COSMIC UPPER LIMITS ON THE ELECTRIC CHARGES OF THE PHOTON AND THE NEUTRINO

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ABSTRACT

More stringent upper limits on the electric charge of photons than those deduced earlier from astrophysical considerations are given. Similar limits for the neutrino are given. These are more tight than those from arguments involving isotropy of cosmic rays.

1. INTRODUCTION

In a recent paper[1] it was shown that an upper limit for the electric charge of radio frequency photons could be deduced from the timing of the millisecond pulsar 1937+21. With e being the electron's electric charge the limit deduced from the time delays was:

$$q/e < 10^{-31.7} \qquad .....(1)$$

(q being the photon electric charge). Of course q is expected to be strictly zero, but it is still interesting to put such limits. In another recent paper[2], similar limits (not so tight as (1)) were sought to be put based on the angular resolution of some optical and x-ray sources.

The limit given by eq.(1) is comparable with the stringent bound on the net excess of charge per baryon constrained to be $\sim 10^{-30}$ from arguments involving the isotropy of cosmic rays[3].

1.1 LIMITS ON q FROM COSMIC MICROWAVE BACKGROUND

The cosmic microwave background with a blackbody temperature $T_B = 2.74°K$ has a photon number density n_γ given by:

$$n_\gamma \approx \beta\left(\frac{KT_B}{\hbar c}\right)^3 \qquad .....(2)$$

Where K is the Boltzmann constant, $\hbar$ is Planck constant C the speed of light and β is a numerical coefficient of order unity. If each of these photons has charge q then the electric force density exerted would be proportional to $\sim n_\gamma^2 q^2$.

If ρ be the average mass density of the universe then the gravitional force density is proportional to $\sim G\rho^2$

The condition that the extra forces due to the excess charge do not dominate cosmological dynamics then requires the constraint:

$$q^2 \leqslant \frac{G\rho^2}{n_\gamma^2} \qquad .....(3)$$

Assuming $\rho = \rho_c = \frac{3H^2}{8 G}$, where H is the Hubble constant then gives:

$$q \leqslant \frac{3H^2}{8\pi \sqrt{G}\, n_\gamma} \qquad .... (4)$$

For $H \approx 100$ km/s/Mpc, this then gives:

$$q \leqslant 10^{-34}\ e \qquad ....(5)$$

1.2. LIMIT ON q OF NEUTRINOS

The above argument cannot be used for the background of cosmic neutrinos as we have roughly equal numbers of anti-neutrinos (The photon of course is its own antiparticle). In ref.(4); the limit on q of neutrinos was deduced by requiring the neutrinos having mass $m_\nu \approx 10$ev and virial velocities $V \approx 300$ km/s to have radii of curvature R of about 10 kpc in the galactic magnetic field so that they can cluster around at that distance and constitute the bulk of the DM in the halo.

Thus this gave:

$$q_\nu / e \approx \frac{m_\nu V}{BeR}$$

For $B \approx 10^{-6}$ gauss, $R \approx 10$ kpc this then gives

$$q_\nu < 2 \times 10^{-32}\ e \qquad ....(6)$$

CONCLUSION

Eqs. (5) and (6) imply bounds more stringent than $\sim 10^{-30}$e deduced from arguments involving isotropy of cosmic rays.

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