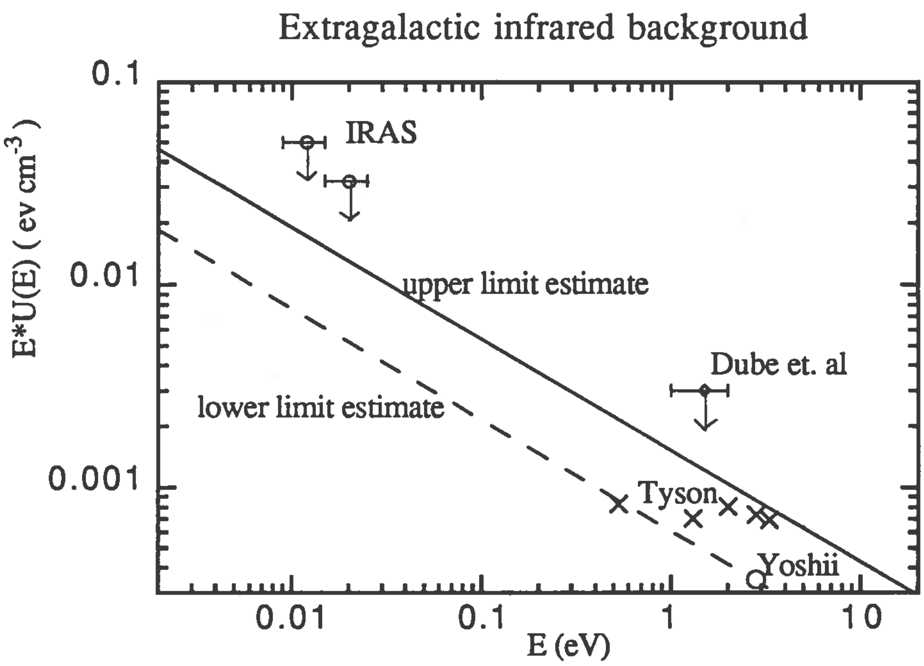

Figure 2: *Estimation of the extragalactic infrared background*

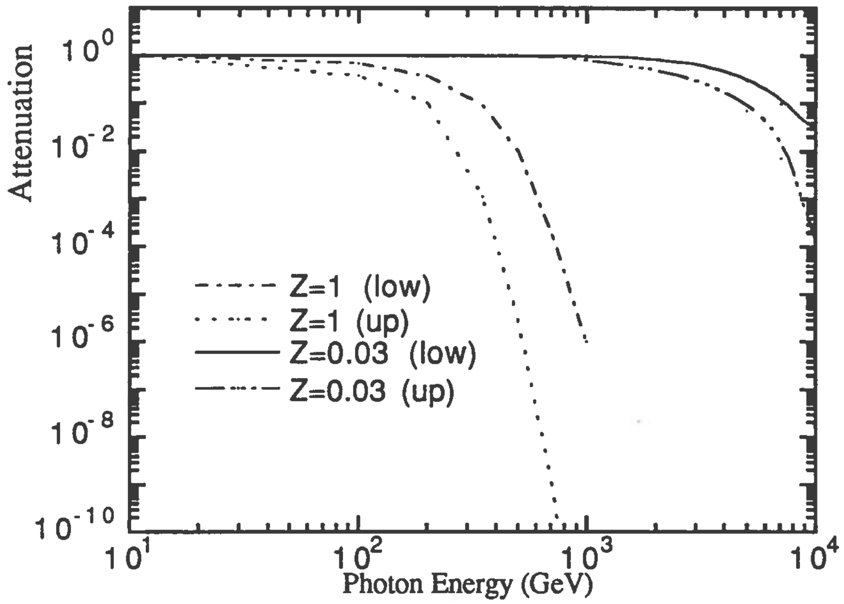

Figure 3: *The absorption of the γ-ray flux for objects at redshift of $z \sim 1$ and $z \sim 0.03$ due to the infrared background. The solid and dotted curves are the upper and lower limit due to the indetermination in the knowledge of the spectrum.*

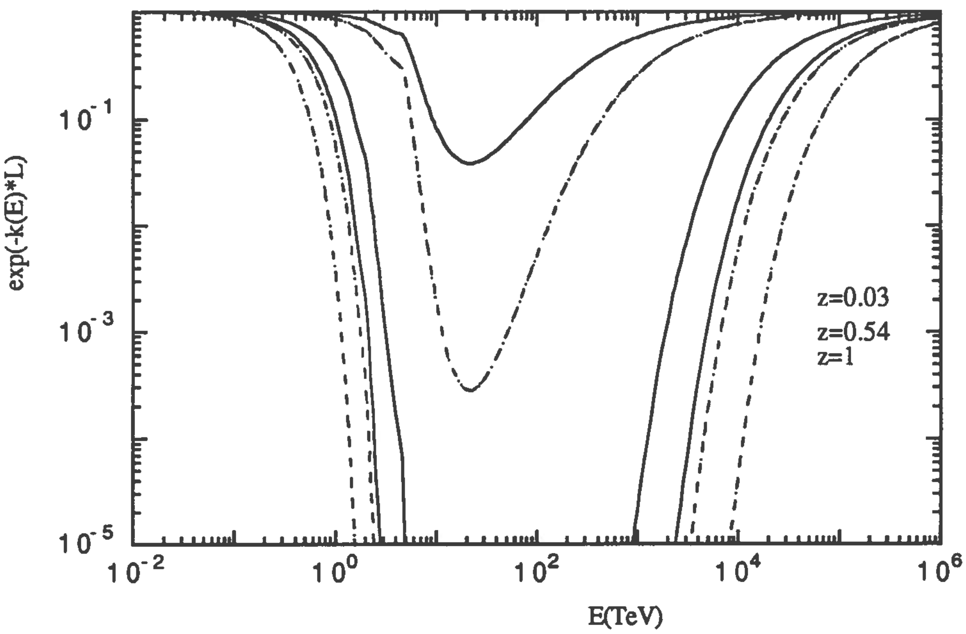

Figure 4: *The absorption of the γ-ray flux as in figure 2 but for a different energy interval.*

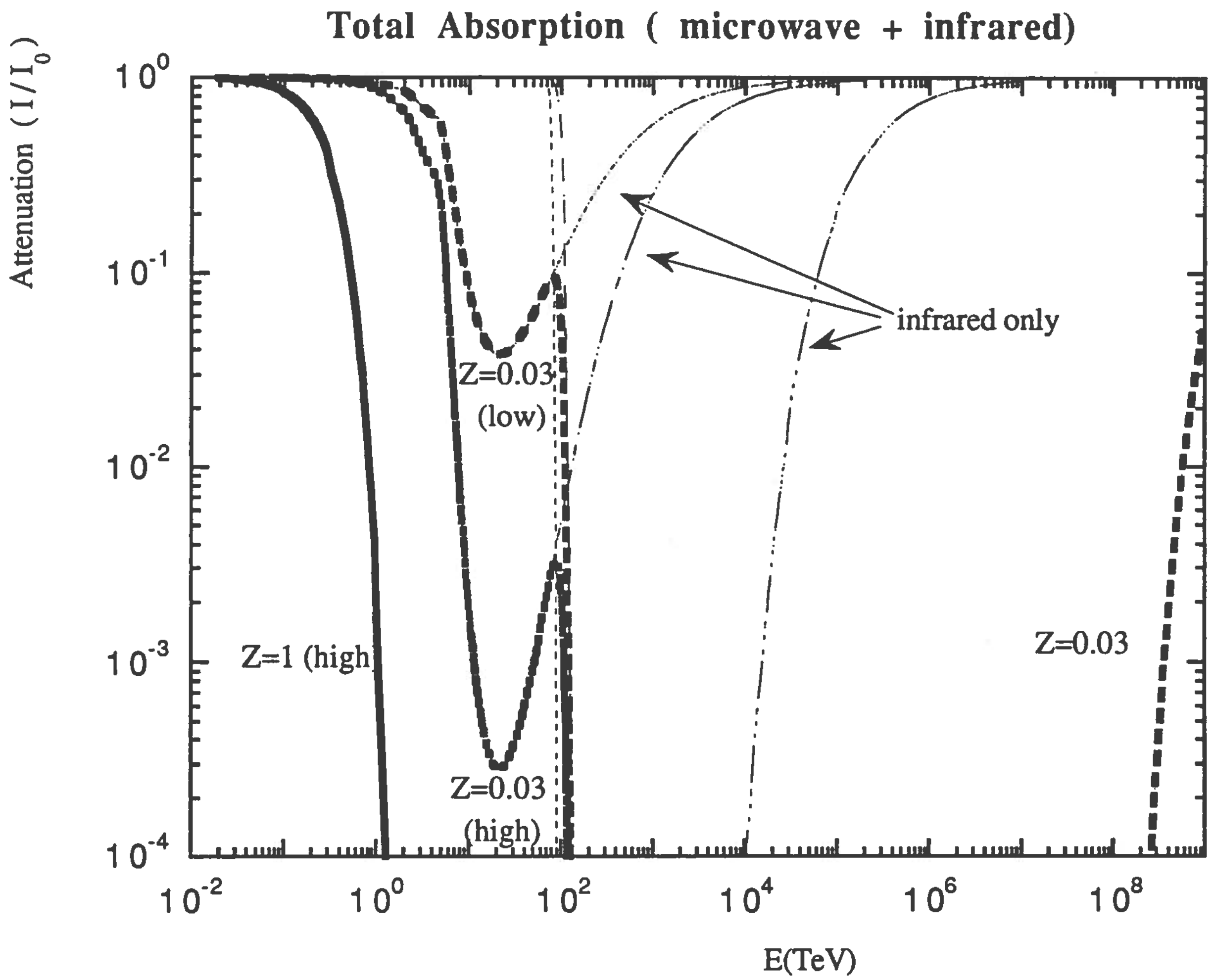

Figure 5: *The absorption of the γ-ray flux for objects at redshift of* $z \sim 1$ *and* $z \sim 0.03$ *due to the sum of the infrared and black-body background.*

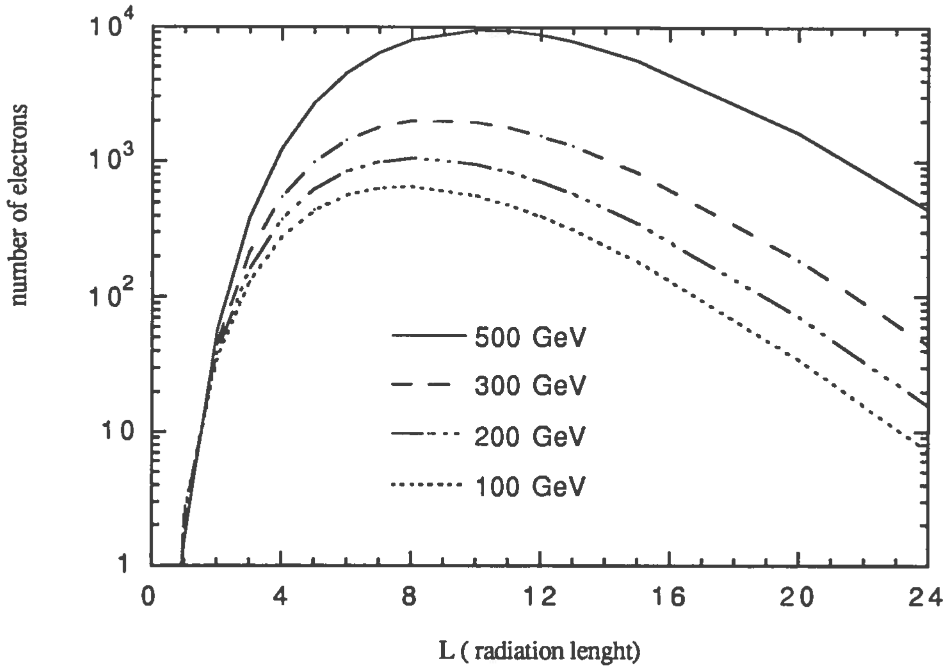

Figure 6: *The number of electrons in a shower in function of the traversed radiation length in air for different primary energy*

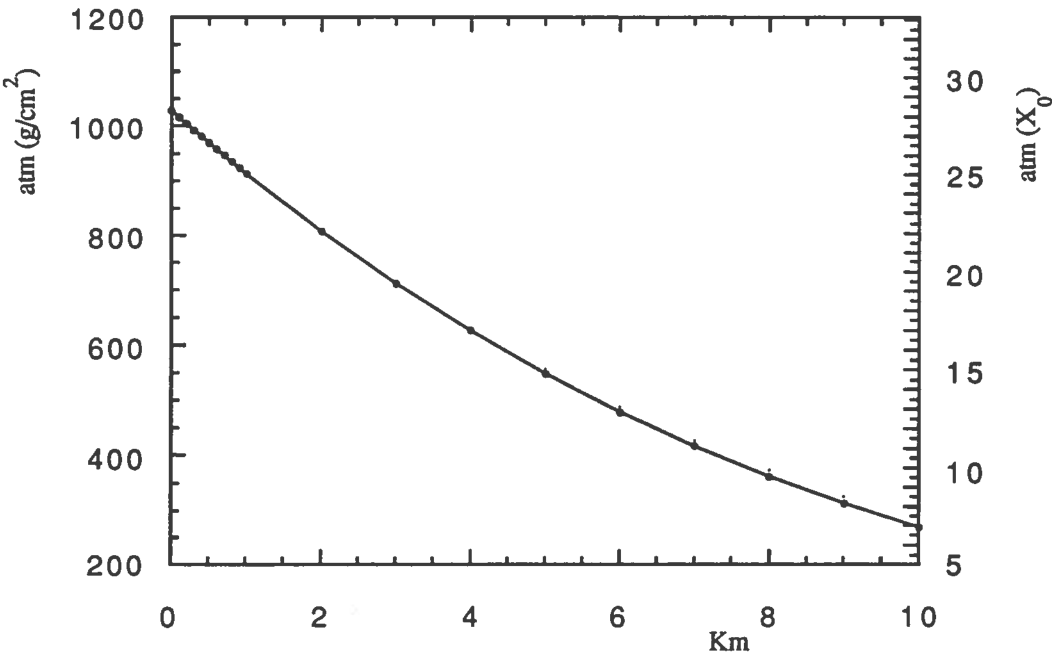

Figure 7: *The relation between the height and the radiation lenght traversed*