High Energy Primary Electrons and the Universal Black Body Radiation *

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** On leave from Tata Institute for Fundamental Research, Colaba, Bombay-5, India.

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ABSTRACT 13117

In this letter we wish to show that in the framework of the galactic halo model, the recent measurements of the electron energy spectrum in the 1 GeV to 350 GeV energy interval are compatible with the presence of a universal black body radiation ($\sim 3.5^{o}$K). The lifetime of the halo electrons is estimated to be $(1.5 \sim 3) \times 10^{15}$ sec.

Author

The energy spectrum of primary cosmic ray electrons has by now been determined by a number of experiments over a wide range of energies[1-9]. In the 0.05 GeV to 5 GeV energy interval[10-12], a negative excess of electrons has been observed. Daniel and Stephens have recently reported results for the electron spectrum in the energy region from 12 GeV to 350 GeV[1,2], and for the fraction of positrons in the electron component at energies $\gtrsim$ 12 GeV by the E-W asymmetry measurements. Combining their results with data at lower energies, Daniels and Stephens conclude that either the proposed[13] universal black body radiation at 3.5^{o} K [14-17] does not exist, or that there exists a second source of high energy electrons. This source would have an intensity and spectrum of the form $dJ(E)/dE = 0.45 \times E^{-1.1}$ $(m^2\ \mathrm{sec.ster.GeV})^{-1}$ below 20 GeV and a power law spectrum with a negative exponent $\gamma = 2.1$ extending from 20 GeV to 350 GeV. Furthermore this source is assumed to contain an excess

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of positrons.

In this letter we wish to point out that $3.5^\circ K$ blackbody radiation is compatible with the recent data on the electron energy spectrum[2,5,8,9] without invoking a second source of electrons. Furthermore, the spectrum assumed by Daniel and Stephens does not clearly follow from the experimental results. We also wish to point out that their measurements of the East-West asymmetry at energies > 12 GeV are open to the alternative interpretation, that they are re-entrant albedo electrons.

To illustrate our point, we have plotted in Fig. 1 the results of electron energy spectrum measurements[2,5,8,9] at the present solar minimum period. These data indicate a change of slope in the electron energy spectrum around 7-10 GeV. Data between 1 GeV and 5 GeV can be represented by the power law

$$\frac{dJ}{dE} = 30\, E^{-\gamma} \quad \text{electrons}/(\text{m}^2 \text{ sec. ster. GeV}) \qquad (1)$$

with an exponent $\gamma = 1.8 \pm 0.15$. If we assume that the halo electron energy spectrum is given by Eqn. (1) there is no conflict with the observations of the non-thermal radio background[18-20]. It has been shown many times[21-23] that the important processes for energy loss of the electrons are compton scattering, synchrotron radiation and leakage from the halo. With the revised value for the compton scattering term due to the presence of a universal black body radiation ($\sim 3.5^\circ K$) one obtains

$$-\left(\frac{dE}{dt}\right)_c = 7.5 \times 10^{-26}\, W_{ph}\, E^2 \text{ [eV/sec]} \quad \text{for } E < 10^4 \text{ GeV}$$

$$-\left(\frac{dE}{dt}\right)_S = 3.8 \times 10^{-15} < B^2_\perp > E^2 \text{ [ev/sec]} \quad < B^2_\perp > = 2/3 < B > \qquad (2)$$

$$-\left(\frac{dE}{dt}\right)_L = \left(\frac{1}{\tau}\right) E \qquad \text{[ev/sec]}$$

where τ is the leakage lifetime of halo electrons and W_{ph} is the radiation energy density (eV/cm^3) for all photons. Most of the contribution for it comes from the black body radiation W_{ph} (b.b) = 0.71 eV/cm^3 [24]. The contribution from star light W_{ph} (s.l.) in the galactic halo has been estimated by several workers with results varying between 0.01 eV/cm^3 [25] and 0.3 eV/cm^3 [22]. Using $W_{ph} = 1\ eV/cm^3$, $\langle B \rangle = 3\mu$ gauss and $\tau = 3 \times 10^{15}$ sec, the rates of energy loss are plotted in Fig. 2 as a function of electron energy. Below 5 GeV the leakage loss (L) is prominent. Compton losses (C) dominate above about 10 GeV. Therefore in the energy interval 1 GeV to ~ 5 GeV the slope of the energy spectrum (Eqn. 1) is preserved. However above ~ 10 GeV the spectrum will be steepened.[21] Using the method of Daniel and Stephens[2] we obtained the equilibrium energy spectrum for this energy range

$$\frac{dJ}{dE} = \frac{30\, E^{-(\gamma + 1)}}{(\gamma - 1)\, b\, \tau} \qquad (3)$$

where $b = -\frac{1}{E^2}\left[\left(\frac{dE}{dt}\right)_S + \left(\frac{dE}{dt}\right)_c\right]$. The value b was evaluated using Eqns. (2). The dashed lines in Fig. 1 are the resulting spectra for two values of τ Within the uncertainties of the measurements both values fit the data.

Secondly, Daniel and Stephens[2] assertion that there exists a positron excess at energies > 12 GeV as opposed to the electron excess in the 0.05 to 5 GeV energy interval,[10-12] should be interpreted with great caution. Measurements of the E-W asymmetry[1,2,26] are liable to be falsified by re-entrant electrons. Below the geomagnetic cut-off, re-entrant electrons were observed by Verma[27] and Daniel and Stephens[1]. Let N_w and N_e be the number of $e^+ + e^-$ arriving from directions which are above the cut-off for one charge and below the cut-off for the other.

Then

$$N_w = P\,\epsilon_P^+ + R\,(1-\epsilon_R^+)$$

$$N_e = P\,(1-\epsilon_P^+) + R\,\epsilon_R^+ \qquad (4)$$

where P and R are the sum of e^+ and e^- of primary and re-entrant nature respectively from these directions. ϵ_P^+ and ϵ_R^+ represent the positive fraction ($\frac{e^+}{e^+ + e^-}$). The E-W asymmetry is then given by

$$A = 2\,\frac{N_w - N_e}{N_w + N_e} = \frac{4\left[(P/R)\,\epsilon_P^+ - \epsilon_R^+\right] - 2\,(P/R - 1)}{(P/R + 1)} \qquad (5)$$

The asymmetry will depend on the relative fluxes of primary and re-entrant electrons. An extrapolation of the measured re-entrant electron spectrum beyond 6 GeV, previously summarized by Verma[27], leads to a ratio of the re-entrant and primary flux (R/P) of about 20 % or more. Daniel and Stephens data are therefore complicated by the presence of re-entrant electrons. In fact, due to re-entrant electrons their E-W asymmetry data are not inconsistent with the negative excess of electrons.

In conclusion we emphasize that in the framework of the galactic halo model, the measurements of the electron spectrum in the high energy region is compatible with the presence of a universal black body radiation ($\sim 3.5^\circ$ K) if the lifetime of the electrons (τ) is assumed to be $\sim (1.5 \sim 3) \times 10^{15}$ sec.

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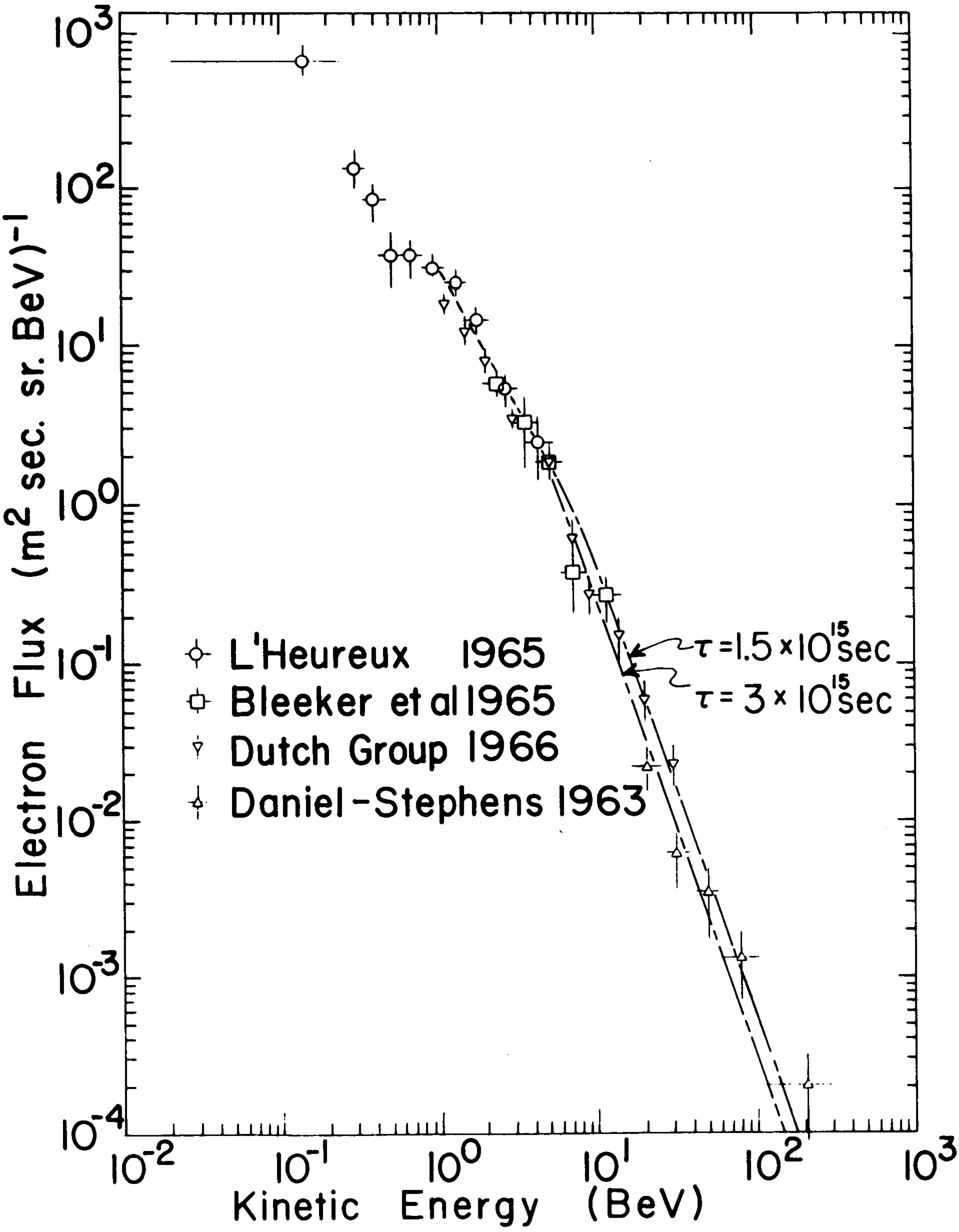
Figure Captions

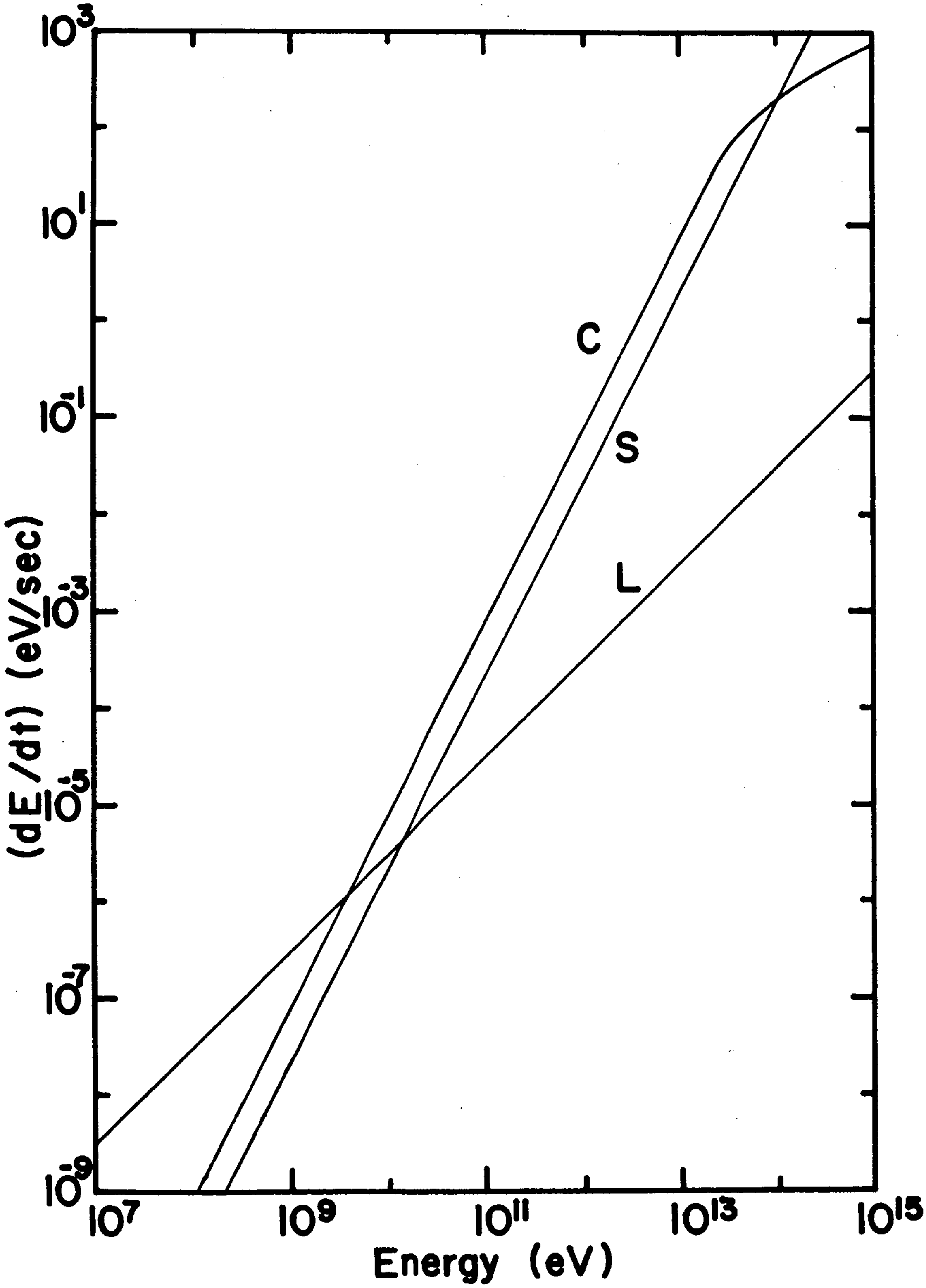
Fig. 1. Calculated equilibrium energy spectrum of electrons in the galactic halo with experimental points taken near present solar minimum period.[2,5,8,9] (The years are the time of the experiment.)

Fig. 2. Electron energy loss rate in the galaxy by Compton scattering (C), synchrotron emission (S) and leakage out of the halo (L).



Electron Flux (m² sec. sr. BeV)⁻¹
Kinetic Energy (BeV)
L'Heureux 1965
Bleeker et al 1965
Dutch Group 1966
Daniel-Stephens 1963
τ = 1.5 × 10¹⁵ sec
τ = 3 × 10¹⁵ sec

Figure 1



10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
(dE/dt) (eV/sec)
C
S
L
10^7
10^9
10^{11}
10^{13}
10^{15}
Energy (eV)

Figure 2