OBSERVATIONS OF THE SOLAR PROTON EVENT OF AUGUST 28, 1966*

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ABSTRACT

The CsI scintillator telescope aboard IMP-III indicated a peak intensity of 6·25 proton/sec cm^2 ster for a SPE (Solar Proton Event) commencing during the period 1600 to 1700 UT on August 28, 1966. This SPE appears to have been associated with the importance 2–3 flare occurring at 22N/06S at 1522 UT on this date. The comparison of this event to other large proton events occurring during the period May 25, 1965 to September 30, 1966, is made.

1. Experiment

The data for this analysis was supplied by the GSFC medium-energy scintillator cosmic-ray telescope, aboard IMP-III. This device, shown schematically in Figure 1, was also flown on IMP-I, IMP-II, and the recently launched IMP-IV, thus providing the long-term monitoring of H and He in the range of 16–80 MeV/nucleon. A brief description of this telescope is given by Balasubrahmanyan *et al.* (1966) and Bryant *et al.* (1962).

Briefly, the telescope consists of a 1-mm CsI ΔE detector 5 cm in diameter, A, separated by 10 cm from a 2-cm CsI E-ΔE detector B of the same diameter. The latter is surrounded by an anti-coincidence counter of Pilot-B scintillator plastic, C. Three photomultiplier tubes look at the light output of each of these detectors. The thin detector measures the energy loss ΔE of a particle completely penetrating it, while the thick detector has a light output proportional to the amount of energy E–ΔE deposited by a particle stopping in it after passing through the thin detector. It is readily seen that the desired coincidence for determining the charge-mass ratio of the incident particle is $AB\bar{C}$, i.e., the particle must penetrate A and B but not pass into C.

The total counts obeying this coincidence are sampled for 40 sec every 400 sec data cycle and stored in an accumulator. Six times during this data cycle the energy of a particle satisfying the $AB\bar{C}$ coincidence is sampled and analyzed by two 512-channel differential pulse-height analysers, one each for the ΔE and E–ΔE crystals. A count from these two PHA's may be considered to occupy a discrete position on a ΔE versus E–ΔE plot, as shown in Figure 2. Because of their unique charge-to-mass ratio,

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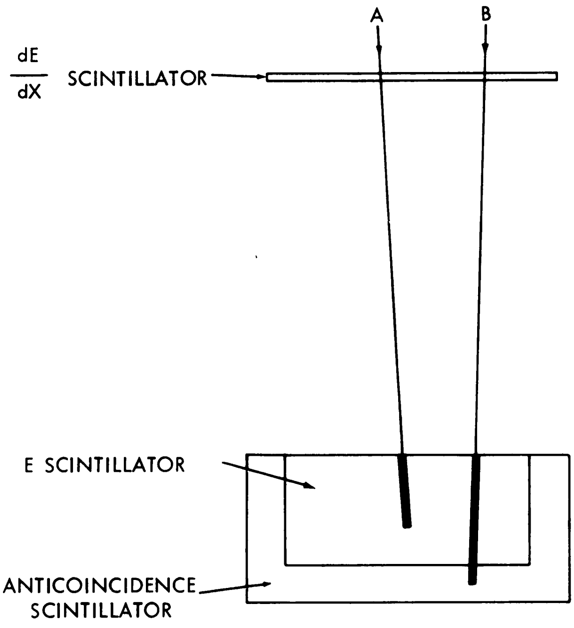

FIG. 1. *Schematic of IMP-III medium-energy cosmic-ray telescope.*

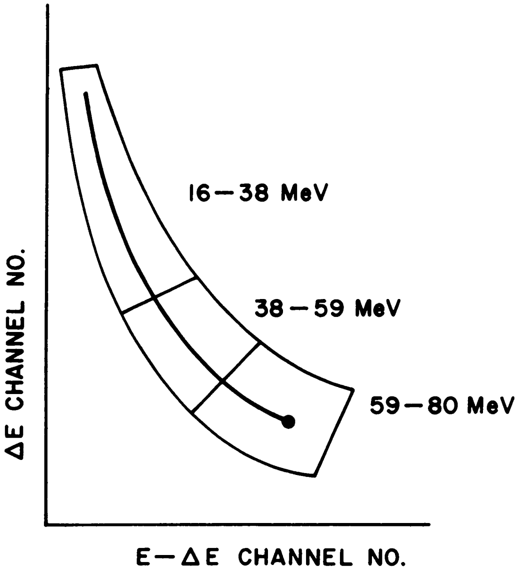

FIG. 2. *Schematic of ΔE vs. E–ΔE array with proton curve and differential energy-counting regions shown.*

proton counts will occupy a certain region of this plot, as signified by the solid curve in Figure 2. The mean geometry factor for this telescope was calculated to be 3·4 cm^2 ster, and the counting time for the $AB\bar{C}$ coincidence is determined by the time that the accumulator is open to such events, i.e. ~40 sec.

2. Analysis

If N_c is the total counts during a time T, and G is the geometry factor then the incident particle intensity is given by

$$I = N_c/TG. \tag{1}$$

This intensity, of course, includes He and electrons as well as H. In order to determine the intensity of protons only, one must find the fraction of the total counts that have the charge-to-mass ratio corresponding to H. This is accomplished by counting the number of events occurring in the prescribed proton region in the ΔE versus E–ΔE array depicted in Figure 2. For the present study 6 hour averages of the $AB\bar{C}$ coincidence counts were taken and during the same time period the counts in the 'boxes' shown in Figure 2 were made, as well as the total number of counts in the entire array. The three boxes correspond to the coarse differential energy ranges 16–38 MeV, 38–59 MeV, and 59–80 MeV.

If N_A, N_B and N_C are the number of counts in each of the boxes in ascending energy, respectively, then the total number of protons counted between 16 and 80 MeV is

$$N_T = N_A + N_B + N_C. \tag{2}$$

Now if N_M is the total number of counts in the array for the same period, the ratios of the protons to total number of particles sampled is given by

$$R_T = N_T/N_M \qquad (16\text{–}80\ \mathrm{MeV}) \tag{3}$$

$$R_A = N_A/N_M \qquad (16\text{–}38\ \mathrm{MeV}) \tag{4}$$

$$R_B = N_B/N_M \qquad (38\text{–}59\ \mathrm{MeV}) \tag{5}$$

$$R_C = N_C/N_M \qquad (59\text{–}80\ \mathrm{MeV}). \tag{6}$$

The proton intensities are now directly computed by the products,

$$J_T = R_T I \qquad (16\text{–}80\ \mathrm{MeV}), \tag{7}$$

etc.

Because of the manipulations of the 512 by 512 arrays and the large number of related calculations, a high-speed computer was utilized for these computations.

Results

The solar proton event (SPE) of August 28, 1966 appears from the above calculations to have a double-peaked structure, the two peaks occurring at 2100 on August 28 and 0300 on August 30, as shown in Figure 3. Recalling that the time resolution of this analysis is 6 hours, the commencement times of these two events are at 1500 (August 28) and 2100 (August 29). The peak-proton intensities for $16 \leqslant E \leqslant 80$ MeV are 6·25 and 4·2 protons/sec cm^2 ster, respectively. It is noted (ESSA, 1966) that there was a 3B-importance flare at 1522 on August 28 and a 1N importance flare at 2114 on August 29, as well as the observation of type-IV radio emission at 1547 and 2032 on these two dates, respectively, both of intensity 2+. There is not enough information at present to determine whether the second peak is the result of another flare, or if it represents the arrival of energetic storm particles.

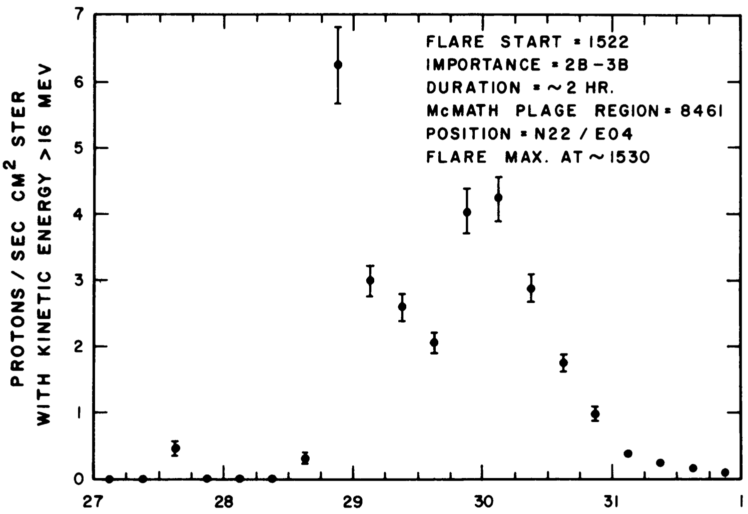

FIG. 3. *Time history of the SPE of August 28, 1966.*

In Figure 4 are shown linear plots of the intensity versus energy for the three differential energy ranges, giving a crude but simple picture of the spectrum of these particles. From the steep slope of these curves, one can conclude that to within a few percent the peak intensities can be interpreted as being correct for all energies $\geqslant 16$ MeV for the solar protons.

In Figure 5 we show the relative differential intensities as a semilog plot of the exponential rigidity as given by

$$\frac{\mathrm{d}J}{\mathrm{d}R} = \left(\frac{\mathrm{d}J}{\mathrm{d}R}\right)_0 \exp(-R/R_0). \tag{8}$$

The characteristic differential intensity $(\mathrm{d}J/\mathrm{d}R)_0$ and characteristic rigidity R_0 as yet have no precisely defined physical meaning, but serve as a basis for comparing different events as suggested by Rinehart (1967). For this particular event the mean

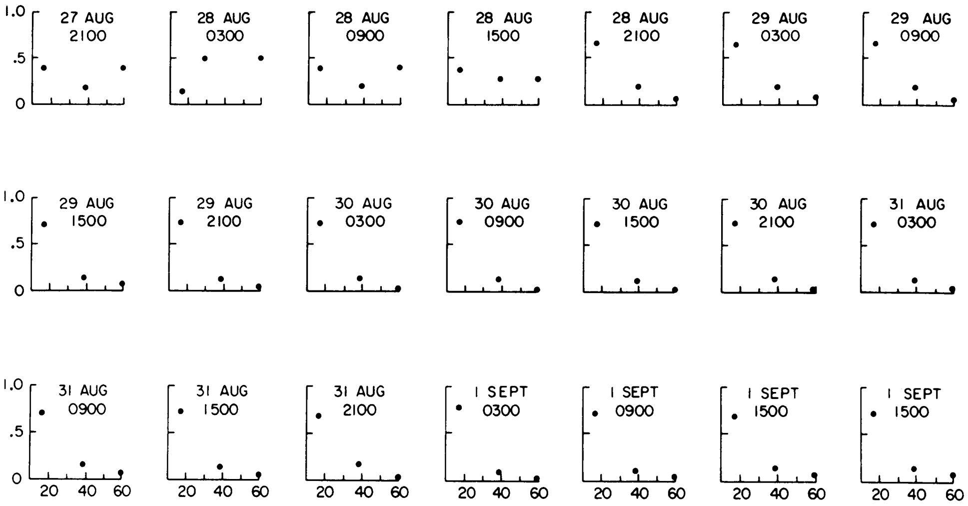

FIG. 4. *Six-hour energy spectra of the August 28, 1966 SPE.*

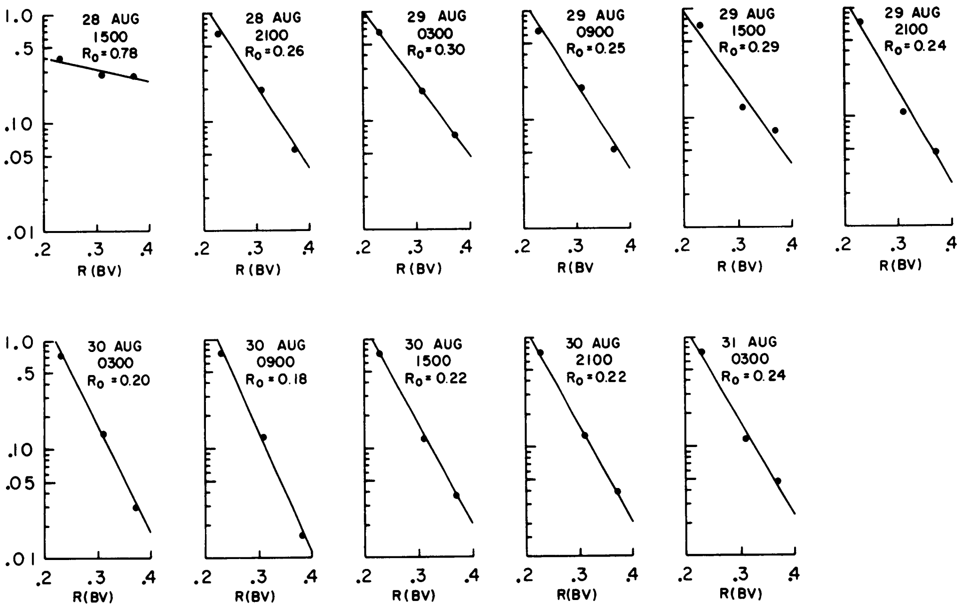

FIG. 5. *Six-hour exponential rigidity spectra of the August 28, 1966 SPE.*

value of R_0 is $\sim$0·25. This value is comparable to values Rinehart has computed for SPE's of several years ago.

3. Correlation with other SPE's and Related Phenomena

Fichtel and McDonald (1967) have suggested that an arbitrary criterion of 0·5 protons/sec cm^2 ster is a good value for the lower limit of the peak intensity of these proton events for correlation with optical flares and type-IV radio emission. This seems to be generally the case for the events presented in Table 1. Herein are tabulated all events appearing above the mean-background level of 0·007 protons/sec cm^2 ster. Except for the events of October 4, 1965, March 24, 1966, and the complex event starting on September 2, 1966, this does seem to be the case. To our knowledge there are some geographic gaps in the radio spectrographic average of the Sun during these particular periods, or at least we were unable to find records of type-IV emission at those times.

This survey of IMP medium-energy detector data is being extended to give a catalog of proton events during most of the period of minimum solar activity to be published.

Table 1

Summary of abrupt prolonged proton-intensity increases above mean background[a] for energies > 16 MeV for IMP-C, May 29, 1965 to September 30, 1966

Date	Time[b]	Peak Intensity	Optical Flare			Type IV	
		(proton/sec cm^2ster)	Time	Impor.	Location	Time	Int.
4 Oct. 1965	0900 UT	2·6	0935	2	S21/W31		
19 Jan. 1966	0900	0·015					
24 Mar. 1966	0300	4·4	0225	3B	N18/W37		
29 Apr. 1966	0900	0·055					
2 May. 1966	2100	0·15	0808	2N	N16/E53	1216	1 –
25 Jun. 1966	1500	0·11	1523	1B	S25/W09	1607	2
4 Jul. 1966	2100	0·045					
7 Jul. 1966	0300	23·0	0022	2B	N35/W45	0053	3
13 Jul. 1966	1500	0·12	1625	1N	N22/E90		
16 Jul. 1966	2100	0·21					
30 Jul. 1966	2100	0·028				2330 28 Jul.	3
28 Aug. 1966	1500	6·25	1522	3B	N23/E04	1547	2 +
29 Aug. 1966	2100	4·2	2114	1N	N07/W71	2032	2 +
2 Sept. 1966	0900	> 38·0[c]	0541	2B	N22/W57		
14 Sept. 1966	0300	0·88					
20 Sept. 1966	1500	0·087	1738	2B	N03/W15		
26 Sept. 1966	0300	0·053				1312	1 –
27 Sept. 1966	1500	0·14				1313	2

[a] Mean background level $\sim$0·007 proton/sec cm^2ster.

[b] Count averaging time is 6 hours, hence time given represents period from 3 hours before to 3 hours after.

[c] This event was so large that the detector and electronics saturated for $\sim$36 hours. C.E. Fichtel by private communication has indicated that emulsion measurements show a peak intensity of the order of 500 protons/sec cm^2 ster.

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