Fast temporal variations of the circular polarization degree during a microwave solar burst

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Abstract

We present new temporal relationships between polarization degree and burst intensity profiles for one example of a complex event observed with high sensitivity and time resolution. The polarization degree shows basically two distinct components: a quasi-steady one, defined as soon as the burst intensity becomes measurable, and another one with fast variations and small amplitude, superimposed on the former one. The fast time variations of the polarization degree might be related to corresponding fluctuations in intensity, at time scales which can be shorter than one second. The event also shows a rapid reversal of the sense of polarization. The example illustrates the importance of degree of polarization measurements with high sensitivity and time resolution; some possible causes that can produce the observed effects are discussed.

Key words: Patrol radio telescope - Sun: microwave bursts - Sun: polarization

1. Introduction

The emission of solar microwave bursts is predominantly circularly polarized (Covington 1951; Akabane 1958; Kundu 1959; Tanaka & Kakinuma 1959; Magun & Matzler 1973), and the I and V Stokes parameters are enough to determine the complete polarization state of the radiation field. The microwave intensity together with circular polarization data, is the only way to infer the magnetic field characteristics in the solar atmosphere above photosphere, where there are no other available sources of information. The temporal variations of the degree of circular polarization can reflect changes in physical conditions in the emission source, and in the propagation medium.

The analysis of simple impulsive bursts observed by patrol telescopes with poor sensitivity and temporal resolution have shown that the degree of polarization is at a minimum during the burst maximum Gelfreikh 1962; Kaufmann et al. 1970). Impulsive events observed with 100 ms time resolution, but poor sensitivity, showed no measurable variations in the degree of polarization associated with fast temporal structures in the intensity (Kaufmann 1978). Bruggmann & Magun (1990) analysed the temporal behaviour of the degree of polarization and suggested that a typical polarization temporal profile does not exist, even for simple bursts. Events observed at 22 GHz, with high sensitivity and time resolution, suggested that the polarization degree can be separated into two components (Kaufmann et al. 1985, 1993): a quasi-steady component defined in the beginning of the burst, and a superimposed component displaying faster temporal variations of small amplitude and a complex correlation with associated intensity structures.

We present here observations of the temporal behavior of the degree of polarization for an impulsive event observed at 7 GHz at the Itapetinga Radio Observatory, Atibaia, Brazil. The observations were performed with a recently renewed patrol telescope, achieving a sensitivity better than 0.5 sfu (1 sfu = 10^{-22} W m^{-2} Hz^{-1}) and a time resolution of 10 ms. It operates with two independent receivers for each circular polarization mode.

2. Observational Results

The figures show the temporal behaviour of I ($S_R + S_L$) and V ($S_R - S_L$) Stokes parameters, and the degree of polarization P (V/I), for an impulsive event which occurred on 1998 November 5. The error bars in the plot of the degree of polarization correspond to $\pm 1\sigma$, which was obtained from the ratio V/I, considering the rms of the S_R and S_L channels. The vertical lines mark the major structures with a time scale of about 10 s in Fig. 1, and the faster structures with durations $\geq 1s$ in Fig. 2 as identified in the intensity temporal profile. The arrows show

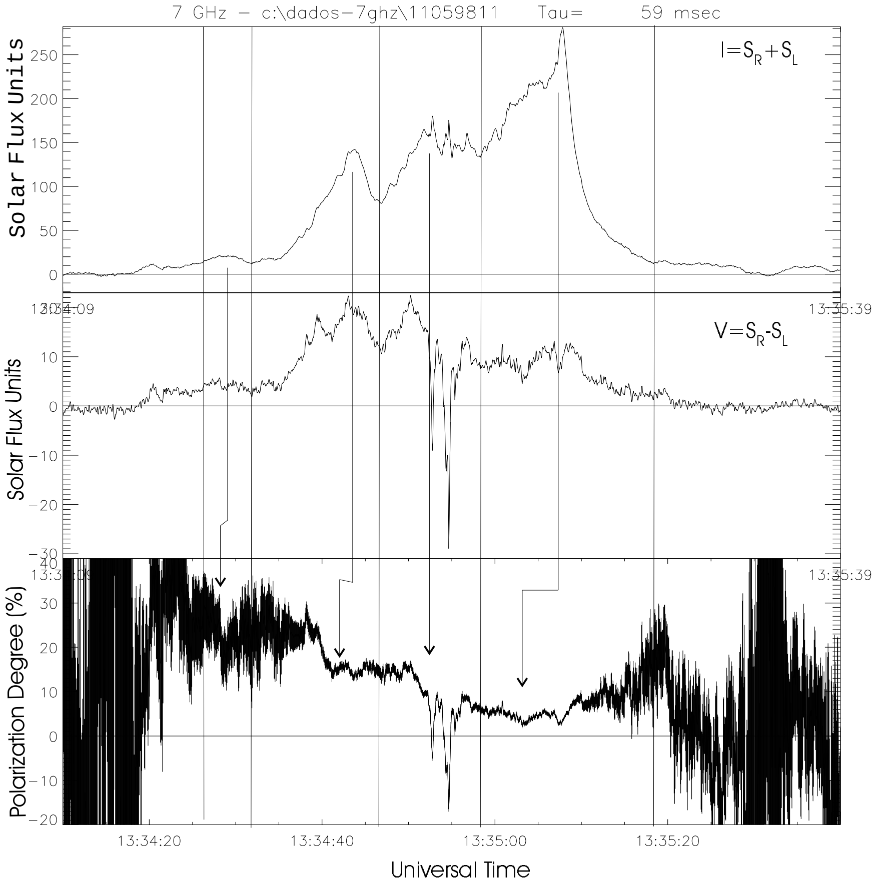

Fig. 1.. Temporal behaviour of the I (S_R+S_L) and V (S_R−S_L) Stokes parameters, and the degree of polarization P (V/I) for the event of 1998 November 5. The major structures of the intensity profile are marked by vertical lines. The arrows show the time differences between intensity maxima and minima in the degree of polarization.

the time correspondence between intensity fast structures and the associated polarization degree variations for the major structures (Fig. 1) and for the subsecond pulses (Fig. 2).

Fig. 1 shows that the polarization degree can be separated in two components: a quasi-steady one with an initial level of about 30% R polarized, defined as soon as the burst intensity becomes measurable, and presenting a minimum of polarization degree in the rising phase of the burst; and another component, superimposed on the former, presenting variations of small amplitude associated with intensity fast structures.

A relatively small decrease of polarization degree occurs in the rising phase of the intensity structures with time scales above 1 s (Figs. 1 and 2).

A pronounced peculiar sense reversal of the polarization degree can be seen in Fig. 1 at about 13:34:53 UT. This effect is known to be very rare (Marques dos Santos et al. 1970), and has been attributed to possible superposition of bursts with opposite polarization. This effect will be studied separately.

Another remarkable aspect of this burst is that the intensity structures with time scales of about 1 s have pulses of subsecond duration superposed on them (showed by arrows in Fig. 2). The subsecond intensity pulses present a complex association with the polarization degree variations. The majority of them shows a positive correlation, but some are negatively correlated while others present no clear association.

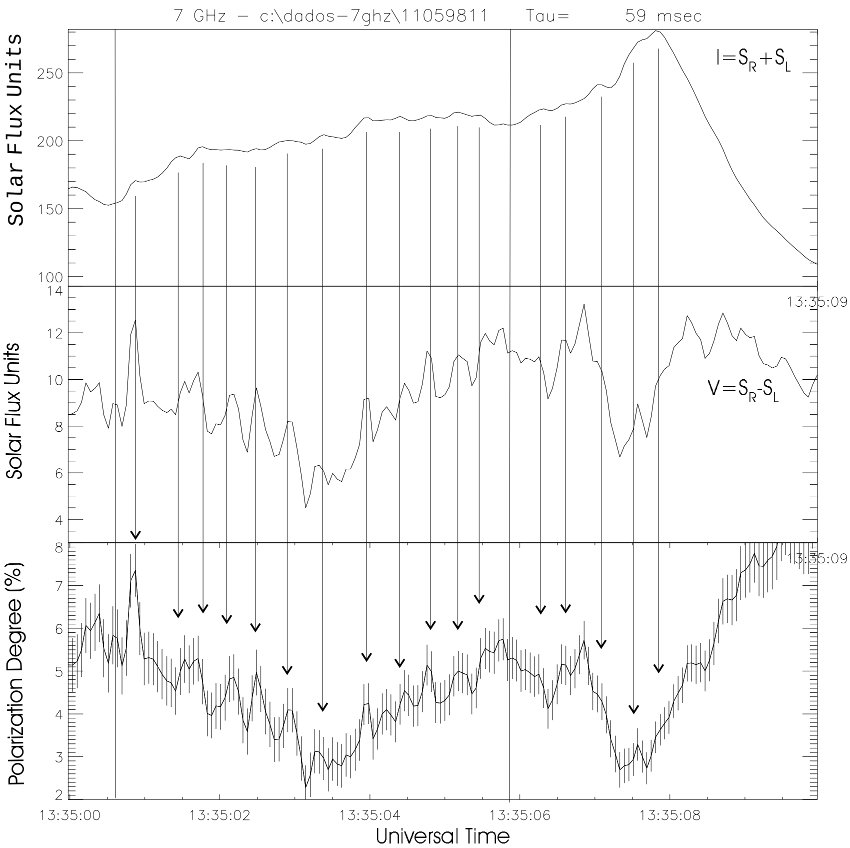

Fig. 2.. Same as Figure 1 showing an expanded view of the last major structure of the burst. The vertical lines mark the $\geq 1s$ structures in intensity. The arrows show the time correspondence of intensity and the degree of polarization for the subsecond pulses.

3. Concluding remarks

The preliminary analysis of a complex burst circular polarization observed with high sensitivity and time resolution at 7 GHz indicates the potential to obtain new informations which may become important for the study of the magnetic field in the bursting region.

The time variations of the polarization degree are representative of changes of the magnetic field and/or the density of the electrons, in the emission source and/or in the propagation medium (Dulk 1985). The interpretation may become rather complex because the results are very sensitive to the time varying parameters assumed for the emission source and for the geometry of the region where the phenomena occur. Previous interpretations were based on data obtained with considerably less sensitivity and time resolution (Bruggmann & Magun 1990). The present results show the importance of detailed diagnostics of the degree of polarization changes with time obtained with higher sensitivity and time resolution. Its interpretation requires a review of the existing models or new aproaches for understanding the whole dynamics of the polarizing processes in solar bursts at microwaves. A complete analysis of this event is in progress.

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