21st International Cosmic Ray Conference

CONFERENCE PAPERS

Volume 6 (SH Sessions)

Edited by R.J. Protheroe

XXI ICRC
6-19 January 1990
Adelaide, Australia

1990

Department of Physics and Mathematical Physics
The University of Adelaide, Australia

FLUCTUATIONS OF GALACTIC COSMIC RAYS IN PERIODS OF SOLAR FLARES

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Abstract

The spectral analysis of neutron and ionizing data from several cosmic ray stations (Moscow, Inuvik, Tixie Bay) has lead us to establish a peculiar behavior of Galactic cosmic ray fluctuations (GCRF) relevant to magnetic spot groups and Solar Flares. The solar surface events during 28 periods of GCRF in 1972-1986 are classified into three categories: (1) presence of active centers on the solar disk without any visible flare occurrence, (2) presence of one or several isolated flares, and (3) quiet periods with no active centers over the solar disk. During the solar activity-associated fluctuations (SAAF), a decrease of the well-known fluctuations of a 160-min recurrence attenuate, but recover their amplitude gradually as the SAAF decay.

1. The occurrence of cosmic ray fluctuations before increases in the solar flare-generated relativistic particle flux observed on the Earth (before a flare was observed in the optical band) was analyzed (Starodubtsev et al. 1984, Starodubtsev and Filippov 1984, Starodubtsev 1985) using the 5-min cosmic ray neutron component data from several worldwide network stations. The events of November 12, 1960, January 28, 1967, January 24 and September 1, 1971, August 4 and 7, 1972, November 22, 1977, and July 23, 1978 were studied. Starodubtsev and Filippov (1984) used the moving averages of three successive points in the data to suppress the $<$15-min pulsations. Gulinsky et al. (1983) used a wide-band filter with transmission (0.49-0.05) ΔT (where ΔT is the data discretization frequency) and with a $\sim$0.01 coefficient of pulsations on the plateau (the filter corresponded to the $1.63 \cdot 10^{-3}$-1.67×10^{-4} Hz frequency band). In all cases, cosmic ray fluctuations with characteristic periods of few tens of minutes were found prior to solar flares in all cases. Comparing between the high-latitude and midlatitude NM data has shown that the cosmic ray fluctuations cannot be of magnetospheric origin. Statistical analyzing all the events has shown that the fluctuation amplitude decreased within 20-60 min prior to cosmic ray increases. This effect was observed at midlatitude and polar stations and proved to be most clearly expressed for western flares (Starodubtsev and Filippov 1984). Analyzing the fluctuation spectrum dynamics has led Starodubtsev (1985) to conclude that (1) statistically significant peaks with periods of 30 min occur in the fluctuation spectra after active regions emerge on the eastern limb of the Sun and persist at least until the onsets of solar cosmic ray increases and (2) a general increase in the power of the 30-min period fluctuations occurred within a time of less than a day prior to arrival of flare-generated shock wave at the Earth. In the latter case, as indicated by Starodubtsev et al. 1984, Starodubtsev and Filippov 1984, Starodubtsev 1985, the interpretation of individual peak in the power spectrum proved to be unambiguous (Starodubtsev 1985).

The conclusions arrived at in the above cited works were confirmed by the results (Gulinsky et al. 1983, Libin 1983) obtained earlier for the flares of May 7, 1978 and November 22, 1977 from the Bologna and Moscow scintillator telescope data and from the Moscow azimuthal telescope and NM data (the flare effects in cosmic rays were shown to be always characterized either by 17-25 min and 40-60 min fluctuations or by rearrangement of the spectra as the whole (Blokh et al. 1984)).

Simultaneously, the cosmic ray fluctuations were also calculated for quiet periods. The rearrangements of the spectra or the high-frequency fluctuations characteristic of flare-generated events proved to occur during quite a number of the periods. Thus, studying the occurrence of cosmic ray fluctuations (or the spectral rearrangement) during solar flares (see all the works cited above) suggests that some mechanisms should exist which affect cosmic rays prior to flare occurrence and whose power is sufficient for the fluctuations observed on the Earth to be generated (in particular, active regions may be one of the factors initiating the fluctuation processes in cosmic rays (Starodubtsev 1985)).

2. The 5-min and 1-hour values of the cosmic ray neutron and ionizing components obtained at Moscow, Inuvik, Tixie Bay, Tokyo, Magadan, and Utrecht were used to study 28 periods during 1976-1985. The periods were classified into three categories: (1) the periods when a large sunspot group moved over the solar disk without any visible flare occurrence (for example, January 22-February 8, 1984), (2) the periods when an active region occurred with one or several large isolated flares (for example, on November 19-22, 1977, February 3 and May 13, 1983, December 5, 1982, etc.), and (3) quiet periods (or nearly-quiet conditions) in 1973-1974, 1980*, and 1984-1985.

The calculations were made by the methods of the spectral and regression analyses (Dorman et al. 1988) using different wide-band and narrow-band filters (J. Max 1983) which make it possible to study the dynamics of the high- and low-frequency fluctuations separately.

The spectra in the events of category (1), i.e. in case of a sunspot group on the solar disk, were calculated in each 3 days after the moment of passage of a sunspot group through the Sun's central meridian. Nine events were analyzed. In five of nine events, a spectral rearrangement was observed 3 days after a sunspot group passage through CM, namely, the spectral index in low-frequency range changed from -1.5 to -2.2, and statistically-significant fluctuations with periods between 40-120 min (outside a 90% confidence interval) and 150-420 min ($\leqslant$ 95%) occurred. In 6 days after the passage through the CM the spectral rearrangement reaches its maximum and, 9-12 days later, the spectra get restored up to the state inherent to quiet conditions in interplanetary medium. Fig. 1 shows the cosmic ray power spectra typical of 5 events of category (1). The dynamics is seen in the temporal behaviour of the spectra (the numerals at the curves) after the passage through the CM. At the same time, the effect was never observed in the rest five events.

In the events of category (2), i.e. during powerful isolated class 2B flares, the spectra were calculated for each day (4, 3, 2, and 1 days before flares, nine events). The spectral rearrangement before flares were observed only in 6 cases. In 3 cases (even if powerful isolated class 2B flares occurred) the spectral rearrangement began after optical flares at the moments immediately before shock-wave arrival at the Earth. Fig. 2 shows the spectral densities of cosmic ray fluctuations typical of six (a) and three (b) events.

As to the ten quiet periods analyzed, the spectral rearrangement effects were observed in three of them. The effect occurred without any evident reason and were relevant to neither shock waves nor sector structure of solar wind (Dorman et al. 1988). Nevertheless, the fluctuations with periods of 40-120 min in high-frequency band and 150-420 min in low-frequency band were, as a rule, well-pronounced under spectral rearrangement. In such cases, the fluctuations began, as a ryle, being formed 8-20 hours before a flare and ended within 2-4 hours after a flare.

The observations of only the 160-min fluctuations have shown that in 50-60% of the analyzed cases the fluctuation amplitude decreases substantially before flares (due, probably, to enhancement of the low- and high-frequency sides of the spectrum).

3. The results obtained proved to be ambiguous. A "precursor" (Starodubtsev and Filippov 1984) was observed in far from all cases of even the same type. Moreover, the precursors were observed even when flares were absent.

Nevertheless, the results obtained do not contradict the hypothesis that the rearrangement of cosmic ray spectra before flares is relevant to passages of active regions, on the one hand, and require that the possible rearrangement mechanisms should be studied in more detail and the precision of cosmic ray observations should be improved, on the other hand. Besides, the results obtained coincide with the results of observing the IMF (Obridko and Shelting 1983) and of the shortwave emission fluxes on the Sun (Ivanov 1983).

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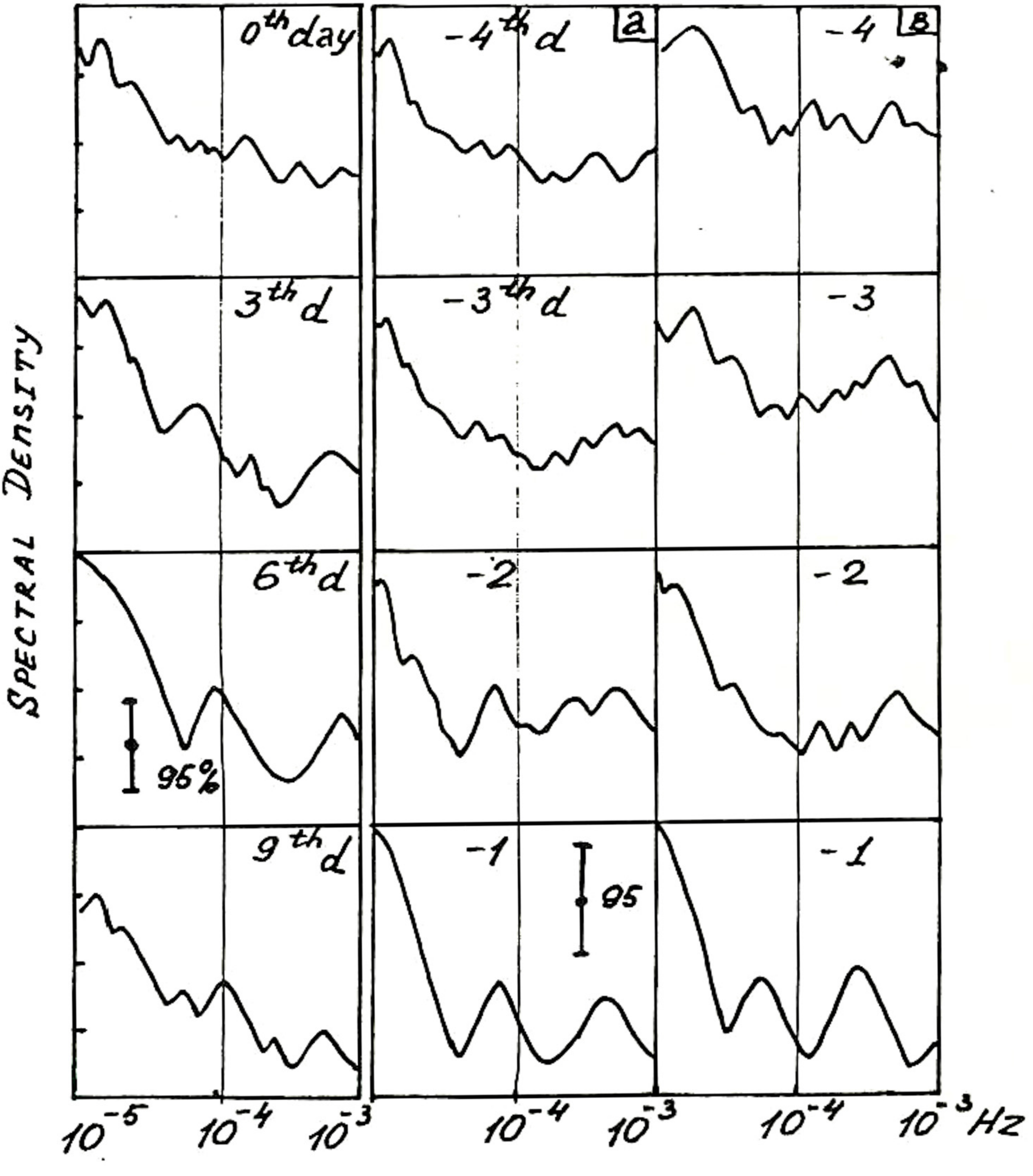
Fig. 1 Fig. 2



0th day
3th d
6th d
9th d
95%
-4th d
a
-3th d
-2
-1
95
-4
B
-3
-2
-1
SPECTRAL DENSITY
10^{-5}
10^{-4}
10^{-3}
10^{-4}
10^{-3}
10^{-4}
10^{-3} Hz