THE POLARIZATION OF TYPE V BURSTS

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ABSTRACT

From observations with the Culgoora spectropolarimeter operating in the frequency range 24-200 MHz, we find that Type V bursts are often polarized in the opposite sense from the preceding Type III bursts. We present here the results of a statistical study of how frequently this occurs and the relationship of such polarization reversals to the position of the source on the disk of the Sun. We then examine two possible reasons for the reversal of polarization. In a paper published elsewhere (Dulk et al., 1979) we give a more detailed description and include observations of source sizes, positions and brightness temperatures of Type III-V bursts.

The polarization characteristics of 73 Type III-V bursts observed at Culgoora between 1977 June 3 and 1978 August 23 have been examined. Four examples are shown in Figure 1 as they appear on the spectrograph (black-and-white) and spectropolarimeter (colour). The first two examples show distinct polarization reversals from Type III to Type V while the last two have almost completely unpolarized Type V bursts. Dulk et al. (1979) discuss these examples in detail, including radioheliograph measurements of source positions, position shifts and sizes.

The polarization characteristics for all 73 bursts are given in Table 1. Type V bursts which follow Type IIIs showing fundamental-harmonic (F-H) structure are listed in the first column, Type V bursts which follow Type IIIs without F-H structure ("structureless") in the second column, and long IIIs, i.e. those for which the Type V part lasted $\lesssim 30$ s, in the third column. It is striking that >60% of the Type V bursts following F-H IIIs had a sense of polarization opposite to that of the Type III while only two of the 41 bursts (<5%) had entirely the same sense of polarization as the Type III.

The degree of polarization of all Type V bursts was low ($\lesssim 0.15$), similar in magnitude to that of the harmonic components of Type III

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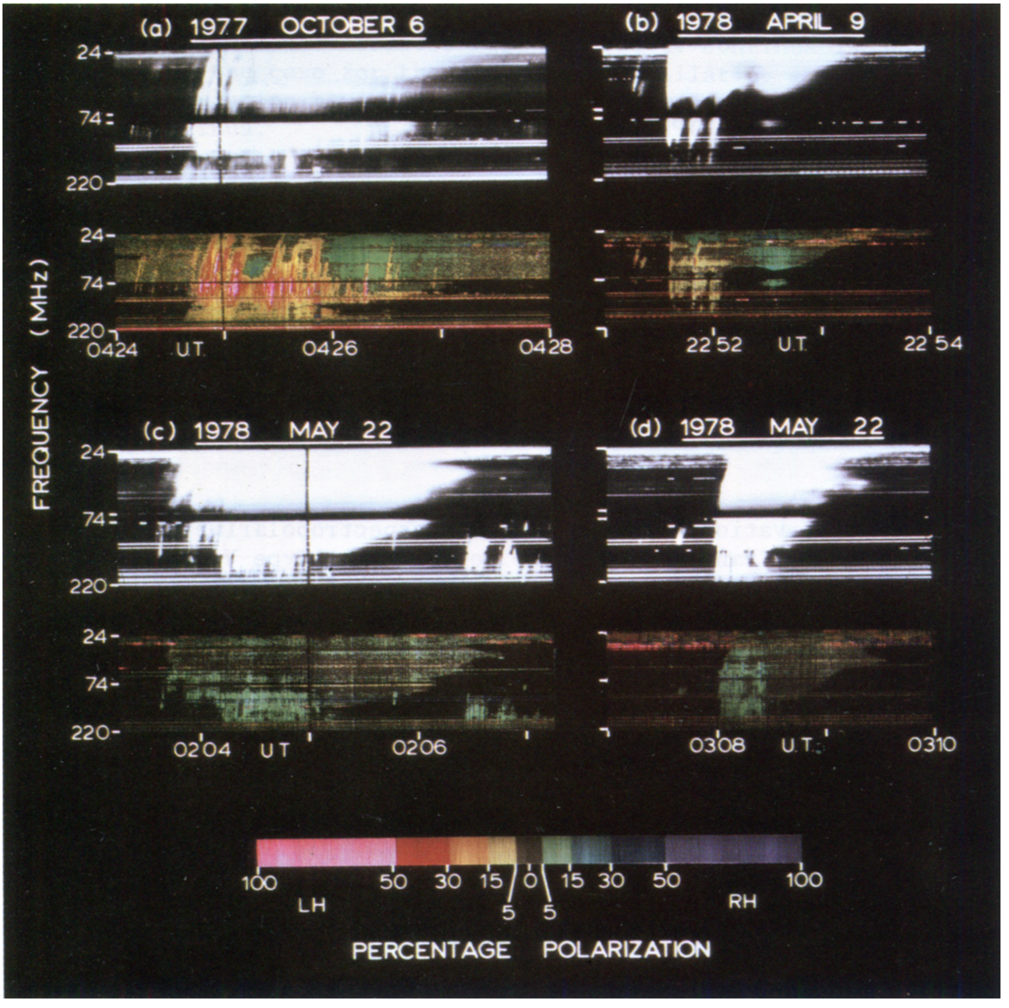

Fig. 1 - Spectrograph and spectropolarimeter recordings of four examples of Type III-V bursts. The polarimeter uses colour to display degree and sense of circular polarization according to the scale in the figure.

bursts. The degree of polarization of the fundamental component of Type III bursts is usually much higher (~0.35) (Suzuki and Sheridan, 1977; Dulk and Suzuki, 1979); this suggests that Type V radiation is plasma radiation at the <u>second harmonic</u> rather than at the fundamental frequency.

Figure 2 is a plot of the positions of 26 Type III-V burst sources from radioheliograph observations at 43 MHz. The position of each

TABLE 1
Sense of polarization of Type V bursts relative to that of the preceding Type IIIs.

	Vs with F-H IIIs	Vs with structureless IIIs	Long IIIs
Opposite	25	2	0
Mixed	7	1	1
Zero	7	12	2
Same	2	5	9

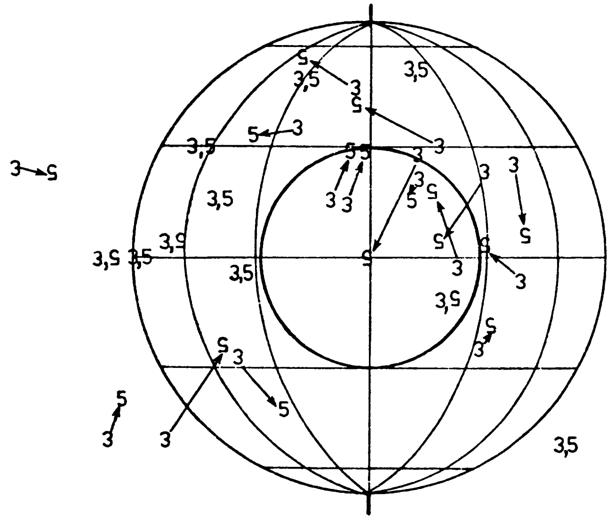

Fig. 2 - Scatter plot of the 43 MHz source positions of Type V bursts and the preceding Type IIIs for bursts with distinct F and H components. The Type III source centroid positions are denoted "3". The Type V centroids are denoted "5" or "Ƽ" (see text). The inner circle represents the size of the solar disk; the outer circle represents a sphere of radius R = 2.1 $R_{\odot}$, the effective height of burst sources at 43 MHz. To aid in judging the angle of the sources from the centre of the disk, lines representing latitudes and longitudes of 30° and 60° have been drawn.

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Type III burst source (denoted by a "3") is joined to the position of the subsequent Type V burst source (denoted by an upright or inverted "5") so that individual Type III-V bursts may be identified. The orientation of the "5" denotes polarization behaviour: the inverted "5" identifies bursts in which the Type V polarization is of opposite sense to that of the Type III and an upright "5" identifies the remainder (same, mixed, or zero polarization). The figure demonstrates that (a) Type V burst sources are often displaced from the Type III source position, sometimes by as much as 1 $R_\odot$, and (b) the magnitude of this displacement is correlated with polarization behaviour, i.e. the bursts showing polarization reversal from III to V tend to have larger position shifts than the others.

Two possible explanations for this polarization reversal are: (1) the magnetic field direction in the Type V source may be opposite to that in the Type III source, or (2) the emission may switch from o-mode in the Type III burst to x-mode in the Type V. (Other possible reasons are discussed and found to be unlikely by Dulk et al. (1979).)

The field direction can reverse if the electrons exciting the Type V radiation are injected on to field lines which are in the same direction as the field lines in the Type III source, but, because of field line curvature, the viewing angle changes from acute to obtuse. The consequences of this are as follows. (i) The Type V source should appear displaced from the Type III source position. As Figure 2 shows, this is observed in many cases. (ii) The polarization reversal should be more prevalent for sources near the limb. However, Figure 2 shows no variation of polarization reversal from centre to limb; several bursts located less than 50° from disk centre have reversals. (iii) Because the coronal field lines diverge most strongly at low heights, one would expect the polarization reversal to be limited to high frequencies, at least in some cases. However, observations show that the polarization of the Type V radiation continues unchanged to the low-frequency limit of the polarimeter, 24 MHz. We conclude that this hypothesis can explain the polarization reversals in some cases; however, since polarization reversals are the norm - not the exception - we consider the hypothesis to be unlikely.

To examine hypothesis (2) - change in mode of emission from o-mode in the Type III to x-mode in the Type V - we utilize the theory of the polarization of harmonic plasma emission developed by Melrose and Sy (1972) and Melrose et al. (1978). In the theory the degree of circular polarization r_c is given by

$$r_c = a(\theta,\theta_0)\ f_B/f_p \quad ,$$

where f_B is the gyromagnetic frequency in the source and f_p is the plasma frequency. The function $a(\theta,\theta_0)$ is a slowly-varying function of the viewing angle θ and the half-angle θ_0 describing the distribution of Langmuir wave vectors in the source region. When θ_0 is small ($\lesssim 30°$) the anisotropic well-collimated Langmuir waves produce o-mode radiation, but if it is large ($\gtrsim 60°$) the more nearly isotropic Langmuir waves produce x-mode radiation.

Dulk et al. (1979) gave evidence, partly based on the theory of Melrose et al. (1978), that Type III bursts are generated by electrons filling a wide cone (with apex angle $\gtrsim 60°$) whose apex is in the acceleration region. In the present case, for Type V bursts, we apply the same theory to sources of apex angle from 10° to 90° and find that the observations imply large sources ($\gtrsim 60°$ cone angle), with the angular distribution of Langmuir wave vectors changing from $\theta_0 \approx 20°$ in the Type III to $\theta_0 \approx 60°$ to 70° in the Type V.

This second hypothesis seems to account for the polarization reversal satisfactorily. There is no need for a special placement of the observer, as hypothesis (1) would require. The problem of why the Langmuir wave distribution should evolve from $\theta_0 \approx 20°$ in the Type III to $\theta_0 \approx 70°$ in the Type V is an interesting one which requires further investigation.

We are grateful to the late Dr. S.F. Smerd for stimulating discussions on this topic and many others. We will miss his deep insight into problems of solar radiophysics.

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References

Dulk, G.A. and Suzuki, S.: 1979, "The position and polarization of Type III solar bursts". Submitted to *Astron. Astrophys.*

Dulk, G.A., Melrose, D.B. and Suzuki, S.: 1979, "Evidence for extreme divergence of open field lines from solar active regions". *Proc. Astron. Soc. Aust.* (in press).

Dulk, G.A., Suzuki, S. and Gary, D.E.: 1979, "The position and polarization of Type V solar bursts". Submitted to *Astron. Astrophys.*

Melrose, D.B. and Sy, W.N.: 1972, *Aust. J. Phys.* 25, p.387.

Melrose, D.B., Dulk, G.A. and Smerd, S.F.: 1978, *Astron. Astrophys.* 66, p.315.

Suzuki, S. and Sheridan, K.V.: 1977, *Izv. Vyssh. Uchebn. Zaved. Radiofiz.*, 20, p.1432 (English trans. 1978, *Radiophys. Quantum Electron.*, 20, p.989).

DISCUSSION

<u>Lin</u>: It seems to me from your diagram that most of the reverse polarization V's occurred in the western hemisphere.

Gary: Even though the study covered more than one year of observations, particular active regions produced several type V's so a few active regions will dominate the data. I wouldn't place too much importance on this. (Referring to the larger number of type V's on the west limb.)

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