BURSTS OBSERVED AT 21 cm WITH THE WESTERBORK INTERFEROMETER

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During the radio observations of the Sun performed at λ = 21 cm on July 1st, 1974 using the Westerbork Radiotelescope (Bregman and Felli 1976; Chiuderi-Drago et al. 1977) four bursts were recorded. Two of them, which present some interesting peculiarity, that it would not be possible to observe with an instrument of lower resolving power, are discussed in this paper.

We want to recall the following limitations of the Westerbork interferometer referring to time and space resolution: a) the four Stokes parameters are averaged over 30^s; b) the position of the burst source can be precisely determined (within 10") only along the baseline direction, while it is fully undetermined in the other direction. Moreover we want to point out that, in processing the data, we fitted every scan with one or two Gaussian curves. Therefore for each burst we consider only the two strongest sources present in each of the four Stokes parameters every 30^s.

The first considered burst was observed from $\sim 10^h34^m$ to $\sim 10^h40^m$ U.T. simultaneously to an optical flare of class I. This burst presents several sources: the average positions of the two longer lasting ones, (1) and (2), are shown in Fig. 1, superimposed to the longitudinal magnetic field structure drawn from a Kitt Peak magnetogram.

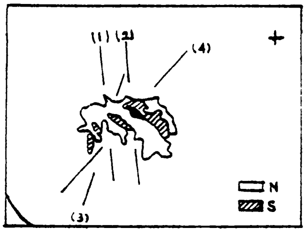

Fig. 1. Sketch of the longitudinal magnetic field structure from a KPNO magnetogram. The black spot indicates the position of the optical flare. (1), (2) and (4) are the positions of the sources mentioned in the text. (3) refers to another burst not considered in the present paper.

The behavior of the intensity and circular polarization of both sources (Stokes parameters I and V) vs. time is shown on the top of Fig. 2, while the observed position and size variation of the two com-

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ponents is shown on the bottom of the same figure. By considering Fig. 1 and 2 we can remark what follows. The source (2) is probably located above, or very close, to the optical flare (which lies close to the neutral line of the magnetic field), it is completely unpolarized and presents an intermittent behavior: at $t = 60^s$, 90^s and 180^s a source of higher intensity appears alternatively in two different positions. In one of these positions, the one symmetrical with respect to source (1), some right hand circularly polarized flux persists for $\sim$ 2 m, suggesting to put this source above the south polarity of the magnetic field at the left of Fig. 1.

Source (1) is almost 100% left hand circularly polarized: as explained in the following, this suggests to assume its position above the region of positive magnetic field in Fig. 1. The size of both components decreases with increasing intensity and vice versa; the sources seem also to move slightly on the solar disk. The maximum brightness temperature exceeds 4×10^8K for (1), and 8.5×10^7K for (2). Both reach their maximum simultaneously to the solar flare.

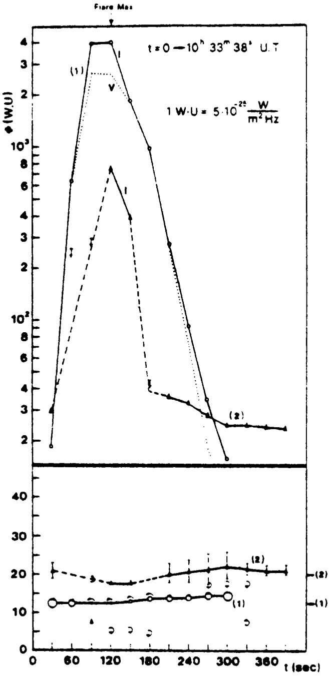

Fig. 2

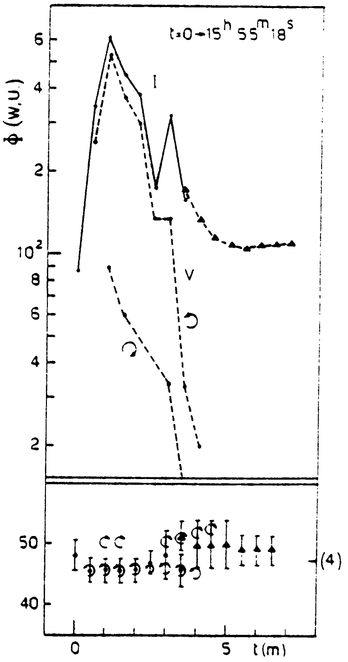

Fig. 3

Fig. 2. Top: Behavior vs. time of the intensity I and circular polarization V of the two main sources of the first burst. Bottom: Behavior vs. time of the position and angular size (circles and bars) of the same two sources. The vertical scale is in units of 10 arc sec along the baseline direction.

Fig. 3. Same as Fig. 2 for the second burst.

The second considered burst was recorded between $\sim 15^h55^m$ and 16^h02^m U.T. simultaneous to a subflare which took place almost in the same position of the previous one. The average burst position (4) in Fig. 1, indicates a coincidence with the flare and with position (2) above. The most interesting peculiarity of this burst is shown in Fig. 3: in the first part of the burst, the source appears strongly ($\sim$ 85%) left hand circularly polarized: 90^s after the first maximum the source increases its size up to $\sim$ 1.5 arc min. The two wings of the source present an opposite circular polarization: 30^s later the source is split into two components with opposite polarization and a second maximum, simultaneous to the subflare maximum is reached. Soon afterwards, the former component disappears and the new one becomes unpolarized and decreases slowly. The maximum brightness temperature reached in this burst is $\sim 1.3 \times 10^7$K.

The most interesting feature of these bursts is, in our opinion, the very high polarization percentage shown by some of the sources. It must be noticed that, had these bursts been observed with a lower resolving power instrument, the total polarization would have never exceeded 60%, due to the averaging over different sources.

The observed polarization can be explained in terms of emission from a thermal source in the presence of a magnetic field, following the treatment of Dulk et al. (1979). According to the above authors, the ratio between the ordinary and the extraordinary optical depth is given by:

$$\tau_o/\tau_x = |(1-|\cos\theta|)/(1 + |\cos\theta|)|^2$$

with

$$\tau_x = 2.6 \times 10^2\ T_8^7\ (\sin\theta)^6\ B_2^{10}\ ,$$

at our observing frequency. $T_8 = T/10^8$K, $B_2 = B/10^2$G, and θ is the angle between $\underline{B}$ and the line of sight. These equations show that a very high polarization percentage ($\tau_o << 1 << \tau_x$) can be obtained only for small values of θ. For this reason we assumed that the strongly polarized source of the first bursts was located above the region of positive field in Fig. 1.

Assuming $T = T_b$ ($\tau_x > 5$), the degree of circular polarization becomes $P = (1 - \tau_0)/(1 + \tau_0)$, and hence $\tau_0 + (1 - P)/2$. These two relationships yield the following approximate conditions for θ and B, for any given P, close to unity:

$$\theta^o < 65.6\ (1 - P)^{0.25}$$

$$B(G) > 2.4 \times 10^7\ T_b^{-0.7}\ (1 - P)^{-0.15}\ .$$

Applying the above formulae to the source (1) of the first burst, which reaches, at t = 180 s, a polarization P = 0.98, with a brightness temperature $T_b = 5.5 \times 10^7$K, we get $\theta \lesssim 24°$ and $B \gtrsim 165$ G. For the second burst we have at the maximum P = 0.85 and $T_b = 1.33 \times 10^7$, which give $\theta \lesssim 41°$, $B \gtrsim 330$ G.

REFERENCES

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Chiuderi-Drago, F., Felli, M., and Tofani, G.: 1977, Astron. Astrophys. 61, pp. 79-91.
Dulk, G. A., Melrose, D. B., and White, S. M.: 1979, Astrophys. J. in press.

DISCUSSION

Kaufmann: Can you compare the burst polarization degree to the pre-existing active region polarization degree?

Drago: Before the burst the active region was almost unpolarized, P ∿ 2%.

Alissandrakis: 1) Do you have sufficient positional accuracy to be sure that one of the burst components is not flare-associated while the other is? 2) What physical mechanism heats the plasma to 10^8 K in your thermal interpretation model? Can you give an estimate of the energy needed?

Drago: 1. For the first flare we have Hα pictures taken at the Arcetri Observatory and nothing appears in the position of one burst.(1). 2. The one I mentioned is one possible easy explanation of such a high polarization but probably is not the only one possible. 3) I cannot give it right now, but it would be easy to calculate it since it's possible to give an estimate of the dimension, temperature and density of the source.

Pick: The projected radio position at 21 cm is probably affected by an altitude effect? What is the uncertainty?

Drago: I did not make any computations, but I don't think it is larger than ∿ 10" since we are close to the disk center.

Kai: Does the source expansion occur continuously or suddenly? Does the degree of circular polarization decrease parallel to the source expansion?

Drago: 1) The source contraction and expansion occurs continuously. 2) For the second burst yes: the maximum of polarization coincides with the intensity maximum. For the first burst the maximum polarization takes place 1^m after the maximum, and then decreases.

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