II-3A-4. Yearly Variation in Activities of Outbursts at Microwaves and Flares during a Solar Cycle with Special Reference to Unusual Cosmic-Ray Increases

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An interesting characteristic of unusual cosmic-ray increases, that they occur only in ascending and descending phases of solar cycles avoiding the sunspot maxima, is investigated whether it is solar effect or not.

It is shown that most intense outbursts at microwaves, which seem to be a good measure for the acceleration of particles in the solar atmosphere, show the same tendency as the cosmic-ray increases have, in spite of the fact that importance 3^+ flares occur most frequently in sunspot maximum.

This tendency might simply be due to some conditions unfavourable to accelerate particles at the sunspot maximum. However, if we reasonably assume that an eruption accompanying both a 3^+ flare and an acceleration of appreciable number of particles is more intense than an eruption accompanying only a 3^+ flare, it may be inferred that the most intense eruptions tend to occur away from the sunspot maximum actually avoiding the maximum phase.

Anyway, unusual cosmic-ray increases occurring away from the sunspot maximum may be solar effect rather than interplanetary modulation effect.

It has been pointed out that unusual increases of cosmic-rays occur only in ascending and descending phases of solar cycles avoiding the maximum phases through three solar cycles (Kodama[1]). In this respect, there arises a question as to whether most intense solar eruptions which may cause the C. R. increases are really absent in sunspot maximum or accelerations and/or escaping of particles are unfavourable.

The C. R. increases are generally accompanied by both solar flares of importance 3^+ and unusually intense solar outburst at microwaves. Their intensities are greater than threshold values, 10^{-18} at 9400 Mc and 3750 Mc (Toyokawa), and 5×10^{-19} at 2800 Mc (Ottawa) in units of w m^{-2}(c/s)$^{-1}$. These outbursts are good indication that acceleration of appreciable *number* of electrons (and probably also protons) occurred during the associating eruptions, since the outbursts at microwaves are believed to be synchrotron emissions from electrons of $0.1 \sim 0.5$ MeV[2)-5)]. Here, it may be noted that the intensity of the outbursts at microwaves is not a measure for the energy of accelerated electrons but rather a measure for the *number* of accelerated electrons. The mean energy of accelerated electrons seems to be nearly independent of the intensities of the outbursts.

The outbursts at microwaves whose intensities are greater than above mentioned threshold values at any frequencies of 9400 Mc, 3750 Mc and 2800 Mc are tabulated in Table I, referring to the observed C. R. increases.

Variations in occurring frequencies of flares and outbursts at microwaves are shown in Fig. 1 and Fig. 2, respectively. As shown in Fig. 1, the occurring frequencies of flares are maximum in the period of sunspot maximum of the present solar cycle and then decrease with increasing years, though the decrease only for 3^+ flares is exceptionally gradual. While, as shown in Fig. 2, most intense outbursts at microwaves (tentatively indicated by radio importance 6) tend to occur away from the sunspot maximum, but the weaker bursts are most frequent at the maximum phase.

This tendency might simply be due to some conditions unfavourable to accelerate

Table I.

Date	Max. time. U. T.	Frequency Mc	Intensity 10^{-18}w m^{-2}(c/s)$^{-1}$	Flare*	C. R. Increase
Feb. 23, 1956	0335	3750 (9400 no obs.)	1.8	3+(74°W)**	yes
Apr. 17, 1957	2042	2800	0.6	3+(70°E)	no (a)
July 10, 1959	0224 (0224)	9400 (3750)	2.7 (0.63)	3+(70°E)	no (b)
July 16, 1959	2154	2800	0.65	3 (30°W)	yes
Apr. 5, 1960	0201 (0202)	9400 (3750)	1.4 (0.6)	3 (60°W)	no (c)
May 13, 1960	0532 (0532)	9400 (3750)	1.8 (0.38)	3+(64°W)	no (d)
Sep. 3, 1960	0104 0108	9400	1.39 1.47	3 (90°E)	yes (small)
	0104.6	3750	1.2		
Nov. 12, 1960	1345.5	2800	0.55	3+(04°W)	yes
Nov. 15, 1960	0228.4 0222	9400 3750	2.4 1.2	3+(33°W)	yes
May 4, 1960***	1015 (Start)	9100(NERA) 2980(NERA)	0.2 0.2	3 (90°W)	yes
	1033	9400(Heinrich-Hertz)	0.06		
	1039	3000 (〃)	≫0.07		

* Solar-Geophysical Data, C.R.P.L.

** Bulletin of Solar Phenomena, Tokyo Astronomical Observatory.

(a), (b): Cosmic-ray increase did not occur but may be attributed to east-west asymmetry[1], since the flares occurred on the east side of the solar disc.

(c), (d): The reason why cosmic-ray increase did not occur is not clear, though radio importance at 3750 Mc is not 6 but 5.

*** May 4 event was observed only in Europe. Intensity of outburst seems to be exceptionally weaker, but a cosmic-ray increase was observed.

particles at the maximum phase of solar cycle. However another following interpretation may be made.

It seems difficult to know an actual intensity of eruptions (e.g. total released energy), but 3+ flares accompanying the outbursts of importance 6 may be associated with bigger eruptions than the eruptions accompanying only 3+ flares. This assumption has been supported by the observations that white-light flares and very wide line-widths of Hα were observed twice at the flares actually followed by the C. R. increases[6),7)].

Thus, it may be inferred that most intense eruptions tend to occur away from sunspot maximum avoiding the maximum phase. In order to explain this curious tendency, the following interpretation would be made. In order that an eruption can occur there would be two processes, one would be a gradual storage of magnetic stress due to a gradual distortion of the magnetic field, and the other would be a trigger action to release the stored energy. Then, in the maximum phase of the solar cycle, there may be too much disturbances to be triggers which result in frequent weaker eruptions. Their time intervals are too short to store much energy to cause the most intense eruptions. While in the descending and ascending phases of the solar cycle, the number of disturbances to be the triggers would be moderate so that most intense eruptions could occur but wearker eruptions are comparatively infrequent.

Anyway, it may be concluded that unusual increases of cosmic rays occurring away from the sunspot maximum may be solar effect rather than interplanetary modulation effect.

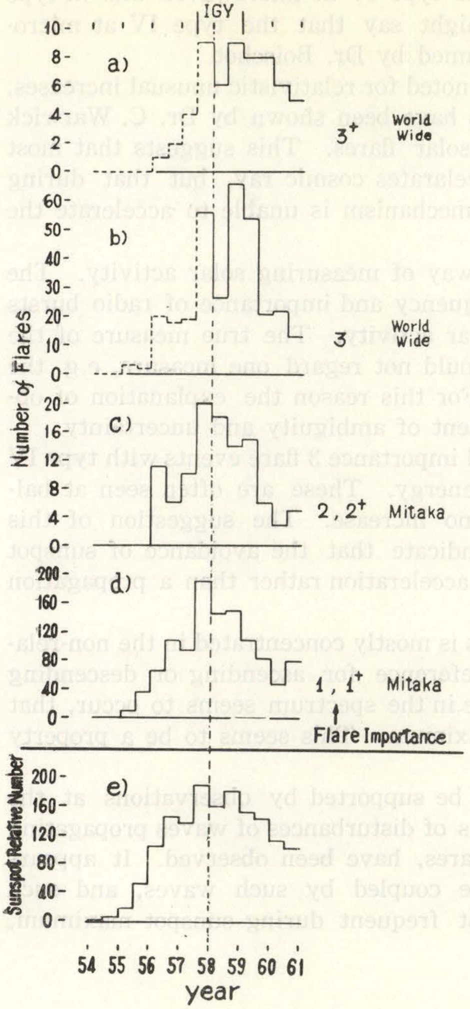

Fig. 1. (a)-(d) Number of flares per half yearly interval.

(e) Sunspot relative number.

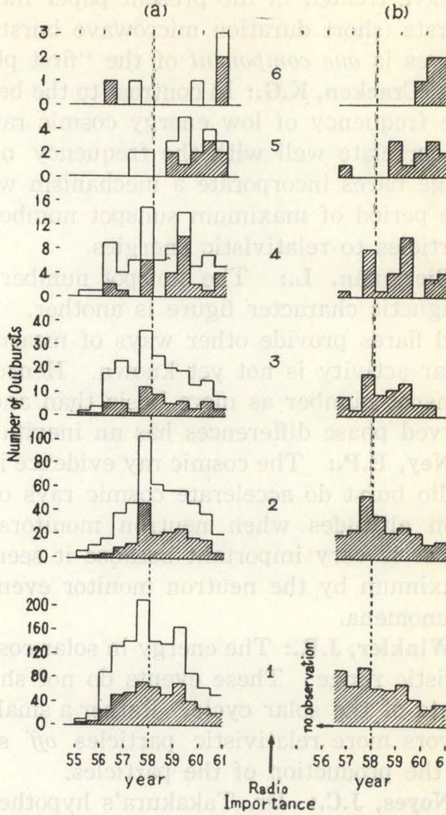

Fig. 2. Year to year variations in occurring frequencies of outbursts at microwaves.

(a) 3750 Mc (Toyokawa) plus 2800 Mc (Ottawa). Shaded parts are for 3750 Mc alone.

(b) 9400 Mc (Toyokawa).

Radio importances are tentatively defined as follows by their intensities. Radio importance 6: The intensity is greater than a threshold intensity of outbursts actually followed by C. R. increases. The thresh-old intensity: 10^{-18} wm^{-2} (c/s)$^{-1}$ at 9400 and 3750 Mc, 5×10^{-19} wm^{-2}(c/s)$^{-1}$ at 2800 Mc. Radio importance 4: Intensity is 0.1–0.32 times of the threshold. Radio importance 2: Intensity is 0.01–0.032 times of the threshold.

References

1) M. Kodama: Paper II-5-P1.
2) T. Takakura: Paris Symposium on Radio Astronomy (edited by R. Bracewell, Stanford University Press, 1959) p. 562.
3) T. Takakura: Pub. Ast. Soc. Japan **12** (1960) 55.
4) T. Takakura: Pub. Ast. Soc. Japan **12** (1960) 325.
5) T. Takakura and K. Kai: Pub. Ast. Soc. Japan **13** (1961) 94.
6) M. Notsuki et al.: Pub. Ast. Soc. Japan **8** (1956) 52.
7) S. Nagasawa et al.: Pub. Ast. Soc. Japan **13** (1961) 129.

Discussion

Hayakawa, S.: Is there any relationship between your microwave burst and the first phase or the second phase of the type IV outburst defined by Dr. Boischot?

Takakura, T.: We have a different picture for the spectrum of type IV outbursts, and which will be shown later by Dr. Tanaka. Anyway, the microwave bursts which

I have treated in the present paper include both type IV at microwaves and M-type bursts (short duration microwave bursts). I might say that the type IV at microwaves is *one component* of the "first phase" named by Dr. Boischot.

McCracken, K.G.: In contrast to the behaviour noted for relativistic unusual increases, the frequency of low energy cosmic ray effects have been shown by Dr. C. Warwick to correlate well with the frequency of large solar flares. This suggests that most large flares incorporate a mechanism which accelarates cosmic ray, but that during the period of maximum sunspot numbers the mechanism is unable to accelerate the particles to relativistic energies.

Biermann, L.: The sunspot number is one way of measuring solar activity. The magnetic character figure is another. The frequency and importance of radio bursts and flares provide other ways of measuring solar activity. The true measure of the solar activity is not yet known. Hence one should not regard one measure, e.g. the sunspot number as more basic than another. For this reason the explanation of observed phase differences has an inevitable element of ambiguity and uncertainty.

Ney, E.P.: The cosmic ray evidence is that all importance 3 flare events with type IV radio burst do accelerate cosmic rays of some energy. These are often seen at balloon altitudes when neutron monitors show no increase. The suggestion of this paper is very important because it seems to indicate that the avoidance of sunspot maximum by the neutron monitor events is an acceleration rather than a propagation phenomena.

Winkler, J.R.: The energy in solar cosmic rays is mostly concentrated in the non-relativistic range. These events do not show a preference for ascending or descending parts of the solar cycle. Rather a small change in the spectrum seems to occur, that favors more relativistic particles *off* solar maximum. This seems to be a property of the production of the particles.

Noyes, J.C.: Dr. Takakura's hypothesis may be supported by observations at the Lockheed Solar Observatory, where observations of disturbances of waves propagating across the solar disk, emanating from solar flares, have been observed. It appears then that different regions on the sun may be coupled by such waves, and such coupling and possible interference will be most frequent during sunspot maximum, when flare frequency is highest.