NIEDERSÄCHSISCHE STAATS- UND
UNIVERSITÄTSBIBLIOTHEK GÖTTINGEN

Werk

Jahr: 1976
Kollektion: fid.geo
Signatur: 8 Z NAT 2148:42
Digitalisiert: Niedersächsische Staats- und Universitätsbibliothek Göttingen
Werk Id: PPN1015067948_0042
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948_0042

LOG Id: LOG_0009
LOG Titel: Short-time variations of solar particle fluxes during the August 1972 events
LOG Typ: article

Übergeordnetes Werk

Werk Id: PPN1015067948
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948
OPAC: http://opac.sub.uni-goettingen.de/DB=1/PPN?PPN=1015067948

Terms and Conditions

The Goettingen State and University Library provides access to digitized documents strictly for noncommercial educational, research and private purposes and makes no warranty with regard to their use for other purposes. Some of our collections are protected by copyright. Publication and/or broadcast in any form (including electronic) requires prior written permission from the Goettingen State- and University Library.
Each copy of any part of this document must contain there Terms and Conditions. With the usage of the library's online system to access or download a digitized document you accept the Terms and Conditions.
Reproductions of material on the web site may not be made for or donated to other repositories, nor may be further reproduced without written permission from the Goettingen State- and University Library.

For reproduction requests and permissions, please contact us. If citing materials, please give proper attribution of the source.

Contact

Niedersächsische Staats- und Universitätsbibliothek Göttingen
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

J. Geophys. 42, 1 – 13, 1976

Journal of Geophysics

Original Investigations

Short-Time Variations of Solar Particle Fluxes during the August 1972 Events

G. Kremser[1] *, W. Riedler[2] and E. Kirsch[3]

[1] Space Research Institute of the Austrian Academy of Sciences, Experimental Space Research Group, c/o Technical University Graz, Graz, Austria
[2] Department of Communications and Wave Propagation, Technical University Graz, Graz, Austria in cooperation with the Kiruna Geophysical Institute, Kiruna, Sweden
[3] Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Federal Republic of Germany

Abstract. Energetic solar particle fluxes were measured with balloon-borne instruments over Kiruna during the August 1972 events. Short-time variations of the particle flux with durations down to a few seconds occurred from 05 to 10 UT on 5 August 1972. Similar variations were observed on simultaneous recordings of cosmic noise absorption. The observations are interpreted as temporal variations of the low-energy (up to some tens of MeV) proton flux. They are discussed in terms of a model, in which drifting protons are intermittently scattered into the loss-cone by a wave-particle interaction process.

Key words: Solar protons – Magnetosphere – Magnetic storm.

1. Introduction

The propagation of energetic solar particles near the earth is largely determined by the geomagnetic field. The different modes of particle entry into the magnetosphere were recently discussed by Morfill (1974) and Gall and Bravo (1974) for protons and by Vampola (1974) for electrons. The understanding of these processes is mainly based on model calculations using the static geomagnetic field configuration.

Investigations on the influence of temporal and spatial field fluctuations during disturbed periods were reported in a number of publications. As a more general result cut-off changes were observed (Barcus, 1969a, b; Bewick *et al.*, 1970; Imhof *et al.*, 1971; Williams and Heuring, 1973). During an isolated substorm strong pitch-angle scattering was found near the boundary of the trapping region (Häusler *et al.*, 1974). A statistical study of the pitch-angle distribution demonstrated its dependence on the substorm phase (Scholer *et al.*, 1974).

We now discuss short-time variations obtained during a strongly disturbed period ($Kp = 7$–8). Solar particle data from balloon-borne instruments are used for this purpose. An advantage of this method is that long-term, high time-

---

* On leave from Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany.

resolution measurements can be performed while the balloon only slowly varies its location. The method provides direct measurements of solar protons with energies above the atmospheric cut-off (about 80–100 MeV) and indirect information on the low energy proton flux by measuring the γ-rays that the protons produce in the atmosphere.

During the solar particle events of August 1972 a total of eight balloons were launched from Kiruna, Sweden ($L = 5.4$) but we shall only refer to balloon KL 3/72, as the short-time variations exclusively occurred within the flight time of this balloon. All balloons carried payloads for measurement of energetic particles and auroral X-rays (Kremser *et al.*, 1974a). Some results were reported earlier, mainly on variations of the energy spectrum (Kremser *et al.*, 1973, 1974b).

2. Instrumentation

The balloon was launched on August 4, 1972, at 17.34 UT. It reached a minimum air pressure level of 4.5 mb and floated at about 5.5 mb during the time of the measurements. From 05 to 10 UT on 5 August 1972 its location changed from a position at 66° N, 15° E to 65° N, 13° E.

The payload contained a scintillation counter with a cylindrical NaI(Tl)-crystal of 2.54 cm diameter and 2.54 cm thickness, and three Geiger-Müller tubes in a telescope configuration. Unfortunately the GM tubes had reached the end of their life (10^6 counts) by the time the event under investigation occurred. A pulse height analysis was performed on the output from the scintillation counter in five channels. The calibration was done in such a way that the five channels correspond to X-ray energy losses of 25, 50, 75, 100 and 200 keV respectively. They are labelled A, B, C, D, E in the Figures. This procedure was applied because the scintillation counter was originally designed for measurements of X-ray photons. It is, however, sensitive to charged particle fluxes, but the species of the particles cannot be separated. As is known from satellite measurements (e.g. Page *et al.*, 1974) protons, electrons and α-particles were emitted from the sun during these events. Inside the atmosphere additional secondary radiations appeared like nuclear γ-rays produced by protons and bremsstrahlung X-rays produced by electrons. The relative importance of these contributions to the count rates of the scintillation counter are discussed below in Section 4.

3. Observations

A summary of observations is given in Fig. 1, containing data from the solar proton monitoring experiment on IMP-5 (Kohl *et al.*, 1973), cosmic noise absorption recordings from Kiruna, and the times of recorded balloon flights. The period of short-time variations occurred on 5 August. It followed a pronounced peak in the particle flux from 03 UT to 05 UT that has been attributed to a cosmic-ray increase caused by an unusual configuration of the interplanetary magnetic field (Venkatesan *et al.*, 1975).

30-second averages of the count rates in the different energy channels of the scintillation counter are shown in Fig. 2 for the time interval 05.00–09.30 UT.

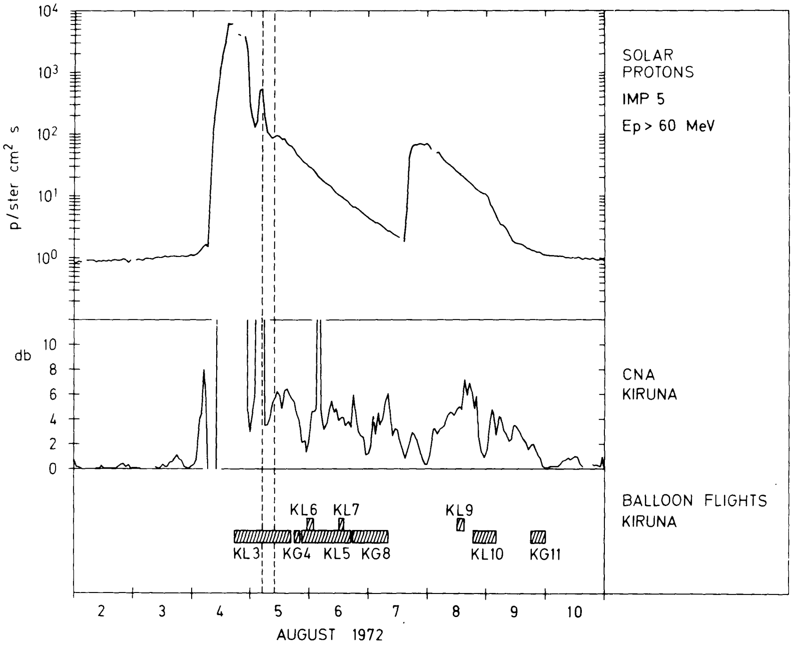

Fig. 1. Development of the August 1972 energetic solar particle events as observed by IMP-5, together with CNA recordings from Kiruna. The time of balloon flights is also shown. The interval of short-time variations is indicated by vertical dashed lines

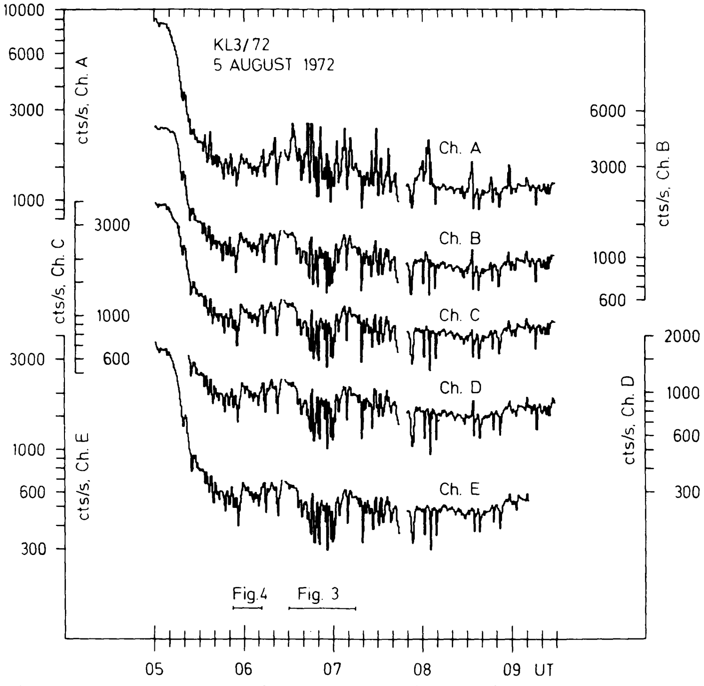

Fig. 2. 30-second averages of the count rates in the different channels of the scintillation counter. The intervals of the high-time resolution data presented in Figs. 3 and 4 are indicated

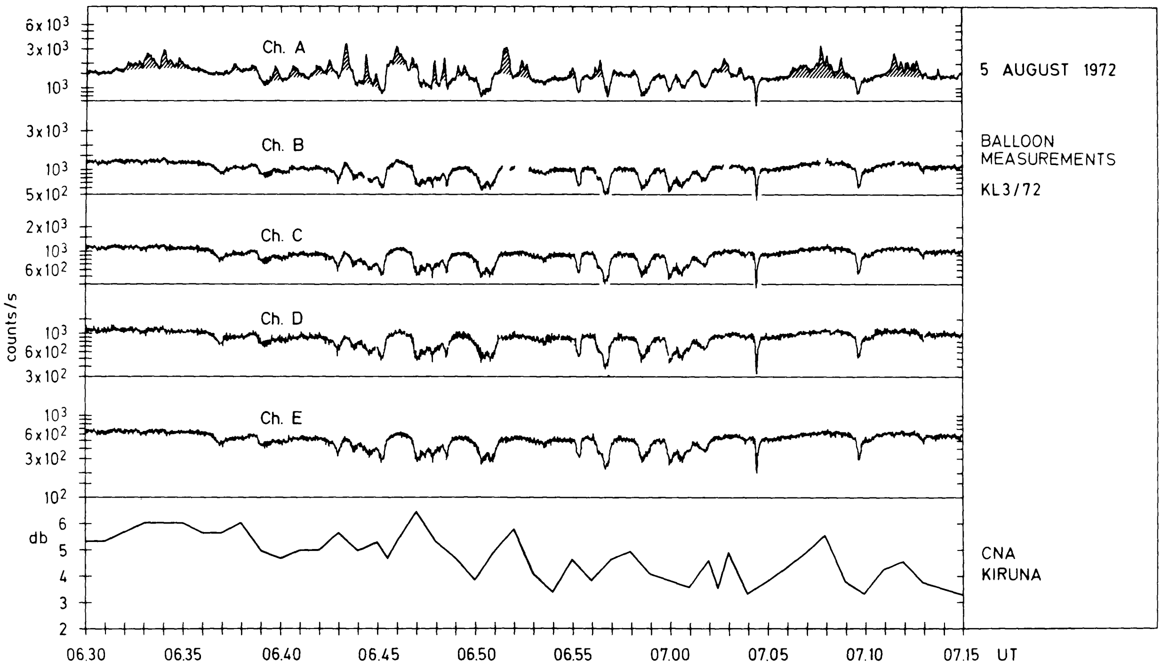

Fig. 3. Example of short-time variations of solar particle fluxes with superimposed auroral X-ray events (hatched area in uppermost curve). The CNA-recording from Kiruna is included for comparison

At the beginning of this interval the count rates decreased due to the end of the above mentioned cosmic ray peak. After 05.30 UT strong temporal variations were recorded in all energy channels. These variations were investigated (Figs. 3 and 4) in more detail by plotting 1-second averages of the count rates obtained during the intervals that are indicated by bars in the lower part of Fig. 2. Cosmic noise absorption recordings have been added. In Fig. 3 the hatched area in channel A indicates variations of the count rates due to auroral X-rays. We attribute these variations to auroral X-rays because they are not to be seen in the higher energy channels. Auroral X-rays have mostly a weak energy spectrum. They can easily be separated from the contributions by solar particles because of their markedly different temporal behaviour. In the present paper these X-rays will not be discussed further.

We are mainly interested in those temporal variations that most clearly appear in channel E. Further examples are shown in Fig. 4 for a period without auroral X-rays. Usually the maxima of these variations were broader than the minima. The minima lasted from some minutes down to a few seconds. They occurred in a rather close sequence or with separations of up to several minutes. The relative amplitudes amount to as much as 50% of the total count rate.

The balloon-borne measurements were performed at a single location. The dimensions of regions, inside which special radiation events occur, often can be determined from riometer recordings of cosmic noise absorption. In Fig. 5 we therefore plotted riometer recordings from several observatories in the European longitude sector. The L-values of these stations range from $L=3.4$ to $L=6.1$. Short-time variations of the cosmic noise absorption were clearly recorded at

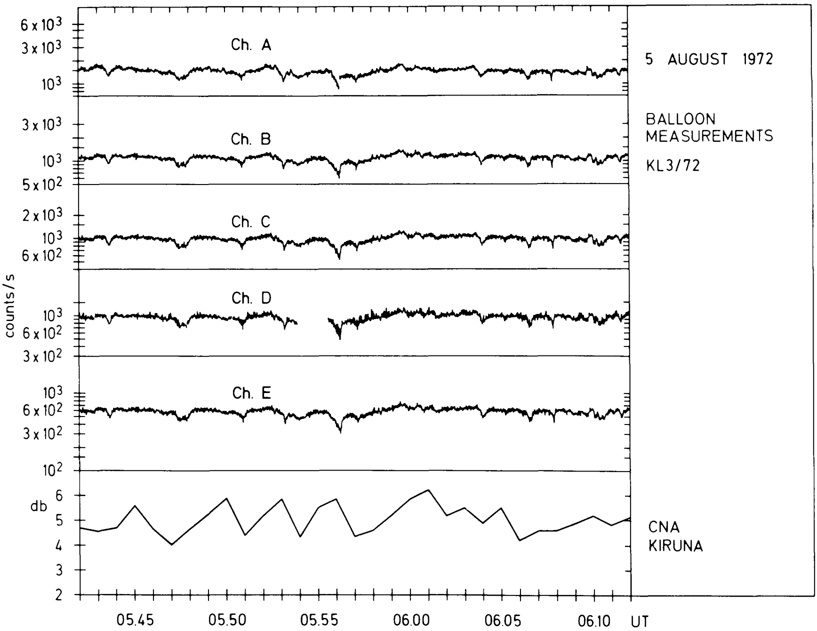

Fig. 4. Example of short-time variations of solar particle fluxes during periods without auroral X-rays. Included are CNA-recordings from Kiruna

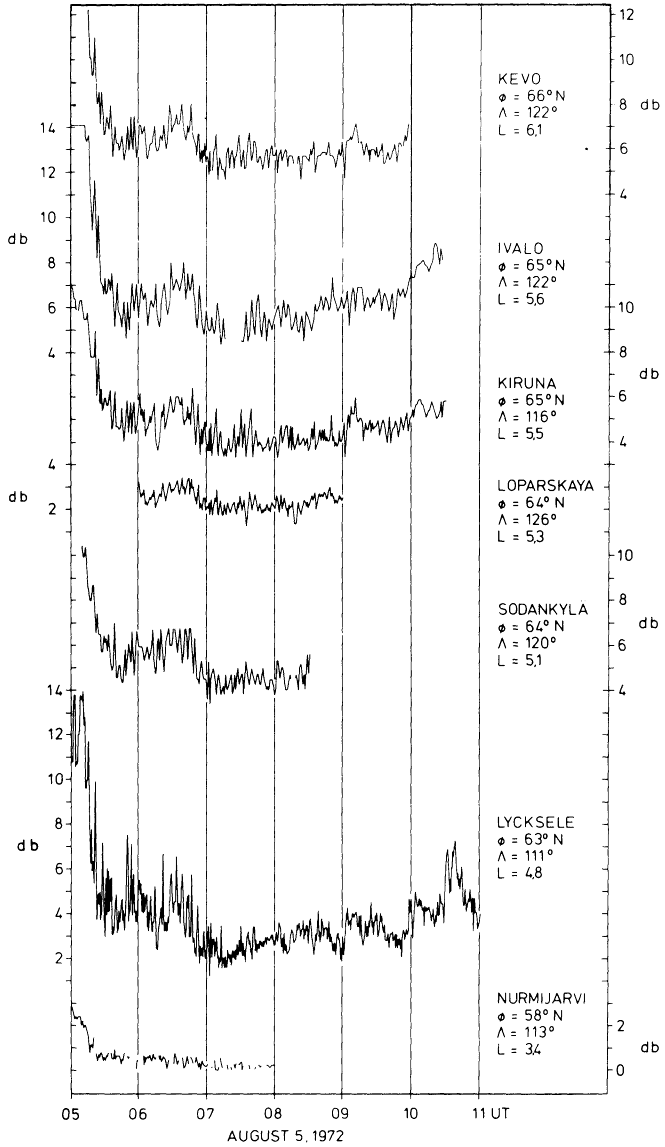

Fig. 5. CNA-recordings from stations in the European longitude sector showing simultaneous variations similar to those measured by balloon-borne instruments. The Loparskaya recording was taken from Brunelli *et al.* (1973)

stations with L values between 6.1 and 4.8. In some cases the absorption varied by more than 2 db in a few minutes. In Nurmijärvi ($L=3.4$) the absorption was too small to permit a clear identification of single peaks. Similar temporal variations also occured e.g. in Iceland ($L=6.2$) and with very great amplitudes in Thorshavn on the Faeroe-Islands ($L=4.5$). They were not observed in the recordings of the Greenland chain of riometers ($L>7.3$) that reaches far into the polar cap.

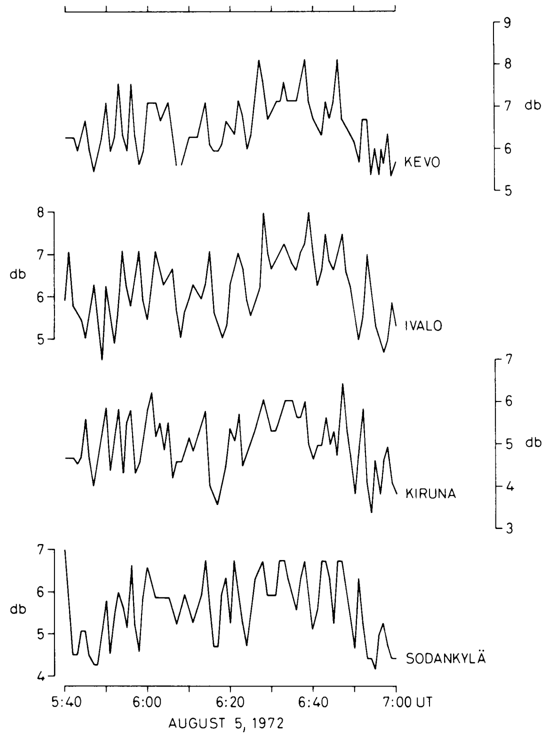

Fig. 6. CNA-recordings from four stations ($L=5.1-6.1$) on an extended time scale (05.40–07.00 UT)

A remarkable feature of the temporal variations of the absorption in the European longitude sector is the strong tendency for these variations to occur simultaneously at different latitudes. This can already be recognized by carefully inspecting Fig. 5 and is demonstrated in more detail in Fig. 6. Here we have plotted on an extended time scale absorption variations recorded at four stations ($L=5.1-6.1$). Obviously many peaks occurred simultaneously at these stations. Some differences can be found in the amplitudes, but these can be due in part to the data reduction procedure. At such high absorption values minor reading errors are transformed in relatively great variations of the absorption.

Comparing now absorption variations to balloon-borne particle measurements (Figs. 3 and 4) we see some similarities between these two recordings but also considerable differences. Before comparing details we have to remember that temporal variations of the kind observed with the balloon-borne instruments are at the limit of the temporal resolution of a riometer. E.g. usual riometers have a characteristic time of about 30 s to record decreases of the absorption. Furthermore, the recorded absorption consists of two different components. One of them is due to the precipitation of auroral electrons and is produced mainly at an altitude of about 90 km. The other component is due to solar protons and is mainly produced at altitudes below about 60 km. Considering these facts the resemblance between CNA and balloon measurements is still close enough to support the assumption that both of them reflect the same kind of temporal variations of the solar particle flux. An additional argument is the fact that this kind of temporal variations of CNA occurred just in the same time interval, during which the variations of the count rates were observed in the balloon recordings.

4. Discussion

For the interpretation of our balloon measurements we have to consider the following components which may contribute to the count rates of the instrument:

The flux of α-particles: it is usually negligible at balloon altitudes (Pfotzer, 1965).

Electrons had direct access to the detector only, if their entry energy was higher than the atmospheric cut-off. For our measurements this amounted to about 10 MeV, and therefore only small electron fluxes could have been present.

The flux of X-rays produced by low energy electrons was probably high enough to be detected by the scintillation counter in spite of the low efficiency of the bremsstrahlungprocess (see annex).

The atmospheric cut-off for protons corresponded to 80 MeV. The proton flux at energies above 80 MeV was high enough (see e.g. Kohl *et al.*, 1973 or Fig. 1, $E_p > 60$ MeV) to produce a considerable contribution to the count rates.

Another major part of the count rates was due to γ-rays produced by the low energy protons. The efficiency of the corresponding production process was estimated by Bhavsar (1962), Hofmann and Winckler (1963), Keppler (1964), Barcus (1969a, b). It has been shown that the main contribution to the γ-ray flux stems from protons with energies between 1 MeV and 30 MeV. In our case γ-rays produced by protons with even higher energies may also have been present (see annex).

It follows from these arguments that the main contributions to the count rates of the scintillation counter are expected from solar protons with energies above 80 MeV, γ-rays produced by solar protons with energies up to a few tens of MeV, and X-rays produced by solar electrons with energies up to some hundred keV. It is unlikely that the observed temporal variations reflect changes of the high-energy proton flux, as no variations of this kind were observed outside the magnetosphere and it is very difficult to imagine how these could be produced in the magnetosphere. Furthermore, they can also not have been caused by variations of the solar electron flux, as the small differences observed in the different channels of the scintillation counter cannot be explained by any bremsstrahlung spectrum. We, therefore, conclude that the fast temporal variations occurred in the low energy proton flux.

Similar variations of the solar particle flux were reported previously (Hudson and Anderson, 1969; Domingo and Page, 1972). These observations concerned variations in the polar cap, that occurred with characteristic times between one half and several minutes. In our case cosmic noise recordings indicate that the variations did not occur in the polar cap but were restricted to the auroral zone. Furthermore, the characteristic times reached down to values of a few seconds. These variations therefore may have been of a quite different origin than those observed earlier. Our aim now is to discuss possible processes that could lead to a fast temporal modulation of the low energy solar proton flux in the loss-cone at auroral latitudes. We must take into account that the magnetosphere was extremely disturbed.

Our measurements were performed at an invariant latitude of about 63°; the riometer recordings were obtained at invariant latitudes ranging from 62° to 66°. At these latitudes the following mechanismus could produce the observed temporal variations:

a) Variations of the geomagnetic cut-off caused by substorm activity (compare Barcus, 1969a, b; Bewick *et al.*, 1970).

b) Radial diffusion of trapped solar protons by violation of the third adiabatic invariant.

c) Geomagnetic field drift.

Mechanism a) and b) can probably be ruled out in our case as the short time variations seem to have occurred almost simultaneously in a latitude range of several degrees. Cut-off changes caused by substorm activity should have time scales of the order of an hour. A diffusion process should smooth out short-time intensity variations. Both of them cannot produce very fast changes.

We shall therefore discuss mechanism c) in some detail. For this discussion we have to remember that the latitude range in which our observations were made corresponds either to the region of pseudo-trapping (Taylor, 1967; Flindt, 1970; Morfill, 1973) or stable trapping. According to Morfill (1973) the limit of stable trapping can normally be expected at an invariant latitude of 68°, i.e. well poleward of the location of our observations. In our case the magnetosphere was extremely disturbed. Brace *et al.* (1974) found the plasma pause to be located unusually close to the Earth ($L=2$) during this storm. It can therefore be assumed that the stable trapping boundary was located at considerably lower latitudes than usual. But if the effect occurred in the stable trapping region instead of the pseudo-trapping region, some additional continuously operating cross-L diffusion must be assumed in order to transport the protons into this region. Otherwise we have to consider drifting protons and possible processes interacting with them in both cases.

These interaction processes will have to explain how the drifting protons were scattered into the loss-cone. Two possible mechanisms were described in the literature. One of them is related to excessive magnetic field curvature and gradients, by which protons are scattered, when they drift through this region (Morfill, 1973). The other mechanism is due to wave-particle interaction. Häusler *et al.* (1974) mention cyclotron resonance interaction with ELF chorus and/or cyclotron or bounce resonance with geomagnetic micropulsations in the ULF-band. Interaction of trapped or quasi-trapped protons is possible with right hand polarized ELF chorus as well as with left hand polarized ULF micropulsations.

The scattering mechanism by excessive magnetic field curvature and gradients seems unlikely in our case, as the flux variations were observed at L-values as low as 4.5, where extreme deviations from the dipole-like configuration of the magnetic field are difficult to imagine. Furthermore, the scattering region should then have been located on the morning and day side. This possibility can, however, not be ruled out completely due to the unusually strong disturbances of the magnetosphere.

We regard wave-particle interaction as the more likely process to scatter drifting protons into the loss-cone. The short-time variations on August 5 appear after an increase of the interplanetary magnetic field from 20 to 40 γ and a change of the field direction to a radially outward direction (Venkatesan *et al.*, 1975). This increase and the following decrease of the interplanetary magnetic field could have been the reason of a compression of the geomagnetic field and a stimulation of ULF micropulsations. Gendrin (1972) mentioned also compressional ULF waves as reason for the modulation of trapped and precipitated electron fluxes observed during a rocket flight. Brunelli *et al.* (1973) have reported on the simultaneous occurrence of micropulsations in a period range similar to that of the particle flux variations.

This possible explanation bears some resemblance to the behaviour of drifting magnetospheric electrons. Wilhelm *et al.* (1972) and Wilhelm (1973) explained short-time bursts of precipitated auroral electrons in the morning side by intermittently operating wave-particle interaction on drifting electrons.

Annex

Estimated production rate of γ-rays and X-rays by solar protons and electrons respectively.

A. γ-Ray Flux

γ-rays are produced mainly in the nuclear reactions (p, p'), (p, n), (p, α) on N^{14} and O^{16}. The energy range of the γ-ray lines is 0.51–7.12 MeV. According to Hofmann and Winckler (1963) about 3 ± 1 γ-ray photons are produced per nuclear reaction, and the γ-ray production rate N_γ can be estimated with the aid of the following equation

$$N_\gamma = \int K \times E_p^\rho \times \frac{dN_p}{dE}\, dE \tag{1}$$

with

$$K = 1.7 \times 10^{-5}, \quad \rho = 3.18 \quad \text{for } E_p < 3\ \text{MeV}$$

and

$$K = 7 \times 10^{-5}, \quad \rho = 1.92 \quad \text{for } E_p > 3\ \text{MeV}.$$

E_p is the proton energy in MeV, dN_p/dE is the differential energy spectrum of the proton flux.

For the time interval 09–10 UT on 5 August 1972 we derive from measurements reported by Yates *et al.* (1973) and Kohl *et al.* (1973)

$$\frac{dN_p}{dE} = 3 \times 10^3\, E^{-1.47}\ \text{cm}^{-2}\,\text{s}^{-1}\,\text{sr}^{-1}\,\text{MeV}^{-1} \quad \text{for } 1\ \text{MeV} \leqq E_p \leqq 30\ \text{MeV} \tag{2}$$

and

$$\frac{dN_p}{dE} = 1.2 \times 10^5\, E^{-2.57}\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}\,MeV^{-1}} \tag{3}$$

for $30\,\mathrm{MeV} \leqq E_p \leqq 80\,\mathrm{MeV}$.

Inserting (2) and (3) in (1) yields

$$N_\gamma = 0.35\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}} \quad \text{for} \quad 1\,\mathrm{MeV} \leqq E_p \leqq 3\,\mathrm{MeV} \tag{4}$$

$$N_\gamma = 19.4\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}} \quad \text{for} \quad 3\,\mathrm{MeV} \leqq E_p \leqq 30\,\mathrm{MeV} \tag{5}$$

$$N_\gamma = 33.4\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}} \quad \text{for} \quad 30\,\mathrm{MeV} \leqq E_p \leqq 80\,\mathrm{MeV}. \tag{6}$$

B. X-Ray Flux

X-rays are produced in the bremsstrahlung process. According to Evans (1955) the X-ray production rate N_x can be estimated with the aid of the following equation

$$N_x = 7 \times 10^{-4}\, \bar{Z} \times E_e \tag{7}$$

with $\bar{Z} = 7.2$ for air; E_e is the electron energy in MeV.

Measurements reported by Lanzerotti and McLennan (1974) for the time interval 09–10 UT yielded a solar electron flux of

$$10^4\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}} \quad \text{for} \quad E_e > 350\,\mathrm{keV}. \tag{8}$$

Using this value we get from (7) the production rate of

$$N_x = 17.6\,\mathrm{cm^{-2}\,s^{-1}\,sr^{-1}}. \tag{9}$$

Acknowledgement. The authors are grateful to Prof. G. Pfotzer for supporting the balloon program and for helpful discussions. They acknowledge the advice of Dr. K. Wilhelm in the preparation of the manuscript. Dipl. Phys. K. H. Saeger greatly contributed to the success of the measurements by supervising the payload construction. Dr. H. Specht was engaged in the data reduction. Riometer recordings were kindly provided by Prof. P. Tanskanen, University of Oulu; Civil Ing. J. Taagholt, Ionosphere Laboratory, Lyngby; Cand. real. S. L. Ullaland, University of Bergen. The balloon program was supported financially by the Max-Planck-Gesellschaft, FRG, the Austrian Science Research Council, the Austrian Academy of Sciences and the Swedish Science Research Council.

References

Barcus, J. R.: Increase in cosmic-ray cut-offs at high latitudes during magnetospheric substorms. J. Geophys. Res. **74**, 4694–4700, 1969a

Barcus, J. R.: Diurnal variation in low-energy cosmic ray cut-offs. Planetary Space Sci. **17**, 1173–1181, 1969b

Bewick, A., Haskell, G. P., Hynds, R. J.: Penetration of low-energy solar protons to low geomagnetic latitudes. J. Geophys. Res. **75**, 4605–4612, 1970

Bhavsar, P. D.: Gamma rays from the solar-cosmic-ray-produced nuclear reactions in the Earth's atmosphere and lower limit on the energy of solar protons observed at Minneapolis. J. Geophys. Res. **67**, 2627–2637, 1962

Brace, L. H., Maier, E. J., Hoffman, J. H., Whitteker, J., Shepherd, G. G.: Deformation of the night side plasmasphere and ionosphere during the August 1972 geomagnetic storm. J. Geophys. Res. **79**, 5211-5218, 1974

Brunelli, B. E., Loginov, G. A., Petrova, G. A., Afanasyeva, L. T.: Normal magnetic field, micropulsations and riometer observations at auroral station Murmansk. Rep. UAG-28, Part III, Ed. H. E. Coffey, p. 727-730. Boulder, Colorado: World Data Center A, 1973

Domingo, V., Page, D. E.: Two-satellite observation of spatial and temporal particle flux variations over the polar caps. J. Geophys. Res. **77**, 1971-1975, 1972

Evans, R. D.: The atomic nucleus. New York: McGraw-Hill 1955

Flindt, H. R.: Local-time dependence of geomagnetic cut-offs for solar protons, $0.52 \leqq Ep \leqq 4$ MeV. J. Geophys. Res. **75**, 39-49, 1970

Gall, R., Bravo, S.: On a model of propagation of 5-300 MeV protons in the earth magnetic cavity, the role of neutral and plasma sheets. In: Correlated interplanetary and magnetospheric observations. Ed.: D. E. Page, p. 433-447. Dordrecht-Holland: D. Reidel 1974

Gendrin, R.: Changes in the distribution function of magnetospheric particles associated with gyroresonant interactions. In: Earth's magnetospheric processes, Ed.: B. M. McCormac, pp. 311-328. Dordrecht-Holland: D. Reidel 1972

Häusler, B., Scholer, M., Hovestadt, D.: Variations of the trapped particle population and of cut-off and pitch angle distribution of simultaneously observed magnetospheric solar protons during substorm activity. J. Geophys. Res. **79**, 1819-1824, 1974

Hofmann, D. J., Winckler, J. R.: Simultaneous balloon observations at Fort Churchill and Minneapolis during the solar cosmic ray events of July 1961. J. Geophys. Res. **68**, 2067-2098, 1963

Hudson, P. D., Anderson, H. K.: Nonuniformity of solar protons over the polar caps on March 24, 1966. J. Geophys. Res. **74**, 2881-2890, 1969

Imhof, W. L., Reagan, J. B., Gaines, E. E.: Solar particle cut-offs as observed at low altitudes. J. Geophys. Res. **76**, 4276-4290, 1971

Keppler, E.: Messung von Röntgenstrahlung und solaren Protonen mit Ballongeräten in der Nordlichtzone. Mitt. Max-Planck-Inst. Aeron. **15**, 1-50, 1964

Kohl, J. W., Bostrom, C. O., Williams, D. J.: Particle observations of the August 1972 solar events by Explorer 41 und 43. Rep. UAG-28, Ed. H. E. Coffey, Part II, p. 330. Boulder, Colorado: World Data Center A. 1973

Kremser, G., Pfotzer, G., Kirsch, E., Riedler, W., Specht, H., Zirm, K.: Erste Ergebnisse aus Ballonmessungen während der solaren Protonenereignisse vom 2.-10. August 1972. Kleinheubacher Berichte **15**, 405-410, 1973

Kremser, G., Pfotzer, G., Kirsch, E., Specht, H., Riedler, W., Zirm, K.: Temporal variations of solar particle spectra (August 4-7, 1972). In: Correlated interplanetary and magnetospheric observations, Ed. D. E. Page, pp. 603-607. Dordrecht-Holland: D. Reidel 1974a

Kremser, G., Riedler, W., Kirsch, E., Pfotzer, G., Saeger, K. H., Slamanig, H., Specht, H., Zirm, K.: Summary of solar particle and auroral-zone X-ray measurements with balloon-borne instruments during the solar particle events of August 1972. SBARMO-Bulletin **VI**, 25-65, 1974b

Lanzerotti, L. J., McLennan, C. G.: Solar particle observations during the August 1972 event. In: Correlated interplanetary and magnetospheric observations, Ed.: D. E. Page, pp. 587-596. Dordrecht-Holland: D. Reidle 1974

Morfill, G.: Nonadiabatic particle motion in the magnetosphere. J. Geophys. Res. **78**, 588-596, 1973

Morfill, G.: Solar particle access into the inner magnetosphere. In: Correlated interplanetary and magnetospheric observations, Ed.: D. E. Page, pp. 399-417. Dordrecht-Holland: D. Reidel 1974

Page, D. E., Domingo, V., Wenzel, K.-P.: MeV electrons, protons and alpha particles observed August 2-12, 1972. In: Correlated interplanetary and magnetospheric observations, Ed.: D. E. Page, pp. 573-585. Dordrecht-Holland: D. Reidel 1974

Pfotzer, G.: Balloon measurements of solar protons and auroral X-rays. Proceedings of a Symposium on high latitude particles and the ionosphere, Alpbach 1964, Ed.: B. Maehlum, pp. 167-204. London: Logos Press 1965

Scholer, M., Morfill, G., Hovestadt, D.: Statistical analysis of the pitch angle distribution of magnetospheric solar protons during geomagnetic activity. J. Geophys. **40**, 37-56, 1974

Taylor, H. E.: Latitude local-time dependence of low-energy cosmic-ray cut-offs in a realistic geomagnetic field. J. Geophys. Res. **72**, 4467-4470, 1967

Vampola, A. L.: Solar electron access to the magnetosphere. In: Correlated interplanetary and magnetospheric observations, Ed.: D. E. Page, pp. 463–478. Dordrecht-Holland: D. Reidel 1974

Venkatesan, D., Mathews, T., Lanzerotti, L. J., Fairfield, D. H., Bostrom, C. O.: Cosmic ray intensity variations during 02–07 UT, August 5, 1972. J. Geophys. Res. **80**, 1715–1724, 1975

Wilhelm, K.: The distribution function of energetic electrons measured during a slowly varying ionospheric absorption event. Space Research XIII, Eds.: M. J. Rycroft, S. K. Runcorn, pp. 527–533. Berlin: Akademie-Verlag 1973

Wilhelm, K., Kremser, G., Münch, J., Schnell, M., Legrand, J. P., Petrou, N., Riedler, W.: Measurements of energetic particle fluxes during a slowly varying absorption event by two co-ordinated rocket flights. Space Research XII, pp. 1437–1447. Berlin: Akademie-Verlag 1972

Williams, D. J., Heuring, F. T.: Strong pitch angle diffusion and magnetospheric solar protons. J. Geophys. Res. **78**, 37–50, 1973

Yates, G. K., Katz, L., Sellers, B., Hauser, F. A.: Report UAG-28, Part II, p. 348, 1973. Boulder, Colorado: World Data Center A.

Received September 8, 1975; Revised Version November 24, 1975