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Discussion

Carmichael, H.: In a slide which I did not have time to show a periodic fluctuation similar to that shown by Dr. Winckler was shown at sea level during the late part of the November 12, 1960 event. The pulsation were observed only by the European stations and Climax in U.S.A. Dr. Webber has stated that the pulsations appeared to be correlated with pulsation seen in the value of H measured by equatorial stations.

Singer, S. F.: Theoretical remark on the apparent flattering of the spectrum of solar cosmic rays at low energies. Such an effect would be expected by the application of the expected Liouville theorem (Swann, Nagashima) if diffusive deceleration is experienced by the particles in propagating from sun to earth (see paper II-5-16).

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-26. Cosmic Ray Intensity Bursts in the Stratosphere in November 1960

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According to our data in November 1960 there were recorded three cosmic ray intensity bursts in the stratosphere on the 14th, 15th and 21th of November.

The general picture of cosmic-ray flares is the following. A measurement carried out on November 14 at 7 hours (universal time) in the stratosphere at a latitude of 64° (the Murmansk region) showed that the cosmic ray intensity is much higher than the normal one. Subsequent three measurements made on this day confirmed this observation.

On the contrary, on November 14 in the stratosphere at latitudes of 51° and 41° a decrease in the normal level of cosmic ray intensity was recorded. A cosmic-ray flare in the stratosphere at northern latitudes occurred against the background of a Forbush decrease.

On November 15 a new flare was recorded which lasted to November 19. On November 21 one more little flare was recorded with about 50 hour duration.

The cosmic-ray flare of November 15 was also recorded on a latitude of 51° (Moscow) which lasted to November 16. In the subsequent period, when at latitude of 64° the flare still lasted, at a latitude of 51° the cosmic ray intensity level was lower than the normal one.

Measurements at a Latitude of 64°

Some data of measurements in the stratosphere obtained with the standard instrumentation (I) at a latitude of 64° for the period 14-23 November 1960 are presented in Table 1. In the third column the meaning of the additional cosmic ray stream at the top of the atmosphere with respect to the normal one is given. These data are obtained by extrapolation of altitude curves of the number of coincidences and the number of discharges in the counter to pressure of 5 g/cm². Marks *C* and *T* in the fourth column show that measurements were made with a counter or with a telescope, respectively. *t* is the approximate duration of the recorded flare in hours.

Fig. 1. shows absorption curves of an additional proton stream in cosmic-ray flares. Pressure P in g/cm² is given along the abscissa and differences between the measured number and the normal number of double coincidences and the number of discharges in a counter are given along the ordinate. Data 5 are obtained in three dimensions by means of a telescope on November 14. Results of these measurements are normalized at P=30 g/cm². Normalization coefficients K are given below the figure. Data I and 2 are obtained in measurements on November 15-1 for the number of double coincidences, 2 for the number of discharges in the single counter. Results of four measurements on November 15 are also normalized at pressure 30 g/cm². Data 3 and 4 are obtained from measurements on November 16 and 17, 3 for the number of double coincidence, 4 for the number of discharges in the single counter.

Table I.

Date of Measurements	Time of Measurements	m	Type of measurements	t
14.XI.60	$8^h30'$	50	C	
	10 45	50	T	
	13 35	70	T	
	15 45	30	T	
15.XI.60	8 30	500	T	
	11 20	200	T	
	13 30	200	T	
	15 40	200	T	100
16.XI.60	8 30	300	T	
	11 10	300	T	
	13 30	300	T	
	15 40	300x)	T	
17.XI.60	8 30	150	T	
	11 30	100	T	
	13 40	100	T	
18.XI.60	8 30	15	T	
	13 30	5	C	
19.XI.60	8 30	0	T	
	13 30	0	C	
21.XI.60	13 30	7	C	
	16 30	5	C	
22.XI.60	8 30	1.5	T	50
	11 30	3	C	
23.XI.60	8 30	0	T	

Solid lines 3, 4, 5 in Fig. 1 with due normalization show absorption curves obtained from measurements during a Forbush-decrease and 1, 2 during the absence of a Forbush-decrease for flares described in our work (2).

As is evident from Fig. 1, the proton path spectrum obtained in measurements on November 16 and 17 (curves 3 and 4) are considerably softer than the spectrum obtained on November 15 (curves 1 and 2). Results of measurements on November 15 were obtained at a time when the Earth was not yet impinged by solar corpuscular streams. Data of absorption curves in these measurements are similar to those obtained for similar cases in other flares. Results of measurements on November 16 and 17 correspond to results of measurements when a corpuscular stream impinged on the Earth. Though a Forbush decrease which could be caused by a solar flare on November 14 at 21h. 18 min. apparently did not occur nevertheless, from the fact of the proton spectrum softening in the outburst according to measurements made in the stratosphere on November 16 and November 17 it follows

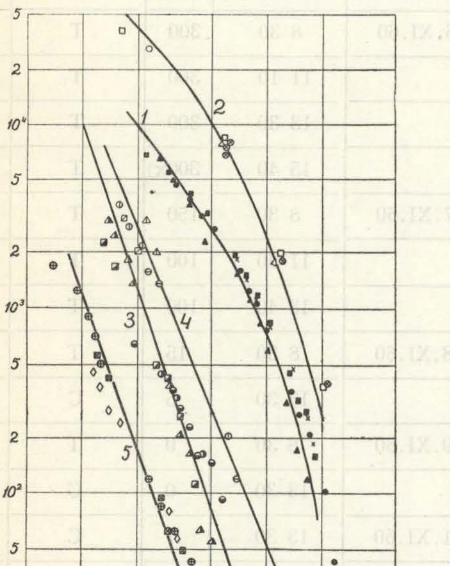

Fig. 1. Altitude dependences of the number of double coincidences and the number of discharges in the counter at a latitude of 64°.

	Starting time of the Instrument	The telescope	The counter	K
Nov. 14	9h15min.	⊕ } 5		2.0
	12h00min.	⊠		3.0
	14h15min.	◇		1.3
Nov. 15	7h00min.	● } 1	○ } 2	2.3
	9h50min.	■	□	1.0
	12h00min.	×	⊗	1.0
	14h10min.	▲	△	0.9
Nov. 16	9h38min.	◐ } 3	⦶ } 4	1.0
	12h00min.	⊖	⊖	1.0
Nov. 17	7h04min.	▲	△	0.45
	9h59min.	◪	⧄	0.30

that the Earth at that time was subjected to the action of a solar corpuscular stream which carried proton magnetic traps. Geomagnetic disturbances which started approximately at 17 hours on November 15, 1960, testify to the arrival of corpuscular streams to the Earth. Thus, we have an interesting case of the arrival to the Earth of the solar corpuscular stream which carried magnetic traps, but did not cause a Forbush decrease in cosmic radiation.

Time Dependence of Cosmic Ray Intensity in the Flare on November 15

Triangles in Fig. 2 show data of proton absolute intensity $N_p(t)$ (extrapolation to the top of the the atmosphere) at a latitude of 51° in the flare of November 15 depending on time. Solid dots show data obtained by measurements at a latitude of 64°. According to data of measurements by a neutron monitor in Leeds (3) the time of the arrrival of solar cosmic-rays is taken as the starting point $t=0$.

Fig. 2 gives also data (circles) of the flare on May 4, 1960, at a latitude of 64° normalised to data of measurements on November

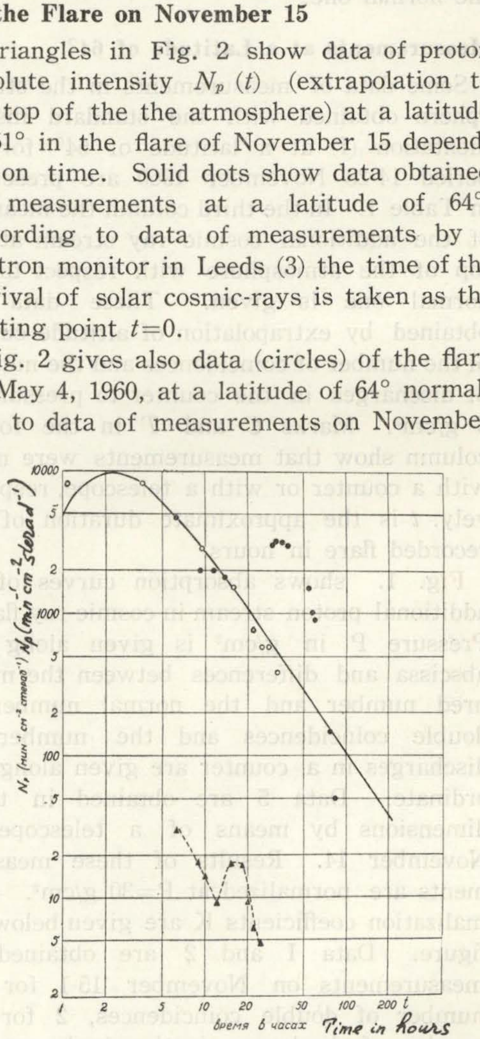

Fig. 2. Proton intensities as a function of time in the flare on November 15.

● for protons with energies > 100 Mev

▲ for protons with energies > 1.3 Bev

○ data for the burst on May 4 normalized to the burst on November 15 at $t=6.5$ h.

The solid curve represents calculation.

15 for $t=6.5$ hours. The solid curve is a result of calculations made in accordance with the formula for diffusion of protons scattering in the medium with magnetic-nonhomogeneities (2).

The irregularity of the $N_p(t)$ dependence attracts one's attention. In the initial stage more or less gradual $N_p(t)$ decrease takes place both at a latitude of 51° and at a latitude of 64°. As follows from the data of the outburst on May, 1960, this decrease should continue, but in subsequent measurements a new increase in $N_p(t)$ was recorded after which the decrease takes place by the law different from $t^{-3/2}$. This enhancement hardly can be accounted for by experimental errors. It was possible, however, to suppose that peaks in $N_p(t)$ intensity are connected with a new cosmic-ray intensity increase which could be caused by another solar flare. Though the possibility of such an explanation of the irregularity in N_p (t) curves is not fully excluded, nevertheless, we can without taking resort to such a hypothesis give a reasonable explanation for the repeated $N_p(t)$ growth by the supposition on the existence of magnetic traps of solar corpuscular streams.

We can hardly doubt that the peak in $N_p(t)$ obtained from measurements at a latitude of 64° (with $t=24$ hours) is caused by the arrival of solar corpuscular streams. With the $N_p(t)$ growth a simultaneous characteristic softening of the proton energy spectrum takes place. The $N_p(t)$ growth and the softening of the energy spectrum are caused by protons leaving magnetic traps of solar corpuscular streams in the sphere of the action of the Earth's magnetic field. We shall try to understand the meaning of the $N_p(t)$ curve behaviour for a latitude 51° supposing the existence of such magnetic traps of solar corpuscular streams.

First four measurements at a latitude of 51°, the results of which are indicated in Fig. 2. were carried out before the arrival of the corpuscular stream to the Earth and subsequent measurements leading to an increase in $N_p(t)$ were conducted after the arrival of the corpuscular stream. Therefore it seems probable that the peak in $N_p(t)$ curve (simillar to the data at a latitude of 64°) is caused by the location of the Earth in the sphere of the action of the solar corpuscular stream with magnetic traps.

However, as actual criterium of the existence of magnetic traps in corpuscular streams is the softening of the proton energy spectrum in the cosmic-ray flare. From this point of view we shall consider data at an altitude of 51°. Protons recorded in events at this latitude have high energies (1.3 Bev) and their intensities were not high. Therefore the method of investigating the energy spectrum based on the data of the proton absorption curve in the stratosphere for a latitude of 51° is inapplicable. We use values of proton intensities in the cosmic-ray flare contained simultaneously in the stratosphere at a latitude of 51° and near sea level. Let us compare proton intensities in the flare obtained simultaneously in the stratosphere and near sea level in different stages of the burst. As evident from Fig. 2. the $N_p(t)$ value obtained during the first measurement at an altitude of 51° is equal to 30 protons $cm^{-2}min^{-1}sterad^{-1}$. At the same time a neutron monitor in Leeds showed a cosmic-ray intensity enhancement by 14%. The decrease in N_p (t) from data of three subsequent measurements in the stratosphere and the decrease of the neutron monitor indications are almost parallel to each other. This is indicative of the constancy of the proton energy spectrum in the burst during this time. If we suppose that the energy spectrum did not change further, then the neutron monitor indication of 7% should correspond to the observed value of the repeated $N_p(t)$ increase according to data in the stratosphere. Actually it did not exceed 1.5%. Such a result testifies to the softening of the proton energy spectrum in the cosmic-ray flare at the time considered. To obtain quantitative data on the degree of the energy spectrum softening it is desirable to analyse in detail results of measurements near sea level and to find the actual cosmic-ray intensity enhancement at this time.

The Energy Spectrum

The proton energy spectrum in the outburst on November 15 is analysed from data obtained simultaneously in the stratosphere at latitudes of 64° and 51° and near sea level. Primary proton critical energy is equal to 0.1 Bev for a latitude of 64° and to 1.3 Bev for a latitude of 51°. The energy cutoff threshold of primary protons will be assumed as equal to 3.0 Bev for measurements near sea level, for instance, in Leeds (3).

In Fig. 3 proton intensity is given along the ordinate and proton kinetic energy is given along the abscissa. Solid dots show data of the proton integral spectrum obtained by measurements in the stratosphere at a latitude of 64°, by means of an instrument which started at 7^h00^m. During transformation of proton paths into energy the proton absorption in nuclear collisions was also taken into account (2). Triangles along curve 1 designate proton intensities with energies above 1.3 Bev obtained at a latitude of 51° by means of an instrument which started at the same time as at an altitude of 64°. Blackened squares show intensities of protons with energies 3.0 Bev according to data of measurements by a neutron monitor in Leeds (3) at the time when instruments

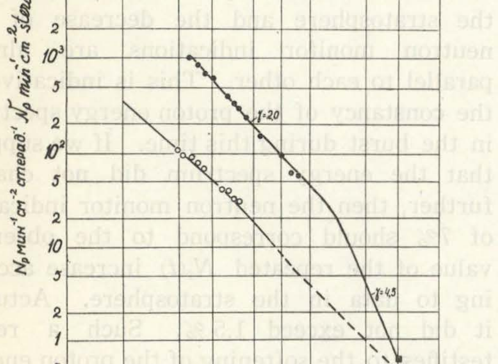

Fig. 3. 1. the proton integral energy spectrum in the flare on November 15, 1960.

●, ▲ according to data in the stratosphere at latitudes of 64° and 51°, respectively.

■ according to data obtained by a neutron monitor in Leeds.

2. the same for the flare on May 4, 1960.

○ according to data in the stratosphere.

□ according to data obtained by a neutron monitor in Prague.

started at latitudes of 64° and 51° were at a high altitude in the stratosphere.

As evident from Fig. 3, the proton energy spectrum in the moderate energy range has exponent $\gamma=2.0$ but $\gamma=4.5$ for protons with energies above 1.3 Bev. The problem of the shape of the proton spectrum in the energy range of several Bevs was discussed in paper (2) on the basis of data on the burst on May 4, 1960. Data of this burst obtained in the stratosphere at an latitude 64° are also indicated in Fig. 3. A clear square shows the intensity of protons with energies more than 3 Bev according to data in Leeds on May 4, 1960 (4). From Fig. 3 it is seen that continuations of low energy proton spectra towards high energy proton spectra give different slopes. This testifies to the absence of a definite correlation between energy spectra of low and high energy protons in events.

Results

1. Data are obtained on the energy spectrum and absolute intensity of solar cosmic-ray protons in cosmic ray flares recorded on November, 14, November 15 and November 21, 1960. In total, during these outbursts in the stratosphere about 70 measurements were made.

2. The proton energy spectrum is investigated in the burst on November 15 in a new energy range 1.3 to 3.0 Bev. Exponent of this integral spectrum is equal to 4.5, and for lower energies from 0.1 to 0.4 Bev the spectrum in the same flare has exponent $\gamma=2.0$.

3. New results are obtained according to which the arrival to Earth of solar corpuscular streams during flares causes not only a sharp softening of the proton energy spectrum, but also leads to an additional enhancement of proton total intensity. This is in good agreement with the conclusions made earlier about the existence of proton magnetic traps in solar corpuscular streams ejected during solar flares. The energy of these protons is about 150 Mev according to observational data at northern latitudes (64°).

4. Data obtained in the stratosphere at a lower latitude of 51° during the flare on November 15, 1960, are in favour of the existence of such solar corpuscular stream

magnetic traps in which protons with energies of ~2.0 Bev can be trapped.

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Discussion for Papers II-3B-26 and II-3B-27 is Combined and given after the Paper II-3B-27.

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II-3B-27. The Energy Spectrum and Time Dependence of the Intensity of Solar Cosmic Ray Protons in Flares

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Introduction

It was established that cosmic ray intensity increases observed in the stratosphere at northern latitudes are due to primary protons generated during large solar flares. For instance, in July 1959 three major class 3+ solar flares occurred following each other in 1-2 days. Considerable cosmic ray intensity enhancements were recorded in July in the stratosphere with the same succession[1),2)].

In the bulk of cases cosmic-ray flares are observed in several hours after a solar flare[1)]. Approximately in a day after solar flares a period usually begins of magnetic storms, ionospheric disturbances and, in a number of cases, aurorae. By the start of a magnetic storm or somewhat later a decrease is observed of the intensity of high energy cosmic rays recorded by ground instrumentation. (This phenomenon is usually called a Forbush-decrease). But there are also cases when cosmic ray bursts in the stratosphere are recorded which are not accompanied by geophysical phenomena. Usually in these cases solar flares occur on the edge of solar disk and corpuscular streams from them miss the Earth. The investigation of cosmic ray bursts for such cases is naturally of interest.

During investigations of cosmic ray increases in the stratosphere the following was revealed: the greater the amplitude of cosmic ray intensity bursts caused by solar protons, the greater the magnitude of a Forbush-decrease[1)]. This was indicative of the existence of a correlation between these heterogeneous phenomena. At the same time it was also established that magnetic storms with sudden commencements accompanied by a Forbush-decrease were not effective as far as the proton intensity decrease in bursts is concerned, as follows from measurements near sea level where the bulk of cosmic ray intensity in due to primary high energy particles arriving from the galaxy[3)]. To explain this fact a supposition was made that protons recorded during a Forbush-decrease do not come from the outside of corpuscular streams, but are carried by solar corpuscular streams themselves. Another step in the elucidation of the properties of solar corpuscular streams was the study of the proton energy spectrum in flares before and during a Forbush-decrease.

If one proceeds from the supposition that