Romanian Reports in Physics, Vol. 57, No. 2, P. 205–209, 2005

APPROACH TO THE ESTIMATION OF THE HIGHEST ENERGY OF THE GAMMA RAYS

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(Received October 19, 2004)

Abstract. In the last decade the issue has been under debate concerning the composition of the ultra high energy cosmic rays. Another debate concerns the limit of the energy of the gamma rays. The present paper provides an approach to estimate the limit of the energy of the gamma rays .

Key words: cosmic microwave background, diffuse radiation, gamma rays, theory.

1. INTRODUCTION

The detection of some events at 10^{20} eV, performed in the last two decades, raises questions concerning the composition of the observed cosmic rays. The most popular picture is that of the proton composition but there are also scenarios which emphasize the light composition of the observed flux.

Bhattacharjee and Sigl (1998) mentioned in a previous paper that some authors claimed that gamma rays could have energies above 10^{20} eV [1]. These scenarios involve heavy particles decaying into gamma rays.

Stecker (2000) also mentioned that gamma ray bursts can produce gamma rays at 10^{20} eV and above, according to E. Waxman [4]. One of the arguments of the latter author is that the energy emitted by the bursts in ultrahigh energy cosmic rays is roughly equal to the electromagnetic energy emitted by the bursts.

To date none of these two assumptions, the heavy composition or the light composition of the cosmic rays at 10^{20} eV, have been rule out. In our approach we adopt the last assumption using a recent paper of Turtur (2004) [5]. In Section 2 we show a possible manner to estimate the largest gamma ray energy using the recent paper of Turtur. Using data and approaches to the electromagnetic radiation we estimate in Section 3 the level of the highest gamma ray energy. Some comments concerning the features of the approach which can be improved are presented in Section 4.

* This paper was presented at the Annual Scientific Session of the Faculty of Physics, University of Bucharest, București, Măgurele, May 28, 2004.

2. APPROACH TO ESTIMATE THE LARGEST ENERGY OF THE GAMMA RAYS

Turtur (2004) derived the present known radius of the Universe for the minumum potential energy of the ensemble of the gravitational field and the electric field [5]. He argued the choice of these two fields within their dominance at large distances. Using only one parameter, the time of the Universe, he found a surprising good agreement between his estimation of the radius and the estimations of other authors.

As he also mentioned he performed a calculation of the forces' equilibrium between gravitation and Coulomb-force, but he did not take the inertia of masses into account. Because of masses' inertia the movement of the universe came to an oscillation around the equilibrium position. If the oscillation were not attenuated, the universe would come back to the point of the big bang one day.

In order to explain the cosmological measurements we observe today he emphasized an attenuation of the oscillation within the universe leading to the equilibrium position today. It seems more likely, we reached this possible state nowadays – many billions of years after the big bang.

In this case, if the universe oscillates around the equilibrium position with not too large amplitudes, it will alternately expand and contract itself within billions of years. We shall adopt this last assumption in what follows.

So our approach takes into account a small dominance of the Coulomb-force to the gravitational force. This leads to a small amount W_a of the potential energy censed by Turtur (2004) around the value of the equilibrium position. We assume in our approach a ratio $\eta = \dfrac{W_a}{W_{total}}$ of the amount of the energy W_a to the total energy of the universe W_{total} at the equilibrium position, emphasized by Turtur (2004) [5].

A way to estimate the highest energy of the gamma rays is to assume that W_a is released in the universe as gamma rays and another part of it is the rest diffuse electromagnetic radiation.

We can write

$$E_{dif} + E_{CMW} + \int \mathrm{d}S \int \mathrm{d}t \int_{E_{\min}}^{E_{\max}} \alpha E^{\gamma} \mathrm{d}E = W_a = \eta W_{total} \qquad (1)$$

where E_{dif} is the diffuse electromagnetic energy in all ranges except the microwave range and the gamma rays range, E_{CMW} is the cosmic microwave radiation energy, α is the flux of the gamma rays, *i.e.* the energy of the gamma rays in time unit and per area unit and per energy unit, at the energy E of all point sources, and γ is the spectral index. The first two terms correspond to the diffuse electromagnetic energy, while the third corresponds to the pointlike sources. The integration is over the surface of the sphere of the universe and over a period of an oscillation. The two parameters α and γ have to be chosen with different values for the already known regions of the electromagnetic spectrum and to be assumed for energies above 10^2 TeV.

3. APPLYING TO THE KNOWN COSMOLOGICAL CONSTANTS

In order to accomplish the calculus it is necessary to assume the values of the ratio η and of the period of the oscillations of the universe. It is obvious that $\eta < 1$. But for our purposes we shall assume the largest value $\eta = 1$. According to Turtur at equilibrium W_{total} is

$$W_{total} = \frac{2c^4}{5g}\sqrt{\frac{3c^2}{4\pi g \rho_M}} \cong 7.37 \times 10^{69}\ \mathrm{J} \tag{2}$$

where $g = 6.67 \cdot 10^{-11}\ \frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}$ and $\rho_M \cong 10^{-26}\ \mathrm{J \cdot m^{-3}}$ is the vacuum mass-density [5].

Using the same radius of the universe and the energy densities ρ of the other electromagnetic regions [3] one can derive the energies in a different manner than (1), *i.e.* using

$$E = \frac{4\pi}{3} R^3 \rho \tag{3}$$

to be

$$\begin{aligned} E_{visible} &= 22.608 \times 10^{63}\ \mathrm{J} \\ E_{SX} &= 22.608 \times 10^{61}\ \mathrm{J} \\ E_{HX} &= 22.608 \times 10^{61}\ \mathrm{J} \\ E_{\gamma} &= 45.216 \times 10^{59}\ \mathrm{J} \\ E_{radio+mw} &= 22.608 \times 10^{59}\ \mathrm{J} \\ E_{3^0 K} &= 9.0432 \times 10^{65}\ \mathrm{J} \end{aligned} \tag{4}$$

where $E_{visible}$, E_{SX}, E_{HX}, E_{γ}, $E_{radio+mw}$, $E_{3^0 K}$ are the estimated energies of visible, soft X (< 1 keV), hard X (1–500 keV), gamma rays, radio and microwave (except 3°K radiation) and 3°K radiations. One can observe from (4) that every other region of the electromagnetic spectrum energy is smaller than 3°K radiation energy by at least two orders. Also one can observe that infrared energy is not accounted. According to Rose (1973) this latter energy is of the same order as the 3°K radiation energy [3].

From (2) and (4) one obtains

$$\frac{W_{total}}{E_\gamma} \cong 10^{10} \quad (5)$$

To date the highest gamma ray energy detected is around 10^{13} eV. Using (4) it follows that the highest gamma ray energy could be 10^{10} times bigger than 10^{13} eV, *i.e.*, 10^{23} eV.

4. COMMENTS

The above approach can be improved using more reliable methods to infer every amount of electromagnetic energy: the global photometric approach of Lilly *et al.* (1996), the data from DIRBE, IRAS, COBE ISO and HDF [2]. According to Lilly *et al.* the infrared radiation energy accounts for 5.924×10^{63} J which is two orders less than the 3°K radiation energy.

Turtur's approach to the universe leads to a cut-off of the gamma rays energy at 10^{23} eV. This level of the cut-off might depends on the ratio $\eta = \frac{W_a}{W_{total}}$. If the ratio $\eta = 10^{-4}$, then the cut-off has to be degraded from 10^{23} eV to 10^{19} eV, which can provide an explanation to the "ankle".

Turtur's approach doesn't emphasize a dark energy. Hence, in order to fit W_{total} and $E_{3^0 K}$ it is necessary to choose $\eta = 10^{-4}$. In this case the highest gamma ray energy must be 10^{-19} eV. This result may suggest that we observe only a ratio $\eta = 10^{-4}$ of the entire energy, *i.e.*, the electromagnetic excess, in which case the cut-off of the gamma rays energy can explain the "ankle" of the cosmic ray spectrum. Otherwise the difference between W_{total} and the present detected electromagnetic energy cannot be explained in Turtur's approach. In order to clear up this problem one must investigate the relationship between local densities and their analougue to large scales, also how gravitation works at large scales, or to improve our methods to detect infrared radiation. But this is not the aim of the present work.

A rough calculus of the redshift of Turtur's Universe edge leads to z = 4.22 when one uses H_0 = 65 km/s/Mpc. Using a bigger value for H_0 one obtains a closer value to $z = 5$. But nowadays the most distant observed sources are at $z \cong 5$ [6].

5. CONCLUSIONS

The above approach uses two parameters: the age of the universe used by Turtur to calculate W_{total} and the ratio η [5]. But the good agreement of the value of radius of the universe with other authors estimations makes this result more reliable. For $\eta = 10^{-4}$ the estimation of the highest gamma ray energy leads to 10^{-19} eV which is the "ankle" of the cosmic ray spectrum.

Aknowledgements. We thank T. Angelescu, A. A. Radu and I. Simaciu for stimulating discussions. This paper was supported in part by SCIRO-CERES Project C.F.96/15.10.2001.

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