OPTICAL AND RADIO OBSERVATIONS OF LARGE SCALE MAGNETIC FIELDS ON THE SUN

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Abstract. It is possible to deduce information concerning large scale coronal magnetic field patterns from the knowledge of the location of radioburst sources.

As the method concerns active centers responsible for corpuscular emission, the knowledge of these structures may have important implications in the understanding of corpuscular propagation in the corona and in the interplanetary medium.

The object of this paper is to show it is possible to deduce information concerning the large scale coronal magnetic field patterns indirectly from knowledge of the location of radioburst sources.

It is now well known that noise-storms, type I bursts and continuum are associated with active centers and the location of emission sources is closely dependent upon the magnetic structure; thus the emission regions of type I bursts and continua may be simple or double or complex (Clavelier, 1968; Daigne, 1968). For several cases the type I bursts source has been found to be bipolar (Kai, 1970). Kai has advanced a qualitative model in which electrons with energies of a few keV are trapped in the magnetic field of a pair of sunspots of inverse polarity.

Recently, an active region giving rise to a noise storm center for several successive days has been studied by Lantos-Jarry (1970). In this case a global and systematic displacement of the mean distribution of the continuum and type I burst sources was observed. This displacement was explained in terms of the coronal magnetic field structure. This structure is illustrated in Figure 1. It represents an arch connecting two regions of opposite polarity, widely separated at the surface of the solar disk. In the present case, one of these regions is the active center giving rise to the noise storm and the other is a large and stable region of opposite polarity, characterized by a faint thermal radio enhancement observed in the corona at centimetric wavelengths.* Very

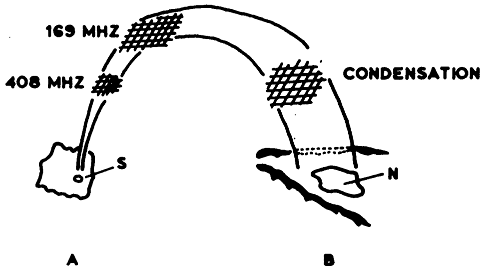

Fig. 1. Coronal magnetic field structure (from Lantos-Jarry, 1970).

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* The metric thermal emission is observed inside the streamer associated with the presence of filaments.

Howard (ed.), Solar Magnetic Fields, 609–615. All Rights Reserved.

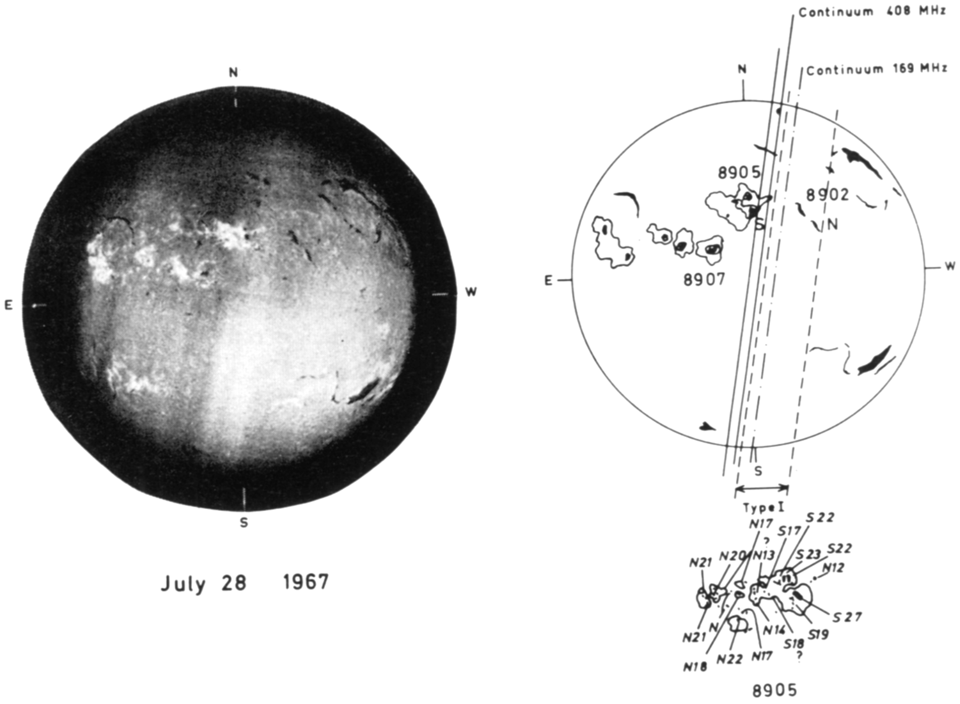


Fig. 2. July 28, 1967, – Hα spectroheliogram (from Meudon Observatory); – schematic representation of the sunspots observed on the spectroheliogram. Mean positions of the continuum storms observed at 169 MHz (–·–·–) and 408 MHz (———); the two broken lines indicate the range inside which the type I bursts are located; – sunspot polarities from Crimea Observatory.

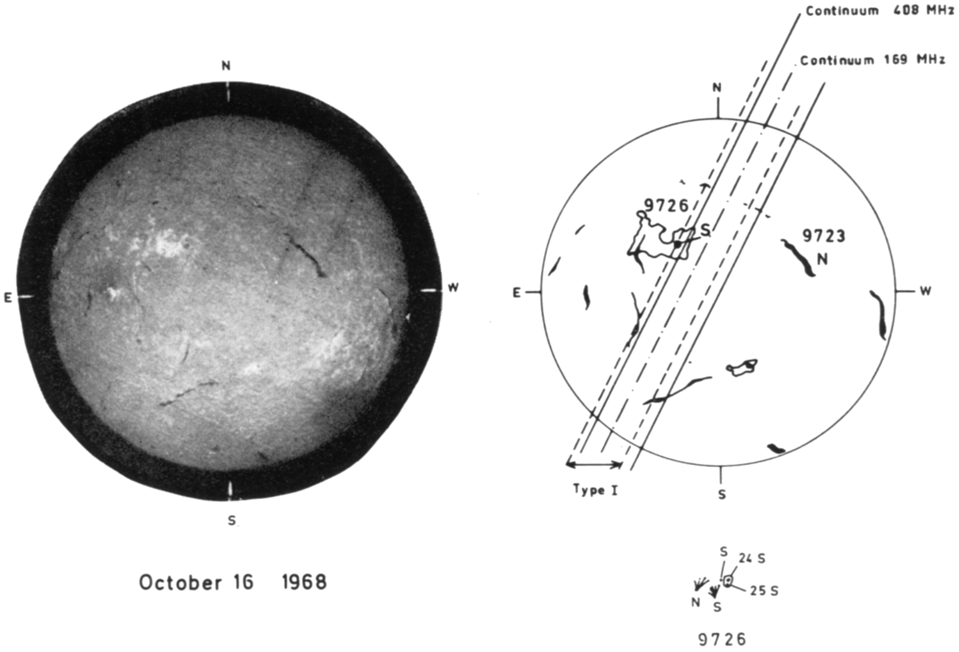


Fig. 3. October 16, 1968, same caption as Figure 2.

likely, this arch is similar to the low or high magnetic arcades as defined by Newkirk and Altschuler (1970) when coronal magnetic fields are calculated.

In this paper, this conclusion will be developed further with examination of several similar sets of observations. The radio-burst positions are obtained with an accuracy of about 1′ of arc from the Nançay interferometer at 408 MHz and from the Nançay East-West radioheliograph at 169 MHz.

In Figures 2, 3, 4, and 5 are summarized observations of active centers for which a displacement of the associated noise storm source has been observed during several successive days. On each figure, the following observations have been shown:

– The Hα spectroheliogram for the day when the active center concerned is near the central meridian.

– A schematic representation of the sunspots observed on K_1 spectroheliograms, the quiescent filaments observed in Hα. On the same diagram are indicated the mean positions of the continuum storms observed at 169 MHz and 408 MHz. Two broken lines indicate the range inside which type I bursts are located.

– The sunspot polarities of the active centers published by the Crimean Observatory.

From Figures 2 through 5, we note the following common features.

(1) The observed mean position of the continuum and type I bursts measured at 169 MHz is systematically displaced relative to the position of the optical active region by about 10° to 20° in the East-West direction, the sense and magnitude depending on the storm center observed. In each case, the type I burst positions are widely spread.

(2) This displacement is always orientated toward a region of polarity opposite to that of the main spots of the eruptive structure giving rise to the noise-storm.

(3) This region of opposite polarity is stable and most frequently delimited by a large quiescent filament. As is well known, filaments represent the limit of two regions of opposite polarity. This region is an old calcium plage persisting on several solar rotations and associated with a thermal enhancement observed on centimetric wavelengths. A thermal metric emission is observed inside the streamers associated with the presence of filaments.

(4) A striking feature is the absence of any other plage between the active center and the region which is at the other foot of the inferred connecting magnetic arch. This property is visible on the Hα spectroheliograms.

We conclude that there may exist large scale coronal magnetic structure between two regions of opposite polarity when they are at the limit of a large region free of any magnetic field. On the other hand, the case of several neighbouring plages will lead to local magnetic field structures with magnetic field lines confining themselves to closed regions.

As an example, some interesting observations from July 1967 may be shown. The Hα spectroheliogram reproduced on Figure 2 shows that there existed for this period several active centers on the Sun: Center 8905, located at 28° N, passed through central meridian passage on July 28 and gave as we have already discussed a noise center systematically shifted westwards. A large number of flares are located in the leading

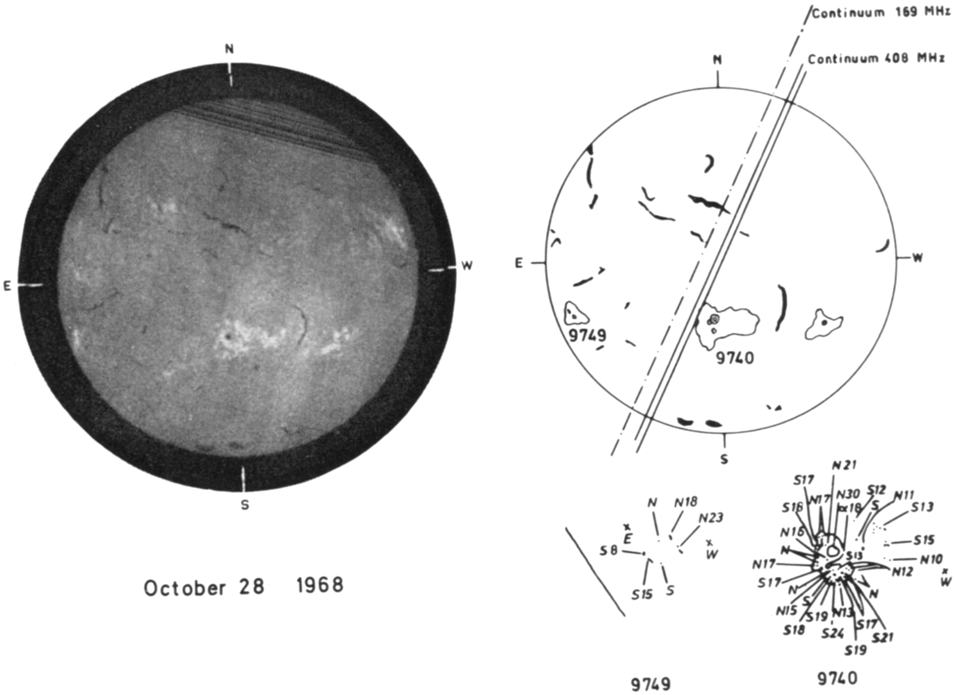


Fig. 4. October 28, 1968, same caption as Figure 2.

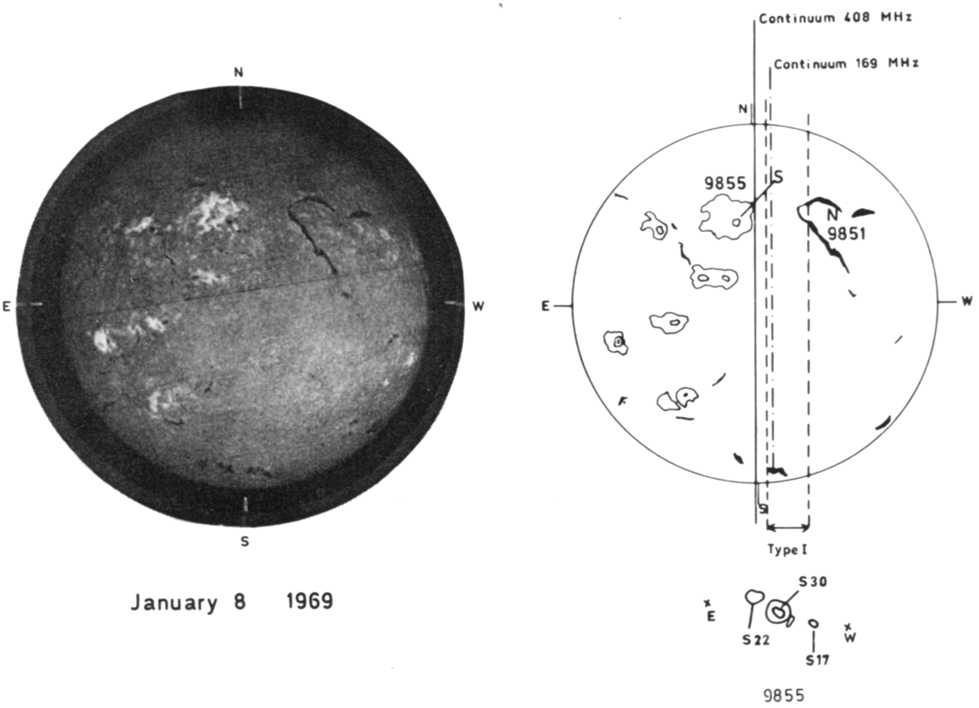
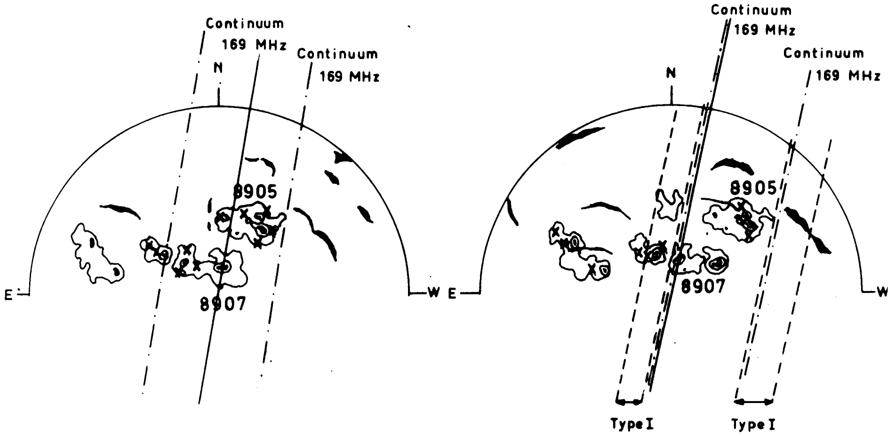


Fig. 5. January 8, 1969, same caption as Figure 2.

part of the active center, whose main polarity is South. A magnetic arch probably exists between Center 8905 and the old calcium plage 8902, barely visible on the Hα spectroheliogram. Center 8907, whose latitude is 15° North also produced a noise storm observed at 408 MHz and 169 MHz on July 29 and 30. The location of the radio sources is shown in Figure 6. In this case, no displacement in the radio position is observed: note that flares are located in the trailing part of the active center. In fact this trailing part is formed by 2 or 3 regions: the noise storm center is located above this part. Like Center 8905, the leading spot is of South polarity but probably does not play a role in the formation of a large scale magnetic field structure, in which electrons whose acceleration is related to eruptive structure would be able to propagate.



July 29 1967 July 30 1967

Fig. 6. July 29, 30 1967, same caption as Figure 2. Crosses indicate the position of the flares.

According to Lin (1970) solar X-ray bursts of energies ⩾20 keV were associated with both Regions 8905 and 8907. But only for Region 8905 were electron events observed near the Earth. Lin concludes that the coronal structure of Region 8907 may differ from Region 8905 in that electrons are trapped at a lower height (below 1 $R_\odot$) while 8905 coronal structure provides our open path from the acceleration region to the interplanetary field lines.

The same kind of magnetic connection as we have just described may exist between two active centers. In this case, the two feet of the magnetic loop would be situated at sunspots: this is the case for 1968 October 28, for which the arch connects sunspots of opposite polarity widely separated at the solar surface. It is now known that we may observe correlated activity above the two active centers. Figure 7 gives an example of this kind of correlation observed on 1969 July 8 with the Nançay radioheliograph. The two active centers were separated by 70° of longitude.

In summary, radio observations give the possibility of indirectly detecting large scale coronal magnetic field patterns. This is consistent with the results of Altschuler and Newkirk (1969–1970). The same kind of observations also gives an estimation of the stability of these structures which may last for up to a few days. Because this method concerns active centers responsible for corpuscular emission, knowledge of these structures may have important implications in the understanding of problems relative to corpuscular propagation in the corona and in the interplanetary medium: indeed sometimes both electrons and protons start to reach the Earth very quickly even when they are emitted from an Eastern flare. Transverse diffusion is unable to account for these transit times. It is possible to invoke magnetic guidance giving the possibility of the corpuscules reaching the region 'connected' with the Earth. Furthermore, Martres *et al.* (1970) have recently shown that large coronal condensations, such as those just associated with the foot of magnetic archs, are the main sources from

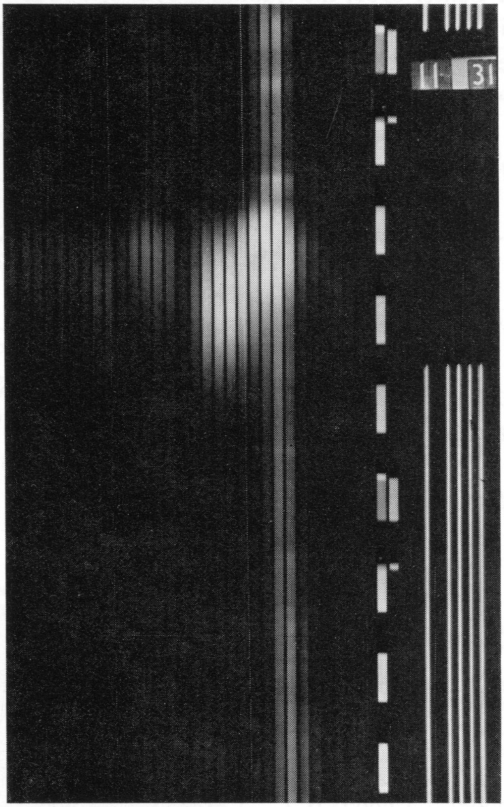


Fig. 7. July 9, 1969, correlated activity between two active centers. The distance between two successive strips is 2′ of arc in the East-West direction. The time scale is indicated by the vertical lines. One single line corresponds to one second.

which the interplanetary magnetic field would emanate. In the same plage region, there are some field lines connecting with the active center and some passing into interplanetary space, and small scale diffusion of energetic particles may be expected. Particles would propagate into the solar wind more easily from these regions. This rough model finds some confirmation in the recent study by Mc Donald and Desai (1970): they show that particles escape preferentially from a region preceding the active center associated with their production. The maximum of corpuscular emission occurs when the active center is still east of the central meridian.

We shall not discuss the implications of these observations for the emission mechanism.

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