Discussion

Parsons, N. R.: Are the asymptotic longitudes scanned by N and S telescopes approximately the same?

Sarabhai, V.A.: This is nearly so at the latitude of Ahmedabad. For the diurnal component the difference in time of maximum due to this would be insignificant.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-4-4. An Attempt of Analyzing Cosmic Ray Storms

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It is being shown that a beam model can explain the sequences of Forbush decreases and storm sudden commencements characteristic of cosmic ray storms. It also explains why there does not exist regular 27-day period in the appearance of cosmic ray storms associated with the return of active regions.

According to Steljes *et al.*[1] the unusual series of events in November 1960 are to be ascribed to one and the same plasma beam covering a considerable part of the Earth's orbit.

Apart from a plasma beam serving as a carrier of a flow of cosmic ray particles emitted from the sun it modulates the normal cosmic radiation by decreasing the intensity, *i.e.* creating a C.R.S. It has been shown that only 45–50 per cent of all observed s.s.c:s appear to be associated with an F.d. On the other hand very few F.d : s have been observed which were not accompanied by an s.s.c. The same beam being responsible for both phenomena it appears as if the plasma has to have special characteristics to be able to generate a C.R.S.

Maintaining the picture introduced by Steljes *et al.* an F.d. might be due to a new burst of plasma travelling along a beam already enveloping the Earth. It is also possible that the beam overtakes the Earth. If it is already filled with plasma having the characteristics necessary for the production of an F.d., a C.R.S. will develop. In both cases an s.s.c. also takes place, associated with the F.d. However, if in the latter case the latter case the beam does not contain any plasma, able to produce an F.d. there can still be an s.s.c. An F.d. will not appear until a new eruption on the sun propagates plasma of the right kind along the beam. The events can be classified as follows:

A) A beam, lacking the properties to produce a C.R.S. is overtaking the Earth. An s.s.c. will take place but no F.d.

B) The beam has also the properties necessary for the production of a C.R.S. An F.d. will take place closely associated with an s.s.c.

C) The beam has overtaken the Earth producing an s.s.c. Later eruptions in the sun propagate plasma along the beam producing either s.s.c:s alone or s.s.c:s. associated with F.d:s.

In the first two cases the time interval between the events on the sun and the correlated s.s.c. or F.d. will vary within wide limits. As concerns the third case observations show that there is a considerable variation as to the time interval between the full development of a C.R.S. and the s.s.c.[2].

Usually an F.d. appearing during the later stages of a C.R.S. is insignificant as compared to the initial one[3]. As the initial F.d. results from the removal of C.R. particles the later plasma stream cannot give rise to an

equally big decrease as there remains only a limited number of removable particles.

In the most simple case a comparatively straight beam overtakes the Earth. Evidently the cosmic ray storm will then be of short duration. Usually the angular width of the beam is considered to be of order of magnitude of 15°. Probably all cosmic ray storms of a longer duration are due to beams passing obliquely across the orbit of the Earth. In the former case the time interval between the flare and the disturbances at the Earth's surface furnishes a crude measure of the propagation speed of the plasma. When the radius of curvature is small and especially in cases when the plasma has to travel along a big part of the Earth's orbit a considerable time will elapse between the flare and the effects observed at the Earth. In case the plasma beam is being propagated more or less straightly towards the Earth it turns out that the time interval is from 22 to 38 hours both as concerns the s.s.c:s and the F.d:s. When the duration of the storm makes it necessary to assume the beam to have a curvature enabling it to cover 20° to 60° of the Earth's orbit the time interval can be 50 to 90 hours. When an F.d. or a s.s.c. is caused by an already existing beam overtaking the Earth, it is often difficult to establish which special event on the sun is to be considered as the origin. The time intervals can be considerable. In such cases it becomes necessary to resort to the most probable occurrences and the association of the whole sequence of events with one and the same active region.

Evidently no pronounced regularity is to be expected concerning the frequency of decreases and C.R.S:s. The structure of individual F.d:s will depend not only on the amount of plasma in the beam but, in case it overtakes the Earth, also on the properties of the boundary region of the beam.

Sometimes the active regions exist through more than one sun rotation period. Much work has been devoted to the question of a corresponding 27-day periodicity as regards F.d:s and C.R.S:s. However, a regular reappearance of C.R.S:s is not to be expected even if the beam survives through several sun rotation periods. This is due to their being dependent not only on the passage of the beam but also on the propagation of plasma from eruptions on the sun. Therefore, probability favours a reappearance after more than 27 days. In rare cases an F.d. might appear before 27 days. This happens if in the first instance a C.R.S. has developed late in the passage of the beam and the latter generates an F.d. immediately when overtaking the Earth a second time. This is in accordance with results reported by Shea and Lockwood[4].

The beam model, as presented above, has

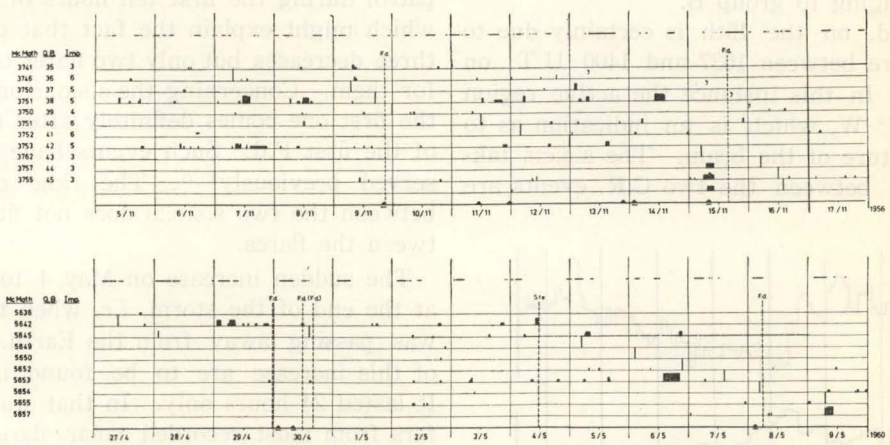

Fig. 1. Diagrams of the active regions of the sun, D.C. events, and s.s.c:s. The black rectangles mark solar flares. Their heights indicate the importance. The black triangles at the lower edges mark s.s.c:s. The dotted lines mark F.d:s and s.f.e. a sudden increase. Hours lacking solar patrol are marked by the broken lines at the upper edges of the diagrams. The curved arrows mark when the active region turns the western limb.

been applied to an attempt to analyse some C.R.S:s. The method is illustrated by Fig. 1. The activity in the sun has been plotted along a time axis. All the active regions have been included which can be considered as the origin of the beam responsible for cosmic ray and geomagnetic events. The Mc Math regions[5] are employed together with the regions listed in the Quarterly Bulletin on Solar Activity[6]. The Mc Math regions sometimes cover several of the latter. Cosmic ray events and s.s.c:s are plotted in the same diagrams.

C.R.S. of Nov. 9, 1956: Apart from the initial F.d. at least one more can be identified in the diagram of the nucleon component. The Mc Math Region 3751 is the most active region producing a 3^+ solar flare on the 7th. Possibly this flare generated the beam responsible for the C.R.S. The first F.d. took place at 2030 U.T. on Nov. 9. The last preceding s.s.c. was 14 days earlier which is too long a time for this s.s.c. to be considered as belonging to the same set of events as those taking place on and after Nov. 9. Probably the s.s.c. and the F.d. mark the time when the beam overtook the Earth. There was also an importance 2 flare on Nov. 8. It is impossible to ascribe the s.s.c. to either one of the two flares. Preferably the F.d. was caused by plasma from the 3^+ flare. It is natural, then, to ascribe both events to this flare. The time difference indicates a case belonging to group B.

The F.d. on the 15th is certainly due to the 3^+ flare between 1037 and 1400 U.T. on Nov. 14. In this instance the active region was at 77° W, which is an indication as to the curvature of the beam. The s.s.c:s taking place between the two C.R. events are certainly due to the series of small flars in the Mc Math Region 3751.

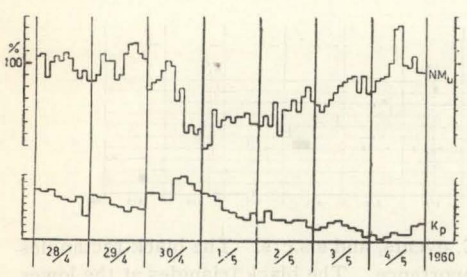

Fig. 2. Intensity variations during the C.R.S. Apr. 9 to May 4, 1960. To the right: 5-minute records of the sudden increase on May 4.

C.R.S. April 29 to May 4, 1960: This C. R.S. is remarkable because of the fact that a small solar flare effect took place at the ultimate end of the storm (Fig. 2). The initial F.d. on April 29 was followed by two decreases very close together. There are three sudden commencements to be considered. The first s.s.c. appeared at 2020 U.T. on the 27th. The 17 days interval from the preceding one indicates that the beam overtook the Earth on April 27. The solar flares to be considered took place in the Mc Math Region 5642. Two flares appeared on April 29, neither of them very big but both displaying high intensity. The first one had its maximum at 0205 and the second one at 0617. Looking at Fig. 2 we note that the first F.d. precedes the second one by 12 hours. If the two flares account for these two Forbush decreases the plasma would have a transit time of maximum 22 hours in the first case and in the second case 34 hours. If there really are two separate F.d:s, on the 30th their time separation is four hours, actually corresponding to the separation of the two flares. The transit time would be 34 hours in both cases. Accepting this correlation there is no flare to account for the first F.d. The flare ought to have taken place about 12 hours before the first one on the 29th. However, there was no proper solar patrol during the first ten hours of April 28, which might explain the fact that there are three decreases but only two flares to account for them. Concerning the s.s.c.:s on the 30th the first one comes definitely after the onset of the first F.d. Such events have been observed previously[2),7)]. The time difference between the two s.s.c.:s does not fit that between the flares.

The sudden increase on May 4 took place at the end of the storm, *i.e.* when the beam was passing away from the Earth. Details of this increase are to be found in Fig. 3. It lasted 24 hours only. In that way it differs from most recorded solar flare effects. In this instance the beam has to be regarded as a carrier of cosmic ray particles from the sun. The passage of the beam explains the short duration of this increase. The onset time was 1135 U.T.

Only one solar fiare can be associated with this sudden increase. It took place in the Mc Math Region 5642, also responsible for the cosmic ray storm. It was observed at the western limb. The time was 1015 to 1105 U.T. The center of the active region had already turned the limb. The transit time of the C.R. particles was approximately 45 min.

C.R.S. May 8, 1960: This storm is included in the lower diagram, Fig. 1. An s.s.c. took place at 0421 U.T. on the 8th closely followed by an F.d. The beam passed very rapidly. The storm cannot be associated with the Mc Math Region 5642. The end of the C.R.S. generated by this region, is too well defined. The events on May 8 have to be due to an extended flare period in Region 5653 (Fig. 1.). The time difference is 38 hrs. Evidently a new beam, originating in the Mc Math Region 5653, overtook the Earth on the 8th.

References

1) J. F. Steljes, H. Carmichael and K. G. Mc Cracken: J. Geophys. Res. **66** (1961) 1363.
2) A. E. Sandström: Astronaut. Acta, **7** (1961) 141.
3) F. Bachlet, P. Balata, A. M. Conforto and G. Marini: Nuovo Cim. **16** (1960) 292.
4) M. A. Shea and J. A. Lockwood: Technical Note, Air Research and Development Command, Cambridge, U.S.A.
5) Solar-Geophysical Data, National Bureau of Standards Central Radio Propagation. Laboratory, Boulder, Colorado.
6) Quarterly Bulletin on Solar Activity; published by the Eidger. Sternwarte in Zurich.
7) F. Bachlet, A. M. Conforto, N. Incci and G. Marini: Nuov. Cim. **13** (1959) 1055.

Discussion

Chasson, R. L.: Analysis of May 4, 1960, flare showed change of characteristic of recovery that was coherent with shutoff of optical flare. Tail did not terminate as rapidly in western hemisphere as it did in Uppsala.

Sandström, A. E.: Perhaps related to difference of location relative to corpuscular stream responsible for preceding Forbush decrease. Guiding field disappeared more quickly at Uppsala. In this case the structure of the boundary region of the beam might have produced different effects in different part of the world.

Carmichael, H.: Dr. Sandström has pointed out that only 50% of SC magnetic storms are accompanied by Forbush decreases and also that there is no correlation between the size of a Forbush decrease and the strength of the accompanying storm. May we say that conductive plasma from the sun can always produce a magnetic storm but can produce a Forbush decrease also only if it contains magnetic field drawn out from the sunspot?

Sanström: It is possible that an F.d. is associated with all S.S.C. although it is too small to appear in the records. It will be concealed by the diurnal variation or other variations. The existence of a difference in prominence of F.d:s indicates, however, that there might be variations in the constitution of the plasma responsible for the F.d:s, which does not affect the S.S.C:s.
This has to be gone into further.

Kodama, M.: According to the result given by Kamiya and Wada, Forbush decreases correspond, nearly one-to-one, with the solar flares accompanied by the solar radio outbursts of Type IV. They have also shown that only these solar flares occuring near the central meridian are responsible for larger magnetic storms, on the contrary, the size of the cosmic-ray storm is nearly independent of the position of the corresponding flare. I suggest to you that their results are effective for your study.

Sandström: I agree.

Rose, D.C.: In regard to the number of Forbush decreases in relative to the number of sudden commencements I think there is a great deal of uncertainty because some increases are very small and can only be seen with equipment having very good statistics. Perhaps as more stations are established with high counting rate equipment

some of the correlations we have discussed may be more clear.

Sandström: Yes, this is my opinion too. It is possible that all S.S.C.s are associated with F.d:s although some of the latter are too small to be observed in competition with other variations.

Pomerantz, M.A.: Following the comment of Dr. Rose, I should like to report in a preliminary manner that small amplitude Forbush decrease indeed occur, and could have been ignored previously because of statistical considerations.

A large plastic scintillator meson telescope is now in operation at NAF McMurdo in Antarctic. During July, an identical high counting rate detector in Swarthmore recorded small fluctuations, which might not have been regarded as genuine Forbush type decrease without the corraboration of the other instrument at a very distant location. The fluctuation are not apparent in the neutron monitor records. Thus, it is clear that the question of whether all magnetic storms are accompanied by cosmic ray intensity modulation remains to be investigated experimentally, and, in fact, this study is now in progress. Just as so have probably not detected some small flare-associated increase, so also the small size decreases need detailed examination.

Sandström: I refer to what I have answered on other questions. The non appearance of F.d. in the records is not a proof that should not be one. I agree with Dr. Pomerantz that instruments with increased counting rates will reveal more F.d:s. However, the different prominence of these from case to case indicates, as I have said, that the properties of the plasma has affects C.R. and geomagnetic conditions in different ways.