ANALYSIS OF EXPERIMENTAL DATA ON INTERSTELLAR ANTIPROTONS IN THE LIGHT OF MEASUREMENTS OF HIGH-ENERGY ELECTRONS AND ^{3}He NUCLEI

L.C.Tan
Department of Physics and Astronomy
University of Maryland
College Park, MD 20742
USA

We have reexamined the interstellar antiproton calculation in view of the recent progress in measurements of interstellar electrons and ^{3}He nuclei. It is found that the divergence between our predicted antiproton flux and the existing datum at very low energies is increased.

It appears that our proposed nonuniform galactic disk (NUGD) model (1) can qualitatively explain the unexpectedly large flux of interstellar antiprotons ($\bar{p}$'s). Nevertheless, it should be noted that some ambiguities existed in the prototype of the model. For instance, it was unclear what fraction of observed $\bar{p}$'s is of local origin. Moreover, previously the value of cosmic-ray escape pathlength (λ_e) was suggested with quite a large arbitrariness.

In order to improve the model itself we have compared the high-energy electron spectrum predicted for it with measured data(2). This comparison is significant in the estimation of astrophysical parameters inherent in the model. Therefore, we find that in the observed proton flux the fraction ε of the protons being of local origin is only 5±1 %, indicating that the dominant part of cosmic-ray protons is contained in the distant component of cosmic-rays. Further, the deduced λ_e value in the H_2 cloud region is about 3 times that suggested by the leaky box model, which is consistent with our conclusion that the main part of observed $\bar{p}$'s is produced in the H_2 cloud region(1).

Thus an improved calculation is performed to deduce the interstellar $\bar{p}$ flix based on our newly obtained parameter values in the NUGD model. In our calculation(see the model elements shown in Fig. 1 of OG 7.2-10) the λ_e value in Box 1 or Box 2 is taken from the empirical relationship given in Ref. (3) (hereafter we use the subscripts 1, 2, I and II to express the quantities referred to Boxes 1, 2, I and II respectively),

$$\lambda_{e12}(R(GV/c)) = 35\ (\ 1 + (\ 1.88\ /\ R\ )^2)^{-n/2}\ R^{-0.7}\ , \qquad (1)$$

where the HEAO 3 data(3) for both the B/C and N/O ratio prefer a value of n=3, only the subiron to iron ratio requires a lesser value of n. However, we note that the preliminary data on iron nuclei obtained by the same group(4) also exhibit a flux increase with decreasing energy which is faster than that predicted for the leaky box model. The reason for it at present is unknown. Since one of the basic assumptions in our NUGD model is that the 'leaky box' concept should be applicable to its individual elements, for the time being the inconsistency shown above makes it reasonable to neglect the data on iron-group of nuclei and keep n=3 in Eq. (1). Thus the deduced $j_{\bar{p}12}$ (i.e., the $\bar{p}$ flux predicted for the leaky box model) is shown in Fig. 1 as the curve OPLB, which is comparable with our previous prediction(the curve TLBF in Fig. 1).

In the deduction of the source term of $\bar{p}$'s in the H_2 cloud region the contribution of 'primary' $\bar{p}$'s, which originate from Box 2 and flow into Box II, should be taken into account (2). Thus the contributions coming from the 'primary' and the 'secondary' (i.e., locally produced) components of $\bar{p}$'s in $q_{\bar{p}II}$ are shown in Fig. 2 for the case of δ= 0.7, where δ is the power index of the rigidity (R) dependence of λ_e. It appears that the dominant part of $\bar{p}$'s is indeed locally produced.

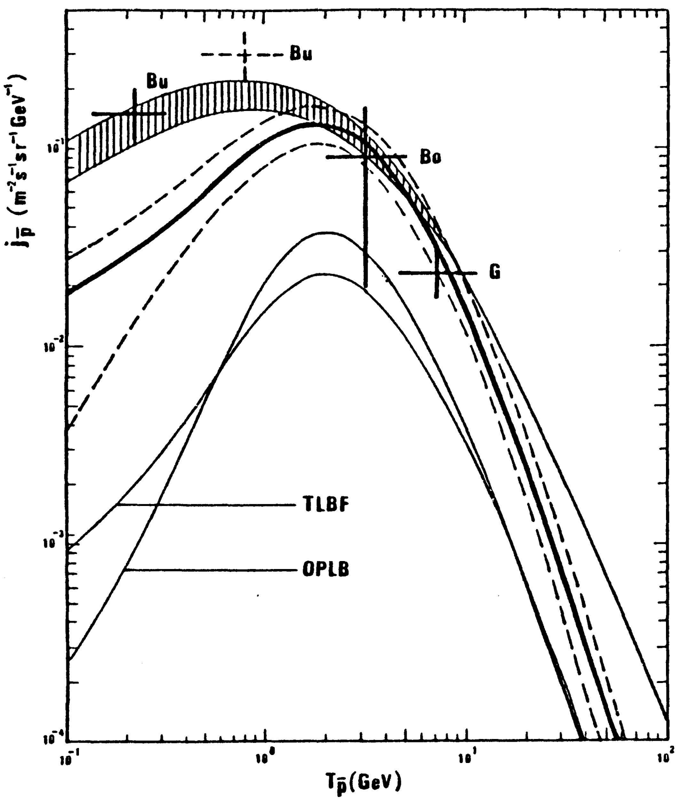

Fig. 1

Obviously, the estimation of the $\bar{p}$ flux in the dence H_2 cloud region, $j_{\bar{p}II}$, should be dependent upon the assumed value of cosmic-ray convection velocity, V. Nevertheless, the convection motion of cosmic rays should play a less serious role in view of the fact that 10 GeV cosmic rays have a diffusion coefficient of about 10^{30} cm^2/s (2). Therefore, the allowable range of the $\bar{p}$ flux may be estimated by assuming some extreme values of V. Here we will consider the cases of V = 0 (no convection motion) and V = 300 km/s (the estimated velocity of galactic wind for the normal galaxy(5)). Thus $j_{\bar{p}II}$ and the $\bar{p}$ flux after the adiabatic deceleration in the assumed boundary layer ($j_{\bar{p}de}$), and the $\bar{p}$ flux reaching the solar neighbourhood from Box II ($j_{\bar{p}s}$), are shown in Fig. 3 for the case of δ= 0.7. Since the observed $\bar{p}$ flux in the solar neighbourhood should contain both the distant and the local components, so that we have

$$j_{\bar{p}NUGD} = (1 - \varepsilon) \, j_{\bar{p}s} + \varepsilon \, j_{\bar{p}12} \; . \qquad (2)$$

In Fig. 1 we compare our newly predicted $j_{\bar{p}}$ (the thick solid line) and its allowable range due to uncertainties of λ_{e0II} and δ (the region between both dashed lines) with our previous prediction (the shaded region) and the existing $\bar{p}$ data(6)-(8). It is found that the consistency of our new prediction with the measured data at $T_{\bar{p}}$, the $\bar{p}$ kinetic energy, above about 1 GeV is significantly improved. However, the divergence between our new prediction and the very low-energy datum(8) is increased, though it is still less than 2 standard deviations.

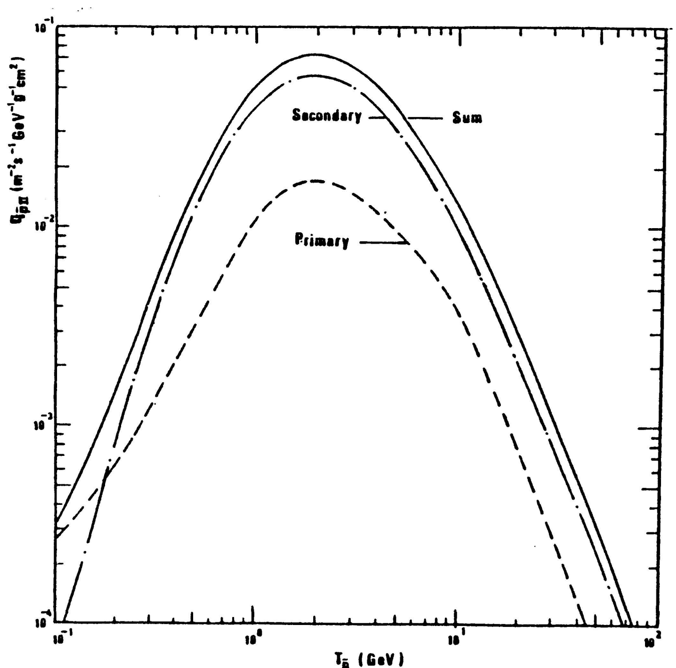

Fig. 2

It follows that the reliability of the datum Bu (8) shown in Fig. 1 may be questionalbe, because the recently measured ^{3}He data in the corresponding energy range do not show a similarly abnormal increase(9). Actually, Jordan and Meyer(9) require a nearly constant value of λ_e ($\doteq$ 15 gcm^{-2}) to explain the measured ratio of ^{3}He to ^{4}He in the energy range of 0.1 - 10 GeV/n. Note their deduced λ_e value, being about 3 times that suggested by the leaky box model, is in agreement with our reported value of λ_{eII}(2). Thus the analysis of the isotope composition of cosmic-ray He nuclei excludes any abnormal increase of λ_{eII} at low energies, and hence any underestimation of $j_{\bar{p}II}$ in our calculation.

Furhtermore, if the left divergence between our new prediction and the datum Bu is due to the existence of an exotic $\bar{p}$ source, the source should be significant only below 1 GeV. It is because we have already explained the existing $\bar{p}$ data at $T_{\bar{p}}$ higher than 1 GeV based on the existing model. It appears that our calculation is in conflict with the extragalactic origin of observed $\bar{p}$'s(10), because at least at $T_{\bar{p}} \geqslant 1$ GeV the contribution of the exotic $\bar{p}$ source should be negligible.

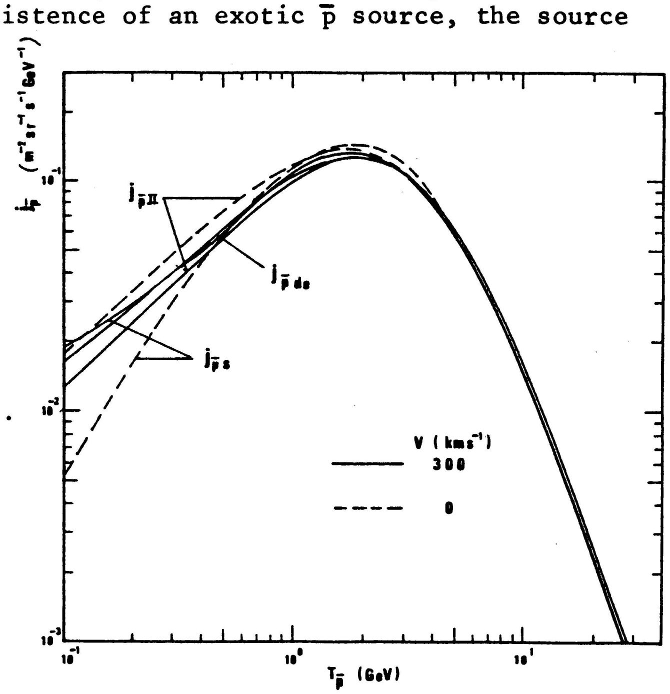

Fig. 3

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