An electron precipitation event recorded at Sanae on 14 November 1974

H.F.B. Minnaar,
P.J. König,
P.H. Stoker
and
B.G. Bowers

Physics Department
Potchefstroom University for CHE
Potchefstroom 2520

Enhanced counting rates were observed in the data obtained by a Geiger-Müller detector at balloon altitudes above Sanae ($L = 4,0$) during a geomagnetic storm with a K_p index of 5_- These increases for aluminium and bismuth Geiger counters are due to X-rays produced by electrons precipitating into the atmosphere. The results are compared with theoretical calculations by *Keppler* (1965), from which the exponential constant of the energy spectrum can be established.

Verhoogde teltempo's is waargeneem met Geiger-Müllertelbuise op ballonhoogtes bokant Sanae ($L = 4,0$) gedurende 'n geomagnetiese storm met 'n K_p-indeks van 5_- Hierdie verhoogde teltempo's kan toegeskryf word aan X-strale vanaf elektrone wat in die atmosfeer presipiteer. Die resultate is vergelyk met die teoretiese berekeninge van Keppler *(1965), waaruit die eksponensiële konstante van die elektronspektrum verkry kan word.*

Data obtained from two balloon flights at Sanae with aluminium and bismuth Geiger counters are presented and discussed below. One of the flights was during the last hour of 26 December 1972, when the magnetic field at Sanae had a K_p index of 1. The other flight was on 14 November 1974 when the magnetic field was much disturbed with a K_p index of 5_-. Counting rates at balloon altitudes were enhanced by X-rays from precipitating electrons.

Bismuth Geiger counters are more sensitive than aluminium counters to X-rays at balloon altitudes, and this difference facilitates determination of the energy of precipitating electrons observed in the upper atmosphere.

Apparatus

The recording apparatus consisted of three thin-walled Geiger-Müller counters. Two of these counters are of the Victoreen type 1B85, and have an aluminium wall with a thickness of 30 mg/cm², an effective length of 7,0 cm and a diameter of 1,9 cm (*König,* 1975). The third counter is a Victoreen type 6306 with a layer of bismuth with a thickness of 105 mg/cm² on the inside. The effective diameter of this counter is 1,71 cm (*Heristchi,* 1967). The layer of bismuth makes this counter more sensitive than the Al counters to X-rays in the energy range 50 keV to 1 MeV. The intensities of charged particles can be deduced from the coincidence counting rate of the three counters in a vertical telescopic arrangement.

Theory

According to *Keppler* (1965) the differential photon spectrum dN(E)/dE produced by the precipitating electrons may be related to the differential energy spectrum of the electrons dN(T)/dT by

$$\frac{dN(E)}{dE} = \int_0^\infty K(E,T)\,\frac{dN(T)}{dT}\,dT\ , \qquad (1)$$

where E and T are the photon and electron energies respectively and where K(E,T) is a function which must be determined theoretically.

An electron travelling through an absorber of thickness dx having N atoms/cm³, produces

$$\frac{d\sigma(E,T)}{dE}\,.dE.N.dx \qquad (2)$$

photons with energy E in the interval dE, where dσ(E,T) is the differential absorption cross-section for the production of bremsstrahlung.

Anderson (see *Keppler,* 1965) calculated the bremsstrahlung spectrum produced by electrons with a differential spectral distribution

$$\frac{dN(T)}{dT} \sim T^{-\gamma} \qquad (3)$$

for different values of γ. *Keppler* (1965) found the bremsstrahlung spectrum for the exponential electron energy spectrum to be

$$\frac{dN(T)}{dT} = Ae^{-T/T_0} \qquad (4)$$

and hence, through (1), the X-ray spectrum is

$$\frac{dN(E)}{dE} = Be^{-E/E_0} \qquad (5)$$

Keppler also calculated the ratio of the counting rates of the aluminium and bismuth Geiger counters for different X-ray spectra as a function of E_0 and atmospheric depth.

Presentation of data

Fig. 1 shows the number of counts per minute for the Bi counter during the disturbed and quiet magnetic field conditions. Fig. 2 shows the corresponding counts per minute for the Al counter. These recordings for the two periods may be compared directly because the primary cosmic ray spectra for these two periods are approximately the same according to neutron monitor data. Therefore the intensity curves for the flight during the quiet magnetic field period may be regarded as the cosmic ray background as a function of atmospheric depth for the disturbed period. The X-ray intensities due to precipitating electrons as recorded by the Bi and Al counters may now be obtained from the differences in the counting rates in Fig. 1 and 2. The ratios of these

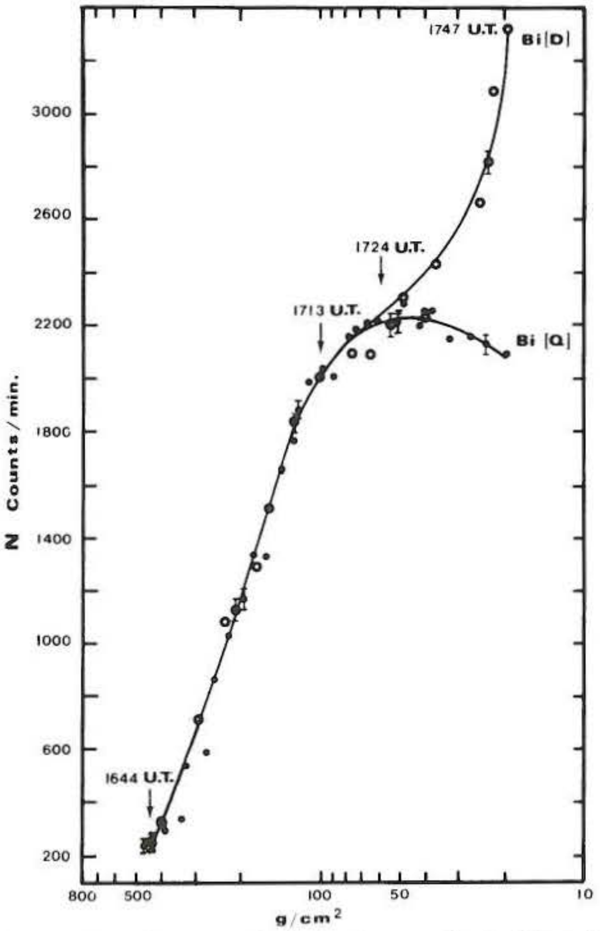

Fig. 1. Intensity-atmospheric depth curves for the bismuth (Bi) counters for quiet (Q) and disturbed (D) conditions.

differences in the counting rates of the aluminium and bismuth counters are shown in Fig. 3 by the dots. The open circles represent the theoretical values for $E_0 = 30$ keV as obtained from the work of *Keppler* (1965). The curves for $E_0 = 20$ and 40 keV are also shown. The value of $E_0 = 30$ keV gives a better fit to the experimental points at atmospheric depths of about 20 g/cm^2 than $E_0 = 20$ or 40 keV. According to Keppler's work the corresponding value of T_0 for an exponential precipitating electron spectrum is 160 ± 30 keV if the two distributions are fitted smoothly together at about 20 g/cm^2 atmospheric depth.

Fig. 4 shows the absorption of 30 MHz cosmic noise by the riometer at Sanae for the duration of the flight

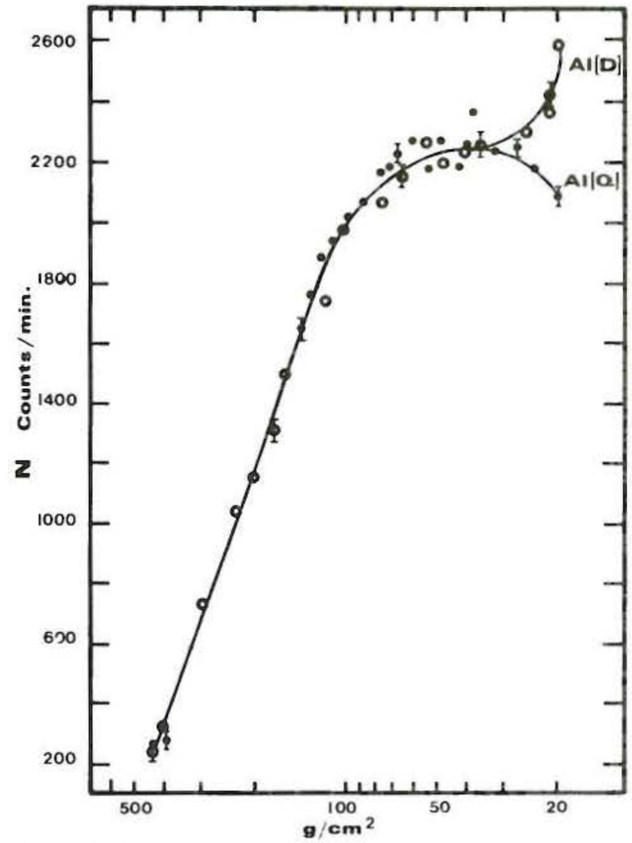

Fig. 2. Intensity-atmospheric depth curve for the aluminium (Al) counter for quiet (Q) and disturbed (D) conditions.

on 14 November 1974. The upper line in Fig. 4 shows the quiet day curve. The period of the flight above the Pfotzer maximum during which the enhancement in counting rates was recorded is also indicated.

The period nearly coincides with the last hour of the magnetic storm, which lasted for a few days. Interesting is the fact that the Pfotzer maximum was reached at approximately the same time as the absorption reached its maximum value. Fig. 4 also shows that there was not much variation in cosmic noise absorption during the last 20 minutes of the flight so that we

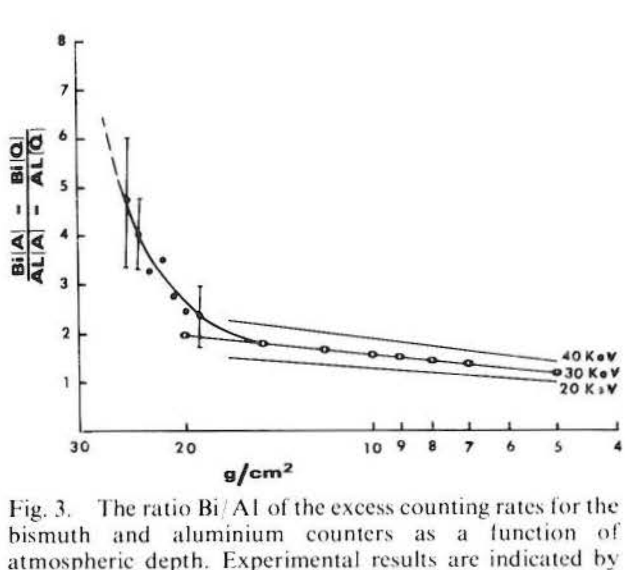

Fig. 3. The ratio Bi/Al of the excess counting rates for the bismuth and aluminium counters as a function of atmospheric depth. Experimental results are indicated by dots, and the open circles represent the theoretical work of *Keppler* (1965).

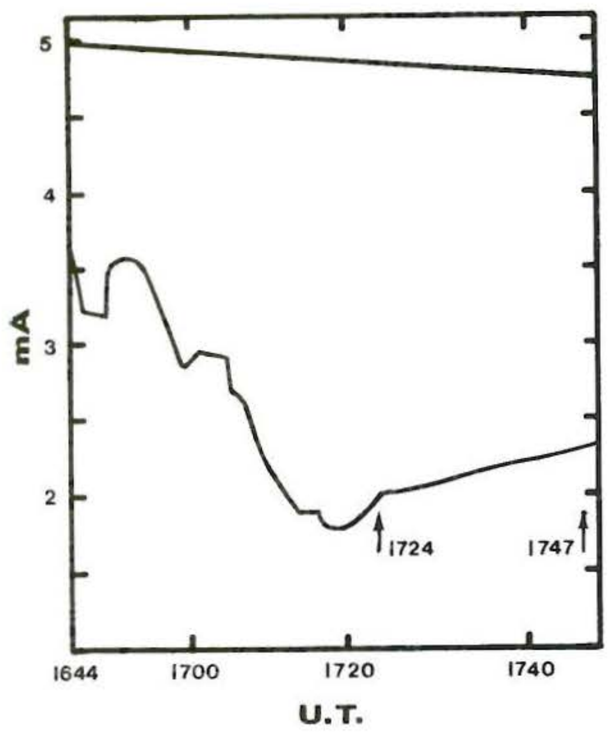

Fig. 4. The absorption of 30 MHz noise at Sanae from riometer recordings for the period of the flight on 14 November 1974.

may assume that there was not much variation in the intensity spectrum of the precipitating electrons from 50 g/cm^2 up to 20 g/cm^2.

Discussion

Fig. 3 shows a much stronger increase in the ratio of the counting rates by the bismuth and aluminium counters for X-rays from precipitating electrons with atmospheric depths greater than about 20 g/cm^2 than calculated by *Keppler* (1965) for depths equal to or less than 20 g/cm^2. If cascade electrons from the precipitating electrons were also recorded, the ratio would tend to decrease with atmospheric depth rather than to increase. Furthermore, according to standard absorption graphs 99,9% of electrons of 150 keV will be absorbed by the 30 mg/cm^2 wall of the aluminium Geiger counter. The enhancement in counting rates of the Al and Bi counters could therefore only be due to X-rays from the precipitating electrons.

The difference between the slope recorded above 20 g/cm^2 and the calculated slope below this atmospheric depth makes it difficult to estimate accurately the value of the energy constant of the X-ray spectrum. These differences in slopes raise the question whether the calculations of Keppler do approximate correctly the variation of the ratio of the X-ray counting rates of the Al and Bi counters with atmospheric depth. A more accurate theoretical approach may be necessary to ensure a more reliable estimate of the energy of precipitating electrons from the enhanced counting rates of Al and Bi Geiger counters at balloon altitudes.

Conclusion

It is possible to obtain the energy spectrum of precipitating electrons from the ratio of the excess counting rates of Al and Bi Geiger counters. Because *Keppler* (1965) made use of a simplified theoretical approach to calculate the X-ray spectra from precipitating electrons, a more rigorous theoretical approach will improve the accuracy with which energy spectra of precipitating electrons can be determined.

Acknowledgement

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