CORONAL MAGNETIC FIELD STRUCTURE DERIVED FROM TWO-FREQUENCY RADIOHELIOGRAPH OBSERVATIONS

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Abstract (*Solar Phys.*). An exceptional variety of positions and polarizations was found for two type I storms and numerous sporadic bursts observed during 15 consecutive days with the Culgoora radio-heliograph at 80 and 160 MHz.

The main observational points for the type I storms are as follows:

(A1) The type I storm centres were not situated radially above the associated sunspots but were displaced systematically northwards.

(A2) They did not always show a uniform daily motion across the disk. The second storm, in particular, shows anomalous movements between 1972 October 27 and 30.

(A3) The sense of circular polarization of the storms was left-handed (L.H.) and remained so as the sources rotated across the disk, except on one day, October 30, when the L.H. polarized source was accompanied by a right-handed (R.H.) polarized companion at both 80 and 160 MHz.

In addition to the persistent storm centres a large number of sporadic bursts occurred. These were mainly of types III and V, with some showing inverted-U structure. The sporadic bursts generally showed a variety of temporal and spatial distributions, particularly at 80 MHz. One sequence of such bursts observed at 80 MHz between 00^h37^m and 01^h05^m UT on 1972 October 29 is illustrated in Figure 1. Some remarkable features shown by the group of the sporadic bursts are the following:

(B1) All sources except No. 2 appeared to lie on an arc extending around the active region in which the associated Hα-flare occurred.

(B2) Irrespective of spectral type all the sources were weakly L.H. circularly polarized.

(B3) No sequence was evident in the positions of successive bursts.

(B4) Sources showing different spectral features usually appeared at different places.

The two-frequency radioheliograph data are combined with optical data to derive a model of the coronal magnetic field structure for this complex of active regions. In attempting this we assume that

(a) type I storms occur in the stronger magnetic fields of active regions, probably in magnetic fields forming closed loops;

(b) sporadic bursts are associated with weaker magnetic fields; when bursts have inverted-U structure their exciting agencies (electrons) are guided around closed

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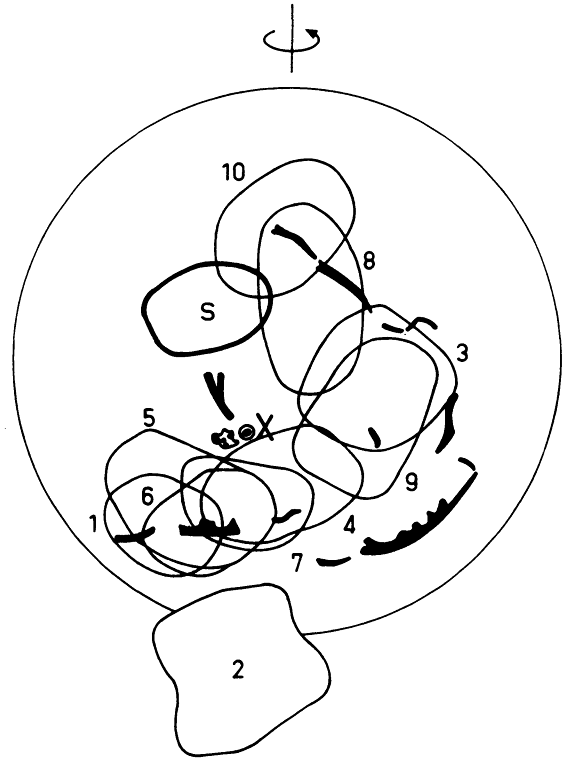

Fig. 1. The distribution of the 80 MHz sources of the sporadic bursts (numbered 1 to 10 for reference) and some prominent quiescent filaments on 1972 October 29. The associated Hα flare ($-N$, 00^h37^m to 00^h39^m UT) indicated by the cross occurred in the region north-west of the associated leading spot. The heavy full contour labelled S is the persistent type I storm ($\sim 80\%$ L.H. circular polarization). The sporadic sources are: (1) III or V: $00^h37^m38^s$, $\sim 6\%$ L.H.; (2) III or V: $00^h38^m16^s$, ~ 0; (3) III or V: $00^h38^m18^s$, $\sim 10\%$ L.H.; (4) III: $00^h39^m24^s$, $\sim 30\%$ L.H.; (5) III: $00^h39^m26^s$, $\sim 5\%$ L.H.; (6) V: $00^h40^m08^s$, $\sim 5\%$ L.H.; (7) III: $00^h40^m42^s$, $\sim 10\%$ L.H.; (8) III?: $01^h00^m11^s$, $\sim 15\%$ L.H.; (9) U or III: $01^h03^m06^s$, $\sim 10\%$ L.H.; (10) ?: $00^h35^m58^s$, $\sim 30\%$ L.H.

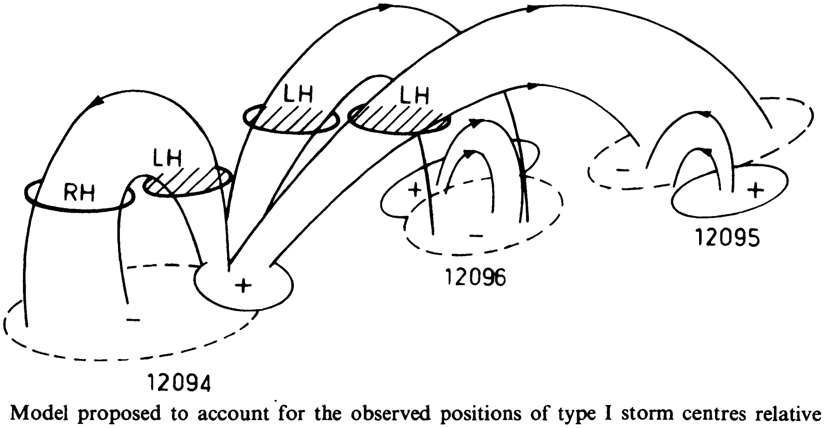

Fig. 2. Model proposed to account for the observed positions of type I storm centres relative to the associated optical features (the numbers refer to McMath plage regions). The polarized radio sources labelled L.H. and R.H. are drawn on magnetic loops; the direction of the field is indicated by arrows and corresponds to the observed polarities of the underlying plage regions (marked + and −).

magnetic loops whereas in normal type III bursts the electrons have access to 'open' magnetic field lines; type V bursts are due to radiation from electrons trapped and reflected in closed magnetic loops.

Figure 2 depicts a model of the magnetic fields associated with the second series of the type I storms. It is suggested that there are three possible sites where type I source regions can exist, and that the apparently anomalous positions (A1) and position shifts (A2) are simply due to the decay of the source at one site and its reappearance at one of the previously inactive sites. It is also suggested that the bipolar structure (A3) is associated with the magnetic field which emerges from the leading spots and closes into the trailing spots (or the region surrounding them) of the active region 12094. This is based on the observation that the leading, L.H. polarized and the trailing, R.H. polarized radio sources of October 30 seemed to overlie respectively the leading positive and the trailing negative magnetic fields of that active centre. These combined heliograph and magnetograph results are probably the clearest evidence yet in support of the ordinary-mode hypothesis for type I storm radiation.

The large quiescent filaments (see Figure 1) indicate boundaries dividing regions of opposite polarity of the weak magnetic fields measured at the photospheric level. Inspection of Figure 1 suggests that the arc joining the 80 MHz sporadic sources is related to the configuration of these filaments. Open weak magnetic fields must di-

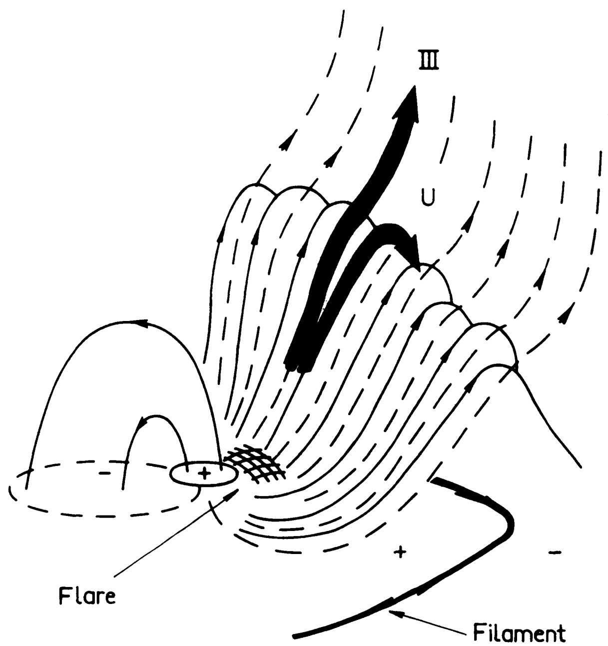

Fig. 3. A suggested model of magnetic fields (light lines with light arrow heads) associated with the widely-spread sporadic sources observed at 80 MHz. The heavy arrows indicate the flow of electron streams which are presumably accelerated in the flare region (shown hatched) and which are responsible for exciting the sources of the aradio bursts of type III (and U). The filament is shown under the field lines.

verge from the flare region to guide the electron streams to the widely-spread radio source sites. The field lines are generally directed toward the filaments, but spread into a wide angle ($\sim 180°$). A suggested model for these fields is shown in Figure 3. Some of the magnetic fields emerging from the active region (12094) cross over the filaments and return into regions of opposite polarity on the other side. Electron streams guided along these field lines give rise to inverted-U bursts and trapped electrons 'mirroring' on these lines produce the type V sources. Other field lines emerging from both sides of the filaments form a cusp-like entrance to the open 'streamer' configuration above the filaments; electrons guided from the active centre along these lines produce the normal type III bursts (B4). The sporadic bursts lying on the arc are partially L.H. polarized, consistent with ordinary mode emission in the field of the model (B2). The sporadic bursts were scattered widely in position and randomly in time (B3). This can be readily explained by the model, since electrons accelerated in the flare region have ready and varied access to many parts of the weak magnetic field bridging the filaments.

DISCUSSION

Smith: Is there any evidence that moving IV did not open the field lines?

Sheridan: No.

Rosenberg: Type III bursts are not always associated with flares but many appear with rising filaments, dark features, etc. But this may be due to an unobserved flare's exciting the filament. Also, there are flares without type III bursts. Acceleration may not occur exclusively in flarès – there is abundent evidence for particle acceleration in the corona.

Pick: The right hand polarized bipolar region was observed only on one day – have you any explanation? Was there observed any modification of the magnetic field pattern?

Kai: We have no direct evidence for the intensification of magnetic fields associated with the trailing spot. But the region surrounding the trailing spot had become active one day before.

Pick: It seems that, according to the aspect of the chain of filaments, another possibility would be a direct injection of electrons from the flaring site into the current sheet (see paper Mercier: 1973, *Solar Phys.* **33**, 177).

Sheridan: Successive (within ~ 2 s) type III bursts have occurred in widely-separated regions so the idea is quite plausible.

Zirin: 'Decent' type III bursts (other than type III storm bursts) do *not* occur without flares.

McKenna-Lawlor: I have observed that certain localized parts of active regions seen in Hα repeatedly show brightenings which are time associated within ± 1 min with the production of type III bursts.

Wild: I haven't heard Zirin press so strongly for a type III-flare association before. Maybe, it is a question of 'decent' vs 'indecent' type III's. There are many 'indecent' type III's which have only low frequency components which appear to be initiated high in the corona.

Rosenberg: There is ample evidence for acceleration high in the corona from decametric type III bursts.

Fainberg: This carries on to kilometric III's as shown by satellite.

Hartz: Confirm Fainberg's observations.

Erickson: At decametric wavelengths it is possible to associate some Hα feature with each type III, however, the association is not with obvious flares. Many type III's are associated with small twitchs and wiggles in Hα, while rather similar twitchs produce no III's. I agree with Zirin that major type III's can practically always be associated with flares.

Leblanc: I would like to confirm that there are two kinds of type III bursts in decameter wavelengths. The first kind are storms of type III burst which appear only at high levels in the corona ($>0.5\ R_{\odot}$). The second kind are type III bursts which come from the very low corona and can be seen at all wavelengths. The storms of type III bursts are not associated with flares, but the other type III bursts which come from the low corona are associated with flares.

Steinberg: What makes you believe that the size of type I's is proportional to the cross section of a magnetic tube of force at the critical surface at f_p, your observing frequency. I understand that the model accounts qualitatively for the observations, but we know that the apparent diameter of type I's vary from one event to the next and sometimes within an event.

Uchida: Was there any indication in the event shown in your last slide that the curved path of the region of appearance of the type III-moving IV events had something to do with dark filaments?

Sheridan: Yes. However, the filament position was not indicated in the slide since the figure becomes too crowded if everything is shown.