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+ On leave from Tata Institute of Fundamental Research, Colaba, Bombay-5, India.

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Long Term Time Variations of the Primary Cosmic Ray Electron Component*

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Abstract

The intensity of primary cosmic ray electrons has been measured from 1960 through 1966 at balloon altitude over Ft. Churchill, Manitoba. Initial measurements were made with an energy-loss vs. range counter telescope from 1960 through 1964. From 1964 through 1966 an energy-loss vs. total energy counter telescope was used. Overlapping data exist for both instruments in 1964. Our results are consistent with the absence of a solar modulation effect for electrons in the 0.25 BV to 1.05 BV rigidity range. The experimental errors lead to an upper limit of 60 percent for the possible fractional change of the electron intensity over this period.

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I. Introduction

Recent experiments have shown convincingly that the modulation of nuclear galactic cosmic ray particles in the solar system depends on the rigidity as well as the velocity of the primary particles. A theoretical interpretation and an application to existing data has been presented by Gloeckler and Jokipii (1966). Clearly, these ideas are best tested through the investigation of modulation effects on particles of widely different rigidity vs. velocity relations. For this reason information on the modulation of the primary cosmic ray electron component is of particular interest. Only very recently has it become possible to accurately determine the energy spectrum of the primary cosmic ray electrons. However, over a limited energy range, we have data on the primary electron flux which cover the years 1960 through 1966 and therefore include a major portion of the solar cycle. In this paper we wish to present the results of a study of the long term variation of the flux of primary electrons in the energy range from 250 MeV to 1 BeV. The measurements were made with an energy-loss vs. range counter telescope from 1960 through 1964 (Meyer and Vogt 1961; Vogt 1962) and with an energy-loss vs. total energy counter telescope from 1964 through 1966 (L'Heureux and Meyer 1965; L'Heureux 1967). Overlapping data with both instruments exist in 1964. The electron energy spectrum under 4 g/cm^2 of residual atmosphere, but corrected for atmospheric secondaries, which was obtained with both instruments in that year is shown in Fig. 1 and displays the agreement between the data.

II. Experimental Results

In Fig. 2 we have plotted the flux of primary electrons in two energy intervals as a function of time. In each year several balloon flights were made from

Ft. Churchill, Manitoba and each data point represents the results from one flight. We selected only those balloon flights which took place when no enhanced solar activity or solar proton fluxes were present. The data are corrected for atmospheric secondaries using the flux vs. depth curves for each year. They are also corrected for nuclear interactions in the detector system. The latter correction has to be applied only to the data from the range telescope. Both instruments were calibrated using high energy electron accelerators. The restrictions in the length of this paper do not permit us to give details on the calibrations and corrections. The errors in Figs. 1 and 2 include uncertainties in the corrections.

For comparison we have included in Fig. 2 the flux of primary protons and helium particles at a rigidity of about 0.75 to 0.8 BV. This interval almost coincides with the mean of our high rigidity electron interval. The proton and α-particle data are based on the work of Webber and McDonald (1964), Vogt (1962), Meyer and Vogt (1963), Fichtel et al. (1964), Freier and Waddington (1965a, b), Balasubrahmanyan and McDonald (1964), Fan, Gloeckler and Simpson (1965), Balasubrahmanyan, Hagge, Ludwig and McDonald (1965), Ormes and Webber (1965), Comstock, Fan and Simpson (1966) and Courtier and Linny (1966). Also included in Fig. 2 are the monthly averages of the Climax neutron monitor data obtained by Simpson from 1959 through 1966 (U. S. Dept. of Commerce, 1959-66).

III. Discussion and Conclusions

It is evident from Fig. 2 that our observations of the flux of primary electrons in the two energy intervals which range from 0.25 BeV to 1 BeV do not exhibit a measurable long term intensity variation from 1960 to 1966. Taking into account

the experimental errors, one may place an upper limit of 60% on the possible intensity variation between 1960 and the period of minimum solar activity around 1964-65. A direct comparison between measurements of proton, helium and electron fluxes is possible in the rigidity interval from 0.5 BV to 1 BV. From Fig. 2 it can be seen that between 1960-61 and solar minimum in 1965 both the proton flux and the α-particle flux increased by about a factor of 3. Thus, the electron intensity modulation amounts to at most 20% of the modulation of protons and α-particles in the same rigidity interval.

Gloeckler and Jokipii (1966) have shown that the long term time variation of the nucleonic primary cosmic ray components between 1963 and 1964 may be represented by

$$J_2 / J_1 = \exp [(\eta_1 - \eta_2) / R\beta]$$

where J_1 and J_2 are the observed fluxes at times t_1 and t_2. η_1 and η_2 are constants at t_1 and t_2. Our results on the electron component are difficult to fit into this picture. The question immediately arises whether we are indeed observing primary particles rather than secondaries which are not expected to show much time variation, since they are primarily produced by protons of several BeV energy. Without being able to here discuss this point in detail, we wish to state the following. Calculations of Verma (1966), as well as measurements of the intensity-altitude dependence (L'Heureux 1967) show that atmospheric secondaries amount to about 30% of the electron flux at the altitudes and energies which we consider. This fact has independently been established by Webber and Chotkowski (1967). Furthermore, the large excess of negative electrons over positrons observed by Hartman (1967) in the 0.5 to 1 BeV energy interval and at comparable altitudes strongly supports the contention that we are observing mostly primary electrons.

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References

Balasubrahmanyan, V. K., and F. B. McDonald 1964, J. Geophys. Res. 69, 3289.

Balasubrahmanyan, F. K., D. E. Hagge, G. H. Ludwig, and F. B. McDonald 1965, Int. Conf. Cosmic Rays (London) 1, 427.

Comstock, G. M., C. Y. Fan, and J. A. Simpson 1966, Ap. J. 146, 51.

Courtier, G. M. and A. D. Linney 1966, Planet. Space Sci. 14, 503.

Fan, C. Y., G. Gloeckler and J. A. Simpson 1965, Int. Conf. Cosmic Rays (London) 1, 380.

Fichtel, G. E., D. E. Guss, D. A. Kniffen and K. A. Neelakantan 1964, J. Geophys. Res. 69, 3293.

Freier, P. S. and C. J. Waddington 1965, J. Geophys. Res. 70, 5753.

Freier, P. S. and C. J. Waddington 1965, Int. Conf. Cosmic Rays (London) 1, 339.

Gloeckler, G. and J. R. Jokipii 1966, Phys. Rev. Letters 17, 203.

L'Heureux, J. and P. Meyer 1965, Phys. Rev. Letters 15, 93.

L'Heureux , J. 1967, Ap. J. 146, 399.

Meyer, P. and R. Vogt 1961, Phys. Rev. Letters 6, 193.

Meyer, P. and R. Vogt 1963, Phys. Rev. 129, 2275.

Ormes, J. and W. R. Webber 1965, Int. Conf. Cosmic Rays (London) 1, 339.

U. S. Dept. of Commerce 1959-1966, Solar Geophysical Data CRPL-F, 173 - 268, Part B, ESSA, Boulder, Colorado.

Verma, S. D. 1966, Enrico Fermi Inst. Notes No. 66-44 (In press, Proc. Ind. Acd. Sci.).

Vogt, R. 1962, Phys. Rev. 125, 366.

Webber, W. R. and F. B. McDonald 1964, J. Geophys. Res. 69, 3097.

Webber, W. R. and C. Chotkowski, 1967, J. Geophys. Res. 72, 2783.

Figure Captions

Figure 1. The primary electron differential energy spectra measured in the summer of 1964 by two different instruments at a depth of about 4 g/cm^2. The squares represent measurements made by the energy loss vs. total energy counter telescope; the circles, measurements made by the energy loss vs. range counter telescope. The solid circle represents the flux of electrons in the energy region from 10 MeV to 250 MeV obtained by combining the measurements in the 10 to 80 MeV and 80 to 250 MeV regions.

Figure 2. Average differential intensities of electrons, protons and helium nuclei from 1959 through 1966. Electron fluxes measured by the energy loss vs. range counter telescope are shown by open circles. Open squares represent electron fluxes measured by the energy-loss vs. total energy counter telescope. The electron data were obtained under about 4 g/cm^2 of residual atmosphere. They are corrected for atmospheric secondaries, but not extrapolated to the top of the atmosphere. Proton and helium nuclei data: circle with dot, Webber and McDonald (1964); open circle, Vogt (1962) and Meyer and Vogt (1963); open triangle, Fichtel et al. (1964); solid triangle, Freier and Waddington (1965a,b); open square, Balasubrahmanyan and McDonald (1964); solid circle, Courtier and Linney (1966); open diamond, Fan et al. (1965); solid square, Balasubrahmanyan et al. (1965); solid diamond, Ormes and Webber (1964); square with dot, Comstock et al. (1966). The neutron monitor data are from the Climax station (U. S. Dept. of Commerce (1959-66)).

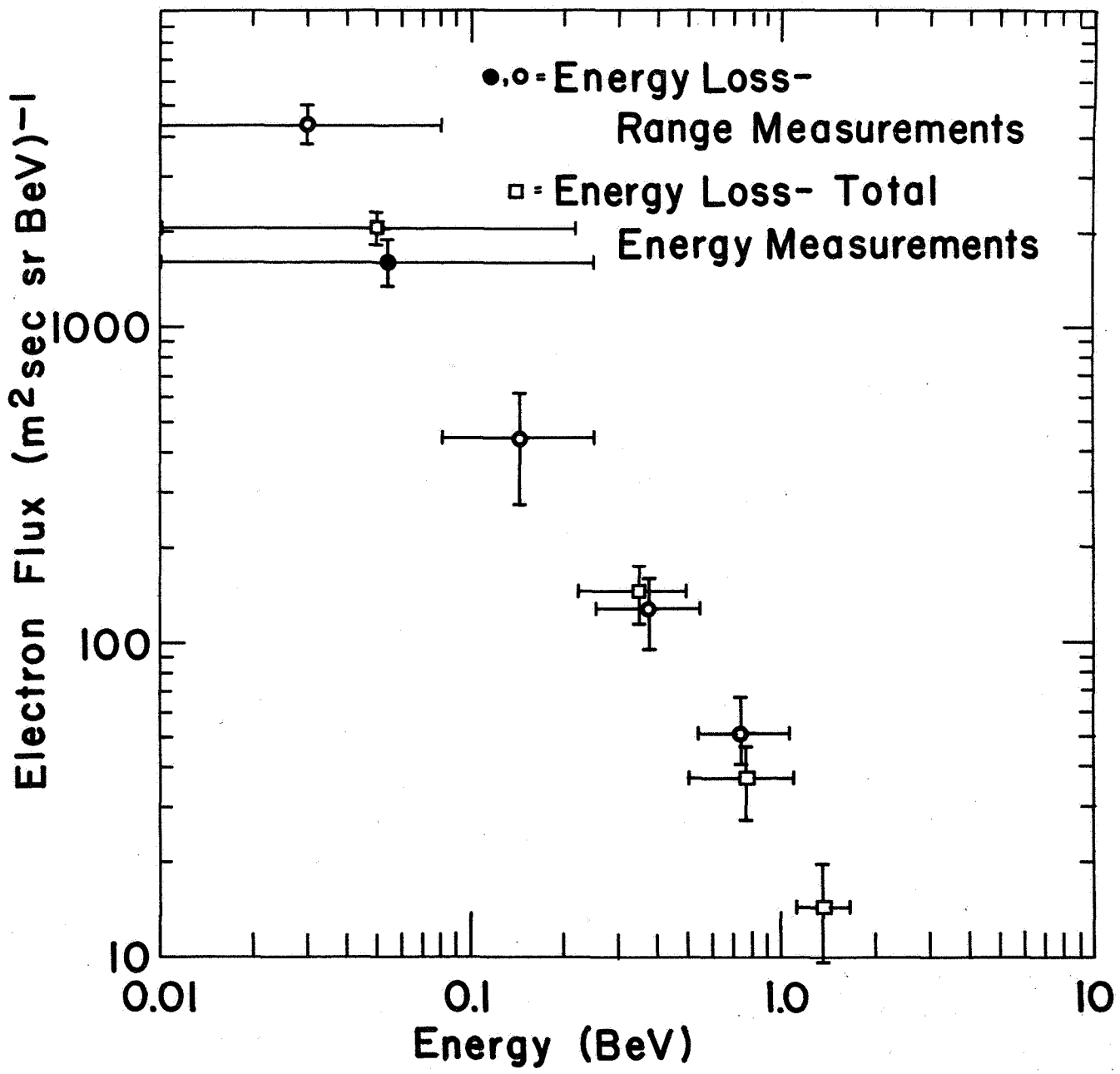
●,○ = Energy Loss-
Range Measurements
□ = Energy Loss- Total
Energy Measurements
Electron Flux (m²sec sr BeV)⁻¹
1000
100
10
0.01
0.1
1.0
10
Energy (BeV)

Fig. 1

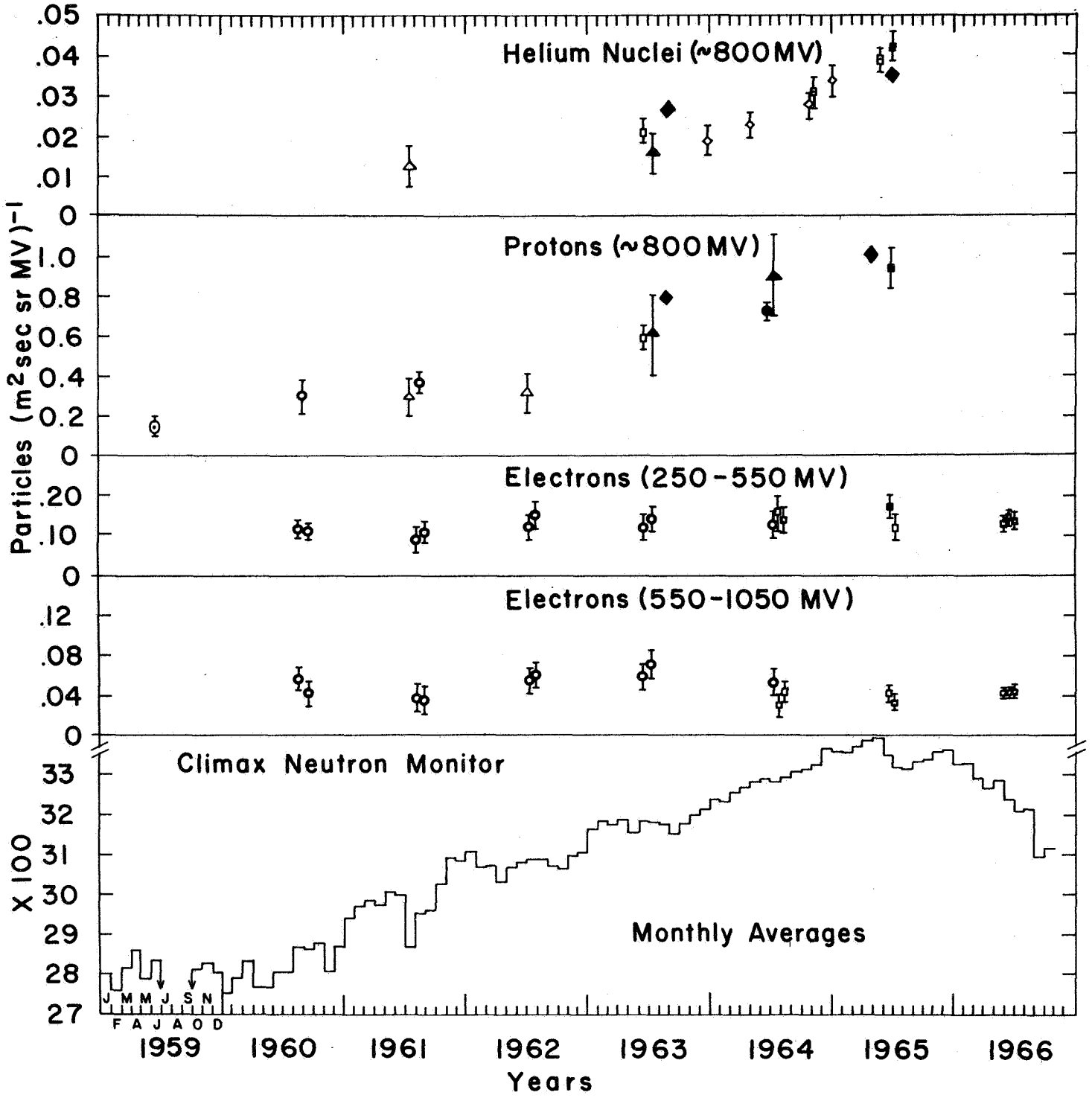
Helium Nuclei (~800MV)
Protons (~800MV)
Electrons (250-550 MV)
Electrons (550-1050 MV)
Climax Neutron Monitor
Monthly Averages
Particles (m²sec sr MV)⁻¹
X 100
J M M J S N
F A J A O D
1959
1960
1961
1962
1963
1964
1965
1966
Years

Fig. 2