COSMIC RAY CONSTRAINTS ON NEUTRON-ANTINUETRON AND HYDROGEN-ANTIHYDROGEN OSCILLATION TIME SCALES

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The phenomenon of neutron-antinuetron ($n\bar{n}$) oscillations has been postulated as another observable manifestation of grand unified theories (GUTS) which predict baryon number nonconservation. The estimated transition times for the $n\bar{n}$ oscillation are model dependent and range between 10^5 to 10^7 secs, for the usual proton decay times $\sim 10^{31}$ yrs. Recently it has been pointed out (Sivaram et al 1982a,1983) that the oscillation may operate in neutron-rich astrophysical sources like supernovae ejecta to build up part of the excess sub-GeV antiprotons observed in galactic cosmic rays, (a well known puzzle). Then known values of the sub-GeV antiproton flux, the interstellar magnetic field, the diffusion time in the galaxy, and the frequency of supernovae can be used to constrain the lower limit on oscillation time. Again data on energetic interstellar gamma rays ($\sim$100MeV), can be used to put limits[2] on hydrogen-antihydrogen mixing ($H - \bar{H}$), another prediction of GUTS and consequently on $H - \bar{H}$ oscillation time as $\gtrsim 10^{14}$yrs. These values are marginally within the predictions of GUTS, and can serve as constraints on alternative unification models of particle physics.

1. Introduction

Grand unified theories of fundamental interactions (GUTS) allow processes in which breakdown of conventionally assumed quantum numbers like baryon (B) and lepton (L) number occurs. Electric charge conservation then makes possible mixings between neutral matter and antimatter like that between neutron and antineutron ($n - \bar{n}$) and hydrogen and anti-hydrogen ($H - \bar{H}$). The estimated transition times for the $n\bar{n}$ oscillation are model dependent and range between 10^5-10^7 secs, depending sensitively on the Higgs boson masses as in proton decay.

Recently some modifications in the usual GUTS models have been proposed such as an $SU(2)_L \times U(1)$ model where global B-L symmetry is spontaneously broken (Mohapatra and Senjanovic, 1982) leading to both ($n - \bar{n}$) and ($H - \bar{H}$) oscillations. The above quoted limits on ($n - \bar{n}$) times, gives a transition time for ($H - \bar{H}$) as $\gtrsim 10^{13}$ years. We shall discuss possible observable consequences in cosmic rays.

2 Neutron oscillation and antiproton background

We write a general Hamiltonian for particle-antiparticle mixing as:

$$H = \begin{pmatrix} E_0 + \Delta E & \Delta e \\ \Delta e & E_0 - \Delta E \end{pmatrix} \text{, where } \Delta e = \frac{\hbar}{\tau_{n\bar{n}}} = 10^{-32} - 10^{-34} \text{ ergs, for}$$

$\tau_{nn'}$/ the oscillation time ranging from 10^5-10^7 seconds, E_o is the free neutron energy and ΔE is the perturbed energy.

Then the intensity of the anti-neutron component in a neutron beam after a propagation time t is given by;

$$I(\bar{n},t) = I\ (n,o)\ \frac{\Delta e^2}{\Delta E^2 + \Delta e^2}\ \mathrm{Sin}^2(\Delta e^2 + \Delta E^2)^{\frac{1}{2}}\ t \qquad ....(1)$$

$$\text{For } \Delta E \neq o, \text{ Max.value of } I\ (\bar{n},t) = \left(\frac{\Delta e}{\Delta E}\right)^2 \qquad ....(2)$$

$\Delta E = g\mu_N B$ in an interstellar or intergalactic magnetic held. μ_N is the nucleon Bohr magneton, g is the anomalous gyromagnetic ratio. If B is in gauss, $\Delta E = 9 \times 10^{-24}$ B ergs. Thus if we have an intense flux of neutrons, we should end up with some antiprotons (as antinuetrons decay to antiprotons). These antiprotons could be produced at low energies straightaway unlike the usual scenario for $\bar{p}$ production from primary cosmic ray collisions, which would require $\bar{p}/p$ to decrease with decreasing energy in contrast with observations where $\bar{p}/p$ increases at lower energies. (Buffington, 1981). If each supernova explosion produces N neutrons, f be the frequency of the explosions, B be the interstellor magnetic field, and t the diffusion time in the galaxy of the particles, then the number of antiprotons produced is

$$\bar{p} = N\left(\frac{\Delta e}{g\mu_N B}\right)^2 xft. \qquad \text{(Sivaram, et.al.1982a,b).}$$

The observations of low energy antiprotons imply $\bar{p}$ energy density of $\sim 10^{-4}$ eV cm^{-3} inside the galaxy. Assuming $f \sim 1/10$ year, $t \sim 10^5$ years and $B \simeq 10^{-6}$ gauss, gives a constraint on the oscillation time as $\tau \gtrsim 10^6$ secs, just within the theoretical bound.

As for $(H - \bar{H})$ mixing on a large scale, one can invoke observations in intergalactic gamma rays. It has been pointed out that the diffuse gamma ray background imposes a limit on the annihilation rate per unit volume in intergalactic space, of $S \lesssim 10^{-32}$ annhs./cm^{-3}. (Steigmann, 1976).

$S = n_H, n_{\bar{H}}\sigma V$, $\sigma v \sim 10^{-10} cm^3/S$, $n_H = 10^{-5}/cm^{-3}$, $n_{\bar{H}}/n_H \sim 10^{-12}$.
From eq.(1), for $\Delta E=0$, $(n\bar{H}/n_H)_{max} = (t/\tau)^2$. For t = Hubbleage $=10^{10}$years, this value of $(n_{\bar{H}}/n_H)$ would give, $\tau \gtrsim 10^{16}$ years. These constraints on the oscillation times from cosmic ray data, would impose limits on the parameters used in GUTS in estimating these time scales.

1. Sivaram, et al, Nature <u>299</u>, 427 (1982a);Astrophys.Lettrs.(in press) 1982b

2. Sivaram, et al, Nature (1983) (to be published)

3. Buffington et al, Ap.J.<u>248</u>, 1179 (1981)

4. Mohapatra, R.N. and Senjanovic, PRL <u>49</u>, 7 (1982).