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MULTIWAVELENGTH OBSERVATIONS OF A PREFLARE SOLAR ACTIVE REGION USING THE VLA

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ABSTRACT

A preflare active region was studied using the Very Large Array at 2, 6, and 20 cm. At 2 cm the region is composed of two components located in regions of opposite polarity. Both components are preheated prior to the impulsive onset of a flare. However, one component develops new structures during preburst phase, and the burst occurs in this location. We believe that the new structures represent emerging flux regions which interact with an overlying loop to produce a neutral sheet, which ultimately is reponsible for triggering the flare.

Subject headings: interferometry — Sun: flares — Sun: radio radiation

I. INTRODUCTION

The buildup of energy in an active region prior to a flare manifests itself in several ways. The most common manifestation is the increase in brightness temperature and increased polarization of the region that flares up (Kundu 1959; Kundu *et al.* 1982). This increase takes place over a period of a few tens of minutes prior to the onset of a flare. However, a decrease in polarization of the preflare region a few minutes before the impulsive onset of a flare has also been reported (Hurford and Zirin 1982; Lang 1974). Kundu (1983) also reported that the sudden onset of impulsive energy release in a flare can occur by a magnetic reconnection process when an emerging loop interacts with a preexisting overlying loop, or when a current sheet forms at the interface between two oppositely polarized closed loops or a quadrupole structure. The time scale for this reconnection process is of the order of a minute to a few minutes. Centimeter wavelength observations with spatial resolution of $\sim 1'$ have until recently led us to believe that the increased brightness temperature of the preflare region is due to increased heating. With the availability of high spatial resolution of $\lesssim 1''$ with the VLA, it is now possible to determine the exact location of the flare relative to the region which is heated. Indeed, with the *Skylab* Apollo Telescope Mount (ATM) X-ray imaging data obtained with a resolution of $\sim 5''$, Kahler and Buratti (1976) found that even in soft X-rays the preflare regions underwent heating; however, it was not always the preheated region that flared up. This has been interpreted by Kundu (1980) as some kind of loop structure linking the two regions, the nonflaring heated region being magnetically connected with the flaring region. Using the VLA, we have studied the preflare activity in a simple active region at 2 cm wavelength. We find that the active region consists of two components both of which are preheated; however, only one component flares up. In this paper we present these observations and discuss their implications.

II. OBSERVATIONS

Observations were made on 1983 May 1 of active region AR 4154, using the VLA in the C configuration. The main objective of the observations was to determine the three-dimensional structure of active regions from observations at three different wavelengths, 2, 6, and 20 cm, in a time-sharing mode. All 27 antennas were used in order to achieve the best possible sensitivity.

On 1983 May 1, when our observations were made, there were a few reported small flares, but most of them could not be observed properly because they occurred either during periods when the antennas were pointed at a calibrator source or during the time of a frequency change. A flare of importance M 2.9 was, however, observed almost completely. This flare occurred in the region AR 4154 between 22:54:00 and 23:01:00 UT. The preflare phase and the impulsive phase of the flare were observed at 2 cm, and the declining phase was observed at 20 cm. Around the peak of the burst, approximately 1 minute of data was lost, because the receiver system takes approximately 1 minute to stabilize after a frequency change.

Synthesized maps were produced at all three wavelengths from 21:00:00 UT to 24:00:00 UT. Because of time sharing, the data at each wavelength were recorded in four time blocks of ~ 8 minutes each during this period. For each time block, a total intensity (I) map was produced excluding the blocks in which the impulsive and declining phases of the flare occurred. In the preimpulsive onset phase, several maps were produced at 2 cm at the rate of one every minute. During the impulsive phase and at the peak of the burst, maps were produced every 30 s. In the declining phase which was observed at 20 cm, 1 minute synthesized maps were produced. All maps were cleaned and restored with a beam of $2'' \times 2''$, $7'' \times 7''$ and $20'' \times 20''$ at 2, 6, and 20 cm wavelengths, respectively. In the preflare phase and during the flare, circular polarization (V) maps could not be produced because the quality of data was not good, and in addition the degree of polarization was small.

III. RESULTS

Figure 1 shows the time profile of the burst in arbitrary units. It is intended to indicate the times during which data were available and maps could be produced at the three wavelengths (2, 6, and 20 cm). Thus, preflare maps could be produced at all three wavelengths around 21:00 and 22:15 UT. The impulsive rise phase of the flare, and its maximum, were

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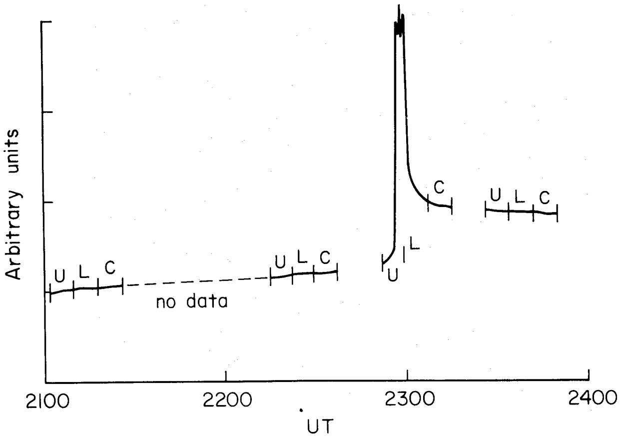

FIG. 1.—Flux vs. time profile of the burst in arbitrary units. Blocks denoted by *L*, *C*, and *U* represent the time intervals during which 20, 6, and 2 cm observations, respectively, were taken.

observed at 2 cm. The postmaximum flare emission observed at 20 cm, and at a still later phase data were obtained at 6 cm. Such spotty observations were, of course, a consequence of the sequential observing procedure that we had adopted.

Figure 2*a* shows the 12 hour synthesized map of the active region, Figure 2*b* shows an 8 minute map (21:02–21:10 UT), and Figure 2*c* shows a 7 minute map (22:15–22:22 UT) at 2 cm. One should note that relative to the whole-day map, the active region is hotter at 21:10 and 22:15 UT, that is, 1 hour 45 minutes and 40 minutes prior to the flare onset at 22:55 UT. Figures 3*a* and 3*b* show two 1 minute maps just before the flare onset, and Figure 3*c* shows a 1 minute map just at the beginning of the impulsive rise phase. The important points to note here are (1) that the two components were located in magnetic regions of opposite polarity (KPNO magnetogram; see Shevgaonkar and Kundu 1984) and (2) that the southern component, which was as compact as the northern component developed considerable structure or additional components during the preflare phase. Indeed, this source has now three components; it is possible that the two new components represent emerging flux. At the onset all three components intensified, and finally the flare took place at the edge of the easternmost component, which is the same as the original compact southern component. We believe that the interaction of the emerging flux region or regions with the preexisting region results in the flare. The *V*-map during the 3 minutes prior to the onset show that the easternmost component was polarized, the polarization being only about 15%. However, the other two components, presumably the emerging flux regions, did not show any significant polarization. The polarization during the rise phase of the burst and at its maximum was only of the order of 10%. Figure 4 shows the temporal evolution of the burst source at 2 cm in the form of 30 sec maps, including its maximum at 22:57 UT.

We have produced 6 and 20 cm maps during preflare and postflare phases. The maps do not exhibit significant structural changes except for an increase in the brightness temperature at both wavelengths before the flare onset.

IV. DISCUSSION

We have used the VLA in the C configuration with all 27 antennas to observe a solar active region and a flare that occurred in that region. We have made our observations at 2, 6, and 20 cm wavelengths in a sequence of approximately 8 minutes at each wavelength. Because of the sequential nature of observing, we do not have the complete time history of the flare at any one wavelength. For the same reason, preflare buildup of the region immediately (a few minutes) prior to the flare onset could be observed only at one wavelength (2 cm).

The observations of preflare phase show that prior to the flare onset, both components of the active region showed preheating; however, the component (southern) in which the flare occurred also underwent structural changes. The southern

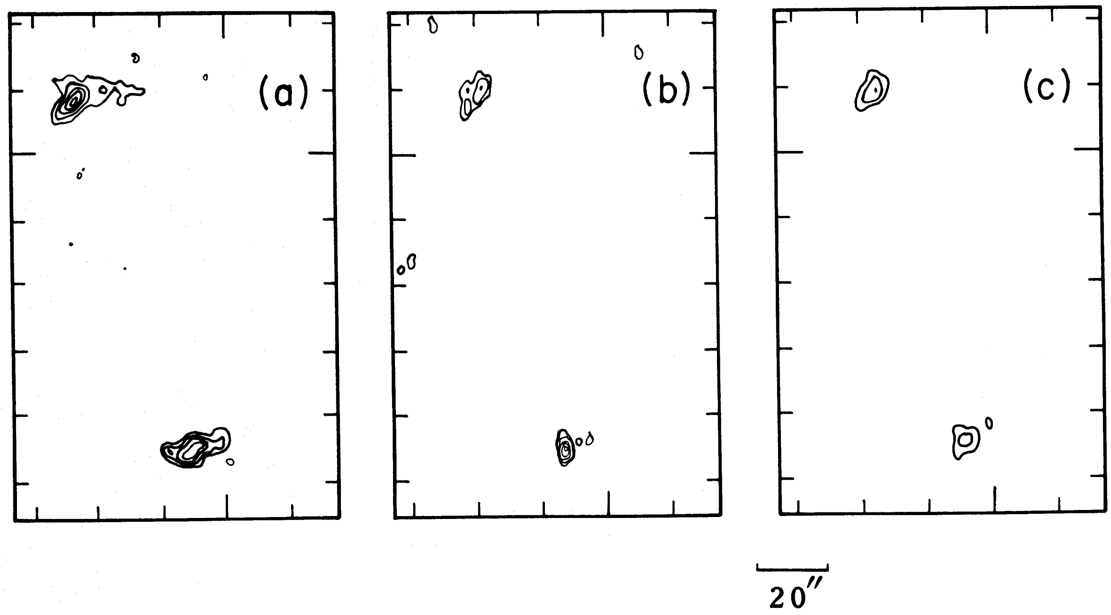

FIG. 2.—(*a*) Twelve hour synthesized total intensity (*I*) map of the active region at 2 cm; contour interval is 2.9×10^4 K. (*b*) *I*-map during 21:02–21:10 UT; contour interval is 1.9×10^5 K. (*c*) *I*-map during 22:15–22:22 UT; contour interval is 1.9×10^5 K.

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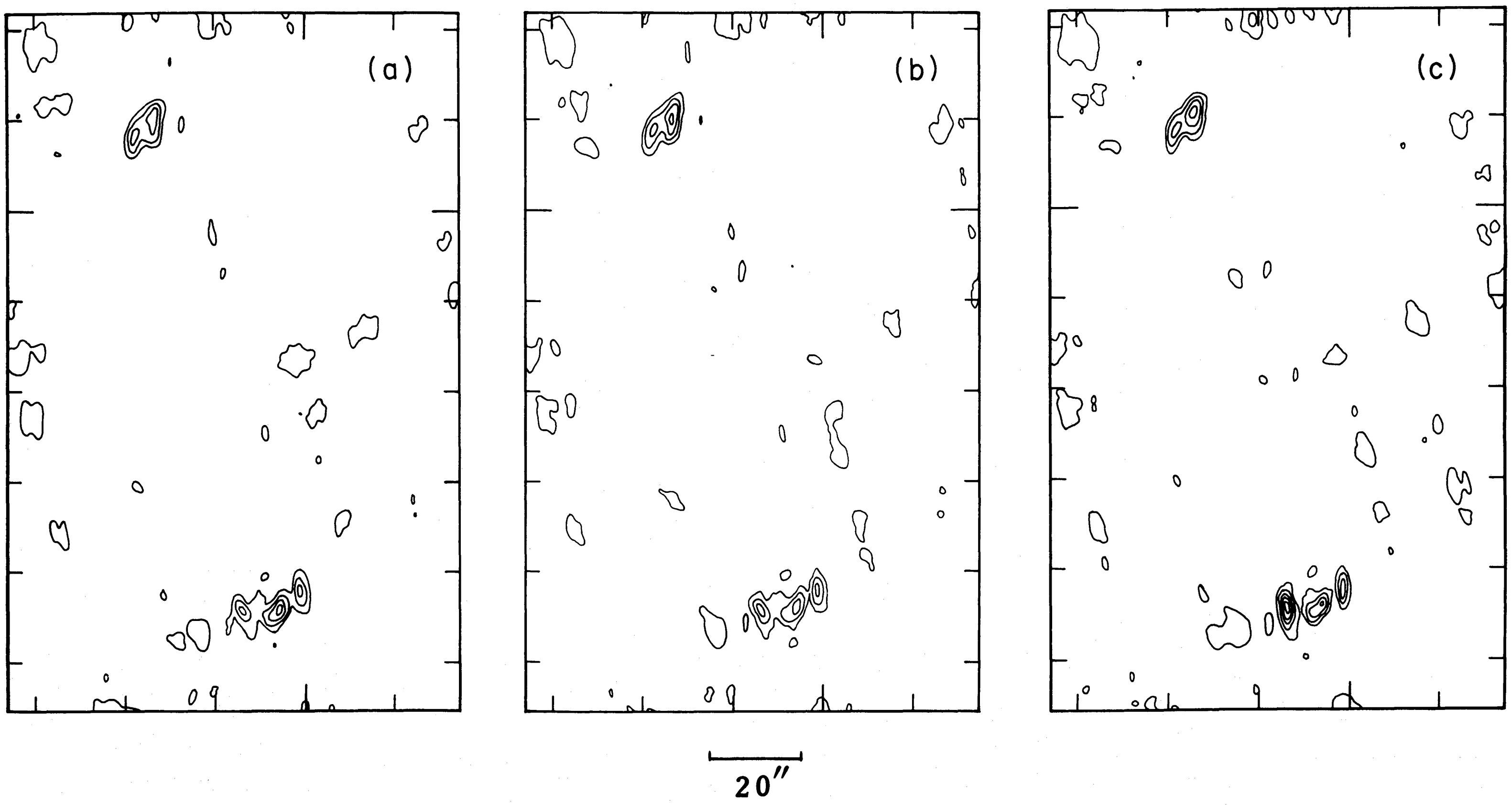

FIG. 3.—(*a*, *b*) One minute maps at 2 cm just before the onset of the flare; (*c*) 1 minute map at 2 cm at the beginning of the impulsive phase. Contour interval is 1.9×10^5 K.

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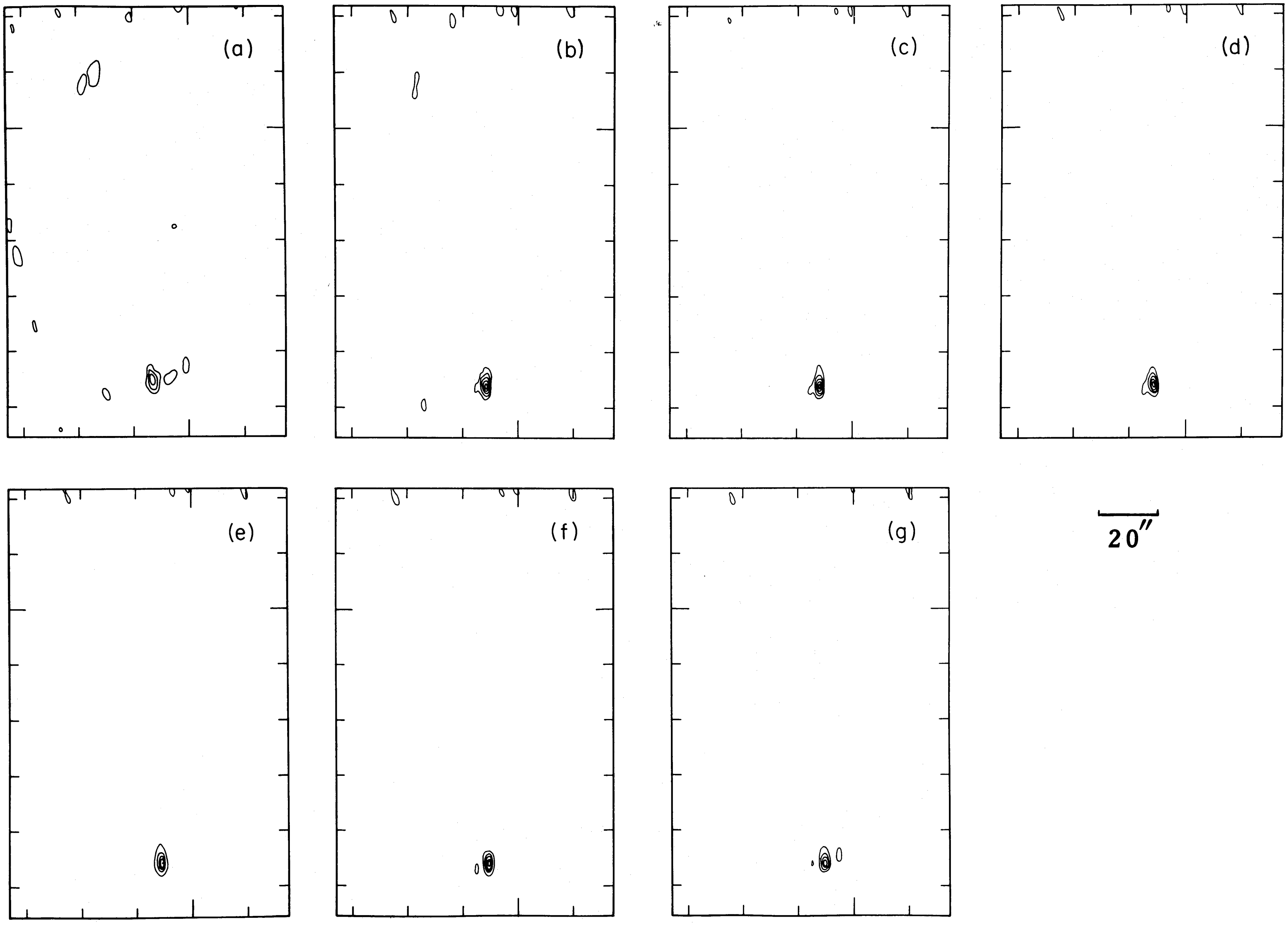

FIG. 4.—Thirty second snapshot maps at 2 cm during the impulsive rise phase and at the peak of the burst. Contour intervals (CI) are (*a*) 3.88×10^5 K, (*b*) 7.76×10^5 K, and (*c*–*g*) 1.55×10^6 K.

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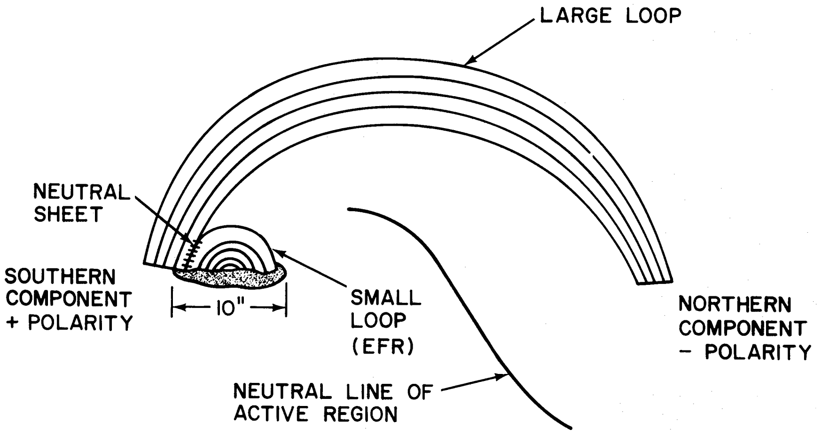

FIG. 5.—A schematic model for an emerging flux region (EFR) forming a neutral sheet with an overlying magnetic loop and triggering the onset of a flare. A similar schematic model was produced by Kahler, Petrasso, and Kane (1976).

component at 2 cm was heated up to $T_b \sim 1.25 \times 10^6$ K between 21:02 and 21:10 UT without any structural changes. This component remained as a single component (without any structure) until 22:30 UT, when its T_b decreased to $\sim 0.6 \times 10^6$ K. In the next half-hour the component developed some structural changes, with two additional components appearing on the west side of the preexisting component; the peak brightness temperature increased up to $\sim 1.5 \times 10^6$ K, and the flare took place at the western edge of the preexisting component. Clearly, the interaction of the new components which we believe to be newly emerging flux was responsible for triggering the impulsive onset of the flare. Similar interactions have previously been reported by Kundu *et al.* (1982) and Willson and Lang (1984). At 6 and 20 cm wavelengths we had no data immediately prior to the flare onset. However, we had preflare active region data $\sim 1\frac{1}{2}$–2 hours prior to the flare start. The maps produced during these times (21:00–21:30 UT and 22:00–22:50 UT) indicate that the flaring region was heated up to $\sim 6 \times 10^6$ K at both 6 and 20 cm wavelengths.

During the entire rise phase of the impulsive burst and at its maximum, the 2 cm flaring region was very compact; its size was $\lesssim 2''$ and its peak $T_b \sim 8.5 \times 10^6$ K. We have no observations of its behavior during the postmaximum phase. During the postmaximum phase the burst was observed at 20 and 6 cm. After the impulsive phase maximum, the 20 cm flaring region continued to decrease in intensity; T_b decreased from 8.5×10^6 K to $\sim 7 \times 10^6$ K over a 2 minute interval, and then increased again to 7.5×10^6 K at 23:07 UT, without significant structural changes. At an even later stage of the postflare phase (24:00 UT), T_b decreased to 6×10^6 K at 20 cm and $\sim 5.5 \times 10^6$ K at 6 cm. At 6 cm, the flaring region appears to expand and be more diffuse in structure in the declining phase.

Although our observations ended at 24:00 UT, clearly the flare continued beyond 24:00 UT. From this duration, we can make an estimate of the magnetic field, using the gyrosynchrotron radiation theory (see Velusamy and Kundu 1981). We estimate an upper limit to the magnetic field of ~ 250 G in the postflare region.

Our observations at 2 cm wavelength provide evidence that emerging flux regions in the corona can trigger the onset of a flare. The two components of the preflare region at 2 cm appear to be linked by a large loop; the multiwavelength observations of the region by Shevgaonkar and Kundu (1984) justify this interpretation. The appearance of additional components close to the preexisting southern component prior to the flare onset implies the appearance of emerging flux regions. The emerging flux region (EFR) in the form of a small loop must be interacting with the overlying large loop to trigger the onset of the flare. Such a scenario was proposed by Kahler, Petrasso, and Kane (1976) from analysis of *Skylab* X-ray and Hα data. Our observations seem to be consistent with this picture (Fig. 5).

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