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A possible excess of antiparticles in cosmic rays

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ABSTRACT

The search for antimatter in cosmic radiation is a continuing one Here we set a limit on the flux that could be truly primordial,i.e not simply due to the interactions of cosmic ray nuclei with the gas in the interstellar medium. The upper limit to the primordial flux is such that, if it is of extragalactic origin, and therfore uniformly distributed through out the universe, the overall $\overline{m}/m$ ratio is $\sim 10^{-9}$.

KEYWORDS: cosmic rays, antiproton, microwave background fluctuations.

1- INTRODUCTION

Some years ago, there were measurements of the flux of antiprotons below 1Gev which were impossible to explain in terms of secondaris from cosmic ray-interstellar medium gas nucleus interactions. Many explanations were put forward, one of which was due to Stecher et al(1984). In their model the excess came from extragalactic particles and it was noted that a spectrum of the from $I(E) \sim E^{-2}$ was approximate. Although the earlier measurements have gone a way there is still a possibility that there is, indeed, a finite extragalactic (EG) antiproton component and here we estimate an upper limit to its magnitude. The procedure is straightforward: to estimate the spectrum of expected antiproton from galactic cosmic ray-interstellar medium interactions and to subtract it from the measured antiproton spectrum.

In order to determine the galactic antiproton spectrum many uncertain parameters need reviewing. One is the precise spectra of primary proton and helium components which are recently been remeasured with the improved instruments[eg. ref(5)], which their data have been used in the present work.

The second factor which may be the most important input in the calculation of antiproton Flux is the amount of matter traversed by particles before they escape from the galaxy. The path length distribution, PLD, normally derived by fitting the observed ratios of secondary to primary cosmic ray nuclei (eg B/C,^{3}He/^{4}He ...) and taken as constant. In the present work, the PLD independently calculated from comparison of the source spectrum of particles, from model of supernova remnant Berezhko et al[4] with the experimental energy spectrum of proton and helium (see also ref [7]). We pointed out that the calculated form of life time in the galaxy is dependent on the energy range as $t_R \sim E^{-a}$, where, a, below and above 3.10^{15} ev primary particle energy is 0.83 and 0.52 respectively. As it is concluded the PLD roughly agree with each other at high energies but not at low energy (< 10 Gev). It is also found the uncertainty, whether the PLD that governs the propagation is related to velocity (e. g ref [14]) or to rigidity? As it is calculated the matter traversed by proton or antiproton is increased at lower energies. It gives the effect of the resulting PLD which is of considerable difference and, reflects consistency with velocity dependence of PLD. The two above mentioned important Factors are used in calculating present antiproton flux.

2-PRIMARY PROTON AND HELIUM SPECTRUM

The precise primary proton and helium spectra are essential in deriving the expected antiproton flux. So a review was done on their recent measurement in the energy range from 0.1 to 10 Gev. The experimental data is from Gaisser et al [8], the Bess experiment [Moiseev et al (9)], and Asakimori et al [1]. The best fit line of data for proton and also helium for energy <100 Gev gives flatter spectrum for helium with slope of 2.68 compared with 2.78 for protons. The relative intensity of helium to protons is calculated to be 4.85 par cent. For the lower energy range, 0.1<E<100 Gev, which is most important in production of antiproton in the Gev energy [see ref (12)], the best fit from Gaisser et al [8] been used in the analysis.

3- ANALYSIS OF ANTIPROTON SPECTRUM

In obtaining the present antiproton fluxes, two sources of uncertainty been improved (I): use of recent precise proton and helium spectra (i.e., advance magnetic spectrometer experiment), (ii), Use of the proper PLD base on experimentally obtained life times of cosmic rays in the Galaxy. The life times are derived from a comparison of the supernova remnant source spectrum and the observed primary cosmic ray spectrum [see ref (7)]. The antiproton flux is obtained from the following formula;

$$\varphi(>E_{\bar{p}}) = 2\times 1,19 \int\int_{E_p E_{\bar{p}}} \frac{\lambda.\delta}{m_{\bar{p}}}(>E_{\bar{p}}, E_p).I_p(E_p).dE_p$$

(1)

where λ=P τ_R C m_p , τ_r; lifetime of particles in the Galaxy[reference (7)], interstellar density of 1 atom/c, c velocity of light, and m_p mass of hydrogen atom . $\sigma(>Ep^-)$, is the p^- production cross sections p-p interactions. $\sigma(E_p / E_{\bar{p}})$. Differential cross sections are used from Szabelski et at [15]. $I_P(E_P)$, differential primary proton is used as described in section 2.2 accounts for p^- produced by n^- decay. For α particles ratio of intensities α/p=0.048, and the other nuclei %14 helium were adopted. Assuming equal production of n^- and p^- the detected flux of p^- will be higher than calculated by a factor of 2 (the n^- decay into p^-)and when allowance is made for α particles and heavier nuclei a further factor of 1.19 must be applied to get the flux of p^- . The calculated p^- flux is shown as dotted line in figure 1, which seem to be a little below the recent antiproton measured fluxes.

4- EXCESS OF GALACTIC $\overline{P}$

To obtain the extragalactic p^-, the recent p^- measurements and a model of galactic p^- been used. The existing measured p^- data after year 1900 were selected which are as follow; Mitchel et al [11], Boezio et al [6], Moiseev et al [9], and Bassini et al [3], which all are shown in figure 1. The excess of their best fit as solid line in figure 1 is subtracted from the average model of galactic antiproton[different models of secondary antiproton production which are from references (16,14 and present work) are shown in figure 2], the result is shown in figure 3 There is considerable excess below 3 Gev and above E=9 Gev, which is not consistent with secondary production model

5- EXTRAGALACTIC SPECTRUM OF ANTIPROTON

Equation (1) shows that the absolute p^- flux depends directly on the inclusive differential cross sections ($d\sigma/dE\rho$)($E_{\bar{p}}$, $E\rho$), For the various interactions, unfortunately many of these σ's have not been experimentally measured, except those for p-p interactions. The attempt is to find a proper fit to measured p production cross sections from p-p interactions see reference [14]. Also we need the inelastic and elastic cross sections for different targets to calculate p^- flux. It is seen the elastic scattering plays a minor role. So we approximate former. It is also assumed that the primary protons provide the largest contribution to the over all flux of secondary p^- and that is true at all energies. Proton contribute about %80 to the total p^- yield the helium nuclei %18 and the CNO group and heavier nuclei about %2. As described the extragalactic antiparticles intensity, (EAI) at different E calculated and shown in table 1.

Ep^-(Gev)	0.32	0.65	1.18	1.89	4.00	9.00	18.00
I, extragalactic Intensity	6.6×10^{-3}	9.6×10^{-3}	8.1×10^{-3}	3.0×10^{-3}	2.75×10^{-3}	6.0×10^{-4}	1.45×10^{-3}

The table shows a sharp decrease of EAI above E=3 Gev indicating negligible EAI. The slope of the best line through al EAI points (solid line in figure 2) is 0.65. Which is used to obtain the total EAI. It is found that the average ratio of EAI to glactic proton to be R=(3.91+2.38) 10^{-5}. Adams et al, reference [2] give a summary of previous experimental works on antiparticles fluxes. They give measured R-values to be in the range 10^{-4} to 10^{-8} which is consistent with the present value of R. The energy density of extragalactic antiproton.

$$\varepsilon_{\bar{p}} = 4\pi/c \int I(E).E.dE$$

Where c is velocity of light and I(E), extragalactic antiproton intensity is calculated to be 10^{-6} ev/cm^3. It is calculated that the energy density fluctuation of cosmic microwave background (CMB), $\Delta\varepsilon_{CMB}$ is about energy density fluctuation of extragalactic antiproton, since; T=2.7k

ε_{CMB}=0.24 ev/cm^3 $\}\Longrightarrow$ $\Delta\,\varepsilon_{CMB}$ =2.10^{-6}

Δ T/T=10^{-5}

Absolute total energy in p^- in universe is E_{total}=4/3π. Vunive $\varepsilon_{\bar{p}}$ = 1.41.10^{79} (Runiv=5000Mpc).

The value is compared with total energy in rest mass, their ratio is, R2

$$R_2 = \frac{M_{\bar{p}}(total)}{M_p(total)} = 10^{-9}$$

6- CONCLUSION

A summary of all recent measured $\overline{P}$ fluxes show that an extragalactic antiparticles are exist in cosmic radiation. This excess in compare with the secondary production models is signified belows Gev and above 9 Gev antiparticle energies. The calculated energy density of extragalactic antiparticles is about energy density fluctuation of cosmic microwave background.

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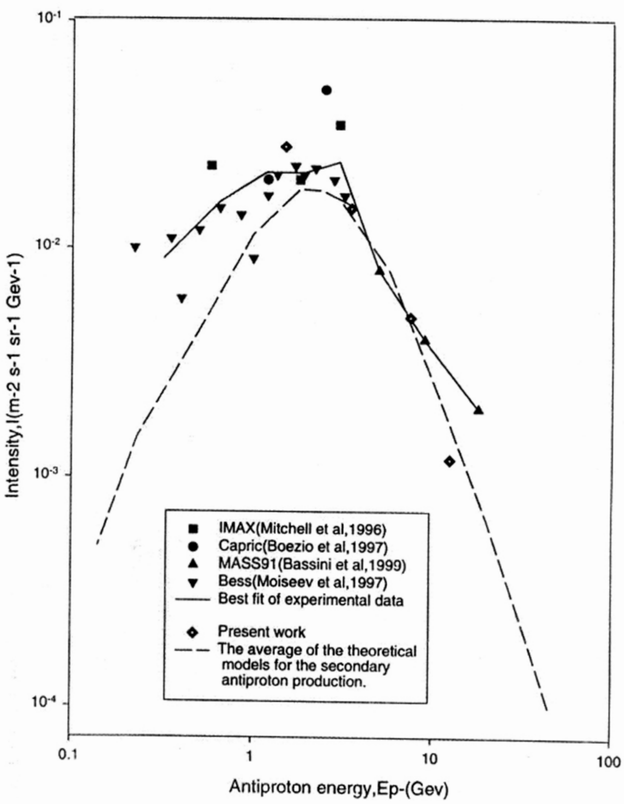

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FiG 1; The recent experimental data of antiproton intensity. The dotted line is average of the secondary antiproton production models.

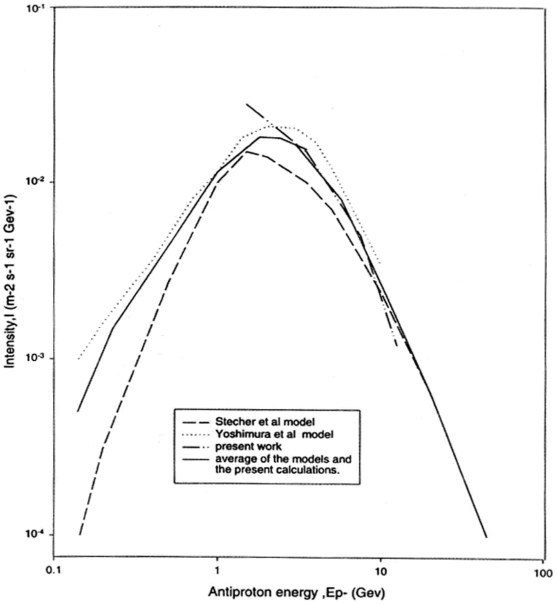

Fig 2; The different models of secondary antiproton production and present calculations.

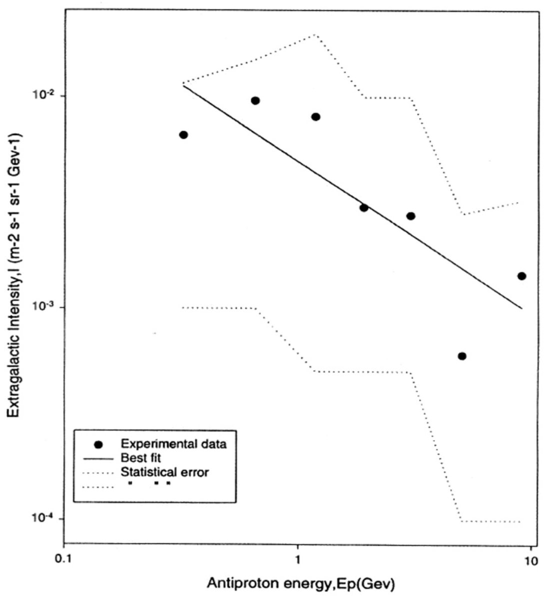

Fig 3; The difference intensity of observed antiproton and corresponding average values from the secondary production models of Stecher et al [14] , yashimura et al [16] and present wok, (the extragalactic intensity of antiproton).