Report

The Mystery of Ultra High Energy Cosmic Rays

B. G. Sidharth[1]
G.P. Birla Observatory & Astronomical Research Centre
B.M. Birla Science Centre, Adarsh Nagar, Hyderabad - 500 063 (India)

Abstract

Ultra High Energy Cosmic Rays have proved to be an enduring mystery for many decades. These include gamma rays as also charged particles. One of the mysteries is what is the exact origin of this radiation, which undoubtedly come from beyond our galaxy. The author has been studying this problem for sometime now, from the point of view of the Snyder-Sidharth dispersion relation and we report some results.

The so called Snyder-Sidharth dispersion relation is given by [1],

$$E^2 = p^2c^2 + m^2c^4 + \alpha^2 l^2 \frac{c^2}{k^2} p^4 \tag{0.1}$$

($\hbar = 1 = c$).
It can be argued that for bosons α^2 is negative and equals -2, whereas for fermions α^2 is positive and undetermined.
If we study bosons with (0.1), instead of the usual relation in which $\alpha^2 = 0$, we will get, with the usual notation,

$$\omega_k^2 = k^2 + m^2 - 2l^2k^4 \tag{0.2}$$

where ω_k stands for the frequency at energy k^2 and we use $\hbar = 1 = c$.
Equation (0.2) shows that for bosons the energy is reduced and given by

$$k_{eff}^2 = k^2 - 2l^2k^4 \tag{0.3}$$

Equation (0.3) shows that there is a slightly different frequency or wave number, which could be attributed to a new boson of mass given by

$$m_\gamma = \left(\frac{\hbar}{c}\right)(k_{eff} - k)\,, \tag{0.4}$$

where we have switched to ordinary units by restoring $\hbar$ and c.
If we consider keV radiation then we get for the new boson mass a value $\sim 10^{-65} gms$. If on the other hand we consider TeV or GeV gamma rays, as are being observed then we can easily deduce from (0.4) that $m_\gamma \sim 10^{-62} gms$.
It is remarkable that in recent observations of gamma rays by the Magic Telescope, de

[1]Correspondence: E-mail: iiamisbgs@yahoo.co.in

Angelis and co-workers find exactly such a Boson with the above mass which are needed to explain observational discrepancies [2].
The other way is to attribute the above mass $\sim 10^{-65}$ to the Photon itself. The important point is that latest observational estimates give an improved upper limit for the photon mass $\sim 10^{-57} gms$ [3, 4, 1]. Pleasingly our value is within this limit. It may be mentioned that exactly this photon mass was deduced by the author in the Planck oscillator - Dark Energy approach, quite different from the approach given above [5, 1]. Such a photon mass can also be deduced on purely thermodynamic considerations within the background Dark Energy [6, 1].
It can be easily seen that this photon mass (or equivalently the above modified dispersion relation) leads to a dispersive velocity for the photon [7, 1]

$$v_\gamma = c\left[1 - \frac{m_\gamma^2 c^4}{h^2 \nu^2}\right]^{1/2} \qquad (0.5)$$

Equation (0.5) shows the velocity dispersion with respect to frequency though this is a very subtle effect which can be observed in only Ultra High Energy Gamma Rays. Moreover there have been claims that such a dispersive lag in the arrival of High Energy Gamma Rays has already been observed [8]. More recently Ellis and other authors have claimed such a dispersive lag in the time arrival of Gamma Rays from an event in the galaxy $mkn537$ [9].
In any case this shows that the effect of the SS dispersion is to reduce the frequency of the incoming radiation by a small amount.
Let us now come to the case of Fermions. In this case the modified energy momentum relation is given by (0.1) so that the extra energy is given by

$$E' = \alpha \frac{lcp^2}{\hbar} \qquad (0.6)$$

This indicates that there would be Cherenkov type radiation, as (0.6) suggests a super luminal effect. There is an undetermined parameter α. We can get a bound for α by the following argument. So far the best test for Einstein's energy mass formula [10] gives an uncertainty of the order

$$\Delta E \leq 10^{-6} mc^2 \qquad (0.7)$$

This means that α is less than 10^{-6}.'The uncertainty in energy due to the ultra relativistic formula (0.1) now can be written as

$$\Delta E = \Delta mc^2, \, \Delta m < 10^{-6} m_e \qquad (0.8)$$

The interesting feature is that the new mass Δm which these considerations throw up is of the order of the mass of the neutrino as can be seen from (0.8). In other words such ultra relativistic cosmic rays could give rise to the production of neutrinos.

References

[1] Sidharth, B.G. (2008). *The Thermodynamic Universe* (World Scientific, Singapore).

[2] Roncadelli, M., De Angelis, A. and Mansutti, O. (2008). *Proceedings of Frontiers of Fundamental And Computational Physics* (American Institute of Physics, New York, 2008), pp.147-157.

[3] Lakes, R. (1998). *Phys.Rev.Lett.* 80, (9), pp.1826ff.

[4] Itzykson, C. and Zuber, J. (1980). *Quantum-Field Theory* (Mc-Graw Hill, New York), pp.139.

[5] Sidharth, B.G. (2006). *Found.of Phys.Lett.* 19 (4).

[6] Sidharth, B.G. (2006). *Found.Phys.Lett.* **19**, 1, pp.87ff.

[7] Vigier, J.P. (1990). *IEEE Transactions of Plasma Science* 18, (1), pp.64–72.

[8] Pavlopoulos, T.G. (2005). *Phys.Lett.B.* 625, pp.13-18.

[9] Ellis, J., et al ArXiv. 0708.2889.

[10] Rainville, S., et al. (2005). *Nature* Vol.438, 22/29 December 2005, pp.1096-1097.