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ENERGY TRANSPORT DURING A SOLAR FLARE: VLA OBSERVATIONS OF THE M1.9 FLARE OF 20 AUG 1992

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Abstract

The GOES M1.9 flare of 20 August 1992 was observed by a large complement of instruments including the VLA, Yohkoh, and a high-speed H-alpha camera. We present a brief overview of the VLA data here. The VLA acquired maps of the evolving microwave emission at 8.4 and 15 GHz with a time resolution of 0.2 s. The main observational results are as follows: i) the microwave sources consist of two, parallel, sheared loops or loop systems; these two loop systems flared sequentially; ii) the second microwave source is clearly associated with two magnetic footpoints; iii) the microwave source shows a disturbance which propagates from the initial footpoint and over the magnetic neutral line; iv) the speed of the disturbance is roughly 3000 km s^{-1}. Points along the loop show a brightening that is delayed relative to that at the primary footpoint, and the two footpoints spread apart over the course of a few minutes.

1. Introduction

During the previous solar maximum the VLA obtained high resolution observations of flare-associated microwave sources. Maps typically possessed a dynamic range of 10:1 and were obtained with a temporal resolution of 10 s. Early VLA maps apparently showed that microwave sources are compact, although the source size typically increases with wavelength from about 3" at 2 cm to 30" at 20 cm (e.g., Marsh & Hurford 1982; Hoyng *et al.* 1983; Kundu & Lang 1985; Dulk, Bastian, & Kane 1986). Furthermore, early work indicated that microwave sources were often associated with magnetic neutral lines (March & Hurford 1982). Since then, advances in hardware and software allow the VLA to map evolving microwave sources with a dynamic range exceeding 100:1 and a temporal resolution of 0.2 s. These developments have

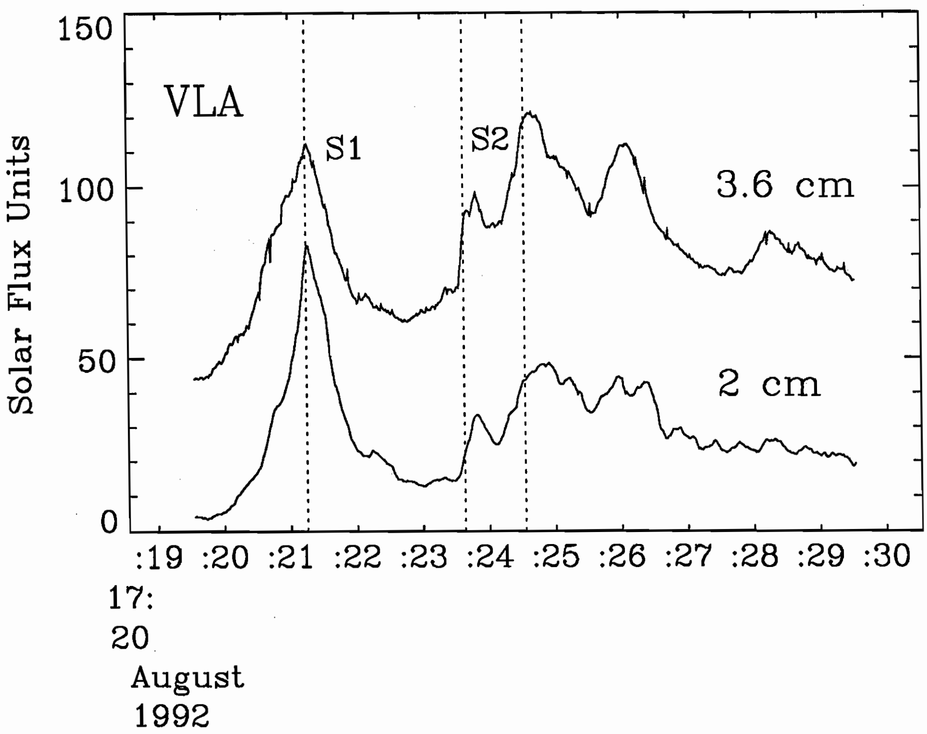

Fig. 1. The time variation of the integrated flux at 2 and 3.6 cm. The vertical dashed lines indicate the times of snapshot maps shown in Fig. 2.

revealed the structure and dynamics of microwave sources with far greater fidelity than ever before possible.

Recent observations show that microwave bursts are more complex than previously assumed. They are not necessarily compact (e.g., Bastian and Kiplinger 1990), nor are they initiated near neutral lines. Furthermore, microwave sources are highly dynamic, as we show here. Since microwave emission provides a tracer of fast electrons (~100 keV), a detailed study of source dynamics provides a new means of constraining the site(s) of electron acceleration and the subsequent transport of fast electrons throughout the flaring volume.

In this paper, we present a brief overview of an extremely well-observed flare that is highly dynamic in microwaves. In addition to microwave imaging observations obtained with good temporal resolution, the flare was observed by the complement of instruments on board *Yohkoh*, and by several groundbased optical observatories. A detailed comparison between the various data sets is defered to another publication. Here, we give a brief overview of the microwave imaging data.

2. Observations

The VLA was used in the D configuration on 20 August 1992 to observe NOAA/USAF active region 7260 between 1430–1830 UT. The 27 antennas of the array were divided into two

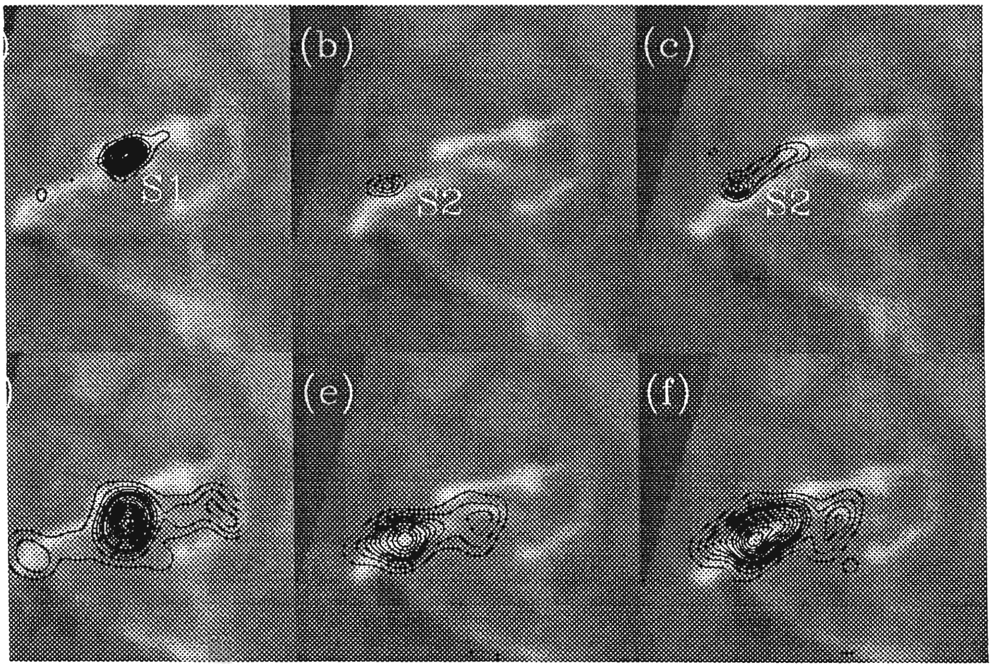

Fig. 2. A comparison of the 2 and 3.6 cm microwave sources with the Hα flare. Figs. 2a-c show brightness temperature contours of the 2 cm source overlaid on Hα at 1721:15, 1723:38, and 1724:33 UT. Figs. 2d-f show the same for the 3.6 cm source. The contour levels are 2, 4, 6, 8, 10, 12, 16, 20, 24 ,28, 32, 36, 40, 44, 48, and 52 in units of 10^6 K for all panels.

independent subarrays in order to observe the source simultaneously at 2 and 3.6 cm (15 and 8.4 GHz) with an angular resolution of $\approx 5''$ and $9''$, respectively. Furthermore, enhancements to the online system and gating of the correlator allowed us to image the evolving source with a time resolution of 0.2 s. Both senses of circular polarization were observed. A GOES class M1.9 flare was observed at approximately 1720 UT in AR 7260 (Fig. 1).

3. Results

Fig. 2 shows the contour maps of the 2 cm and 3.6 cm sources compared with Hα filtergrams obtained with the high-speed Hα camera (Kiplinger *et al.* 1988). The times of the snapshot maps correspond to those indicated by dashed lines in Fig. 1. It is clear that the source corresponding to the first impulsive spike of emission (designated S1) is different from the source corresponding to to the series of impulsive spikes which follow (designated S2). As is apparent from Fig. 2c and f, sources S1 and S2 appear to be two, parallel, sheared, magnetic loops or loop systems. This interpretation is corroborated by the VLA polarization maps, which show a clear polarization gradient along the length of each source and, in the case of S2, a polarization reversal.

Source S2 is of particular interest for other reasons. Between 1723:34–1723:44 the 2 cm microwave images show a clear signal which propagates across the magnetic neutral line of S2 with an apparent speed of ≈ 3000 km s^{-1}. Fig. 3 shows a two-dimensional representation of the brightness of S2 as a function of time (abscissa) and position along the loop (ordinate). Several features are apparent: i) variations are strong and impulsive at the SE footpoint ($\approx 7''$); ii) they are increasingly delayed with position along the loop; e.g., the maximum of a peak

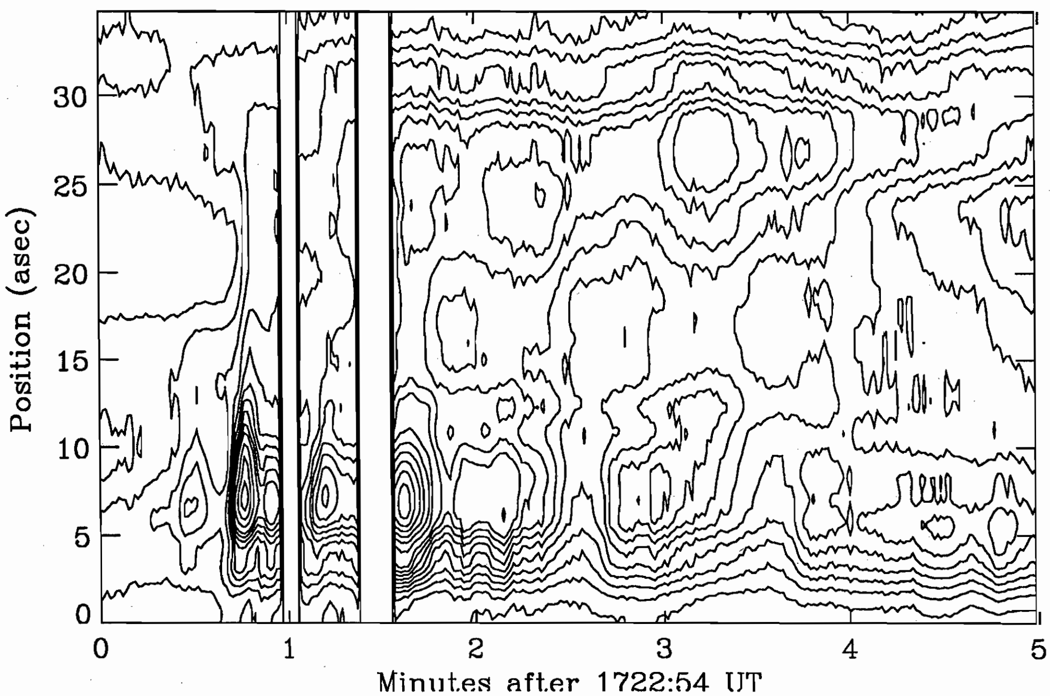

Fig. 3. Variation of the 2 cm brightness as a function of time and position along the loop shown in Fig. 2c. The southeast footpoint of the loop is near the bottom of the figure at 7″ and the northwest footpoint is at the top near 25″. The contour levels are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24 and 26 times 10^6 K.

near 7″ is delayed relative to that at 25″; iii) the microwave-emitting footpoints spread $\approx 7''$ over ≈ 4 min of time.

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