MULTIPLE WAVELENGTH OBSERVATIONS OF FLARING ACTIVE REGIONS

Kenneth R. Lang
Department of Physics, Tufts University, Medford, MA 02155

Abstract. The radio emission of quiescent active regions at 6 cm wavelength marks the legs of magnetic dipoles, and the emission at 20 cm wavelength delineates the radio wavelength counterpart of the coronal loops previously detected at X-ray wavelengths. At both wavelengths the temperatures have coronal values of a few million degrees. The polarization of the radio emission specifies the structure and strength of the coronal magnetic field ($H \approx 600$ Gauss at heights $h \approx 4 \times 10^9$ cm above sunspot umbrae). At 6 cm and 20 cm wavelength the solar bursts have angular sizes between 5" and 30", brightness temperatures between 2×10^7 K and 2×10^8 K, and degrees of circular polarization between 10% and 90%. The location of the burst energy release is specified with second-of-arc accuracy. At radio wavelengths the bursts occur within the central regions of magnetic loops, while the flaring Hα kernels are located at the loop footpoints. Coronal loops exhibit enhanced radio emission (preburst heating) a few minutes before the release of burst energy. The radio polarization data indicate magnetic changes before and during solar bursts.

Displacements of the radio emission with respect to their optical wavelength counterparts indicate that sunspot-associated sources at 6 cm lie at altitudes of $h \approx 4 \times 10^9$ cm above the photosphere. The brightness temperatures of the 6 cm sources are a few million degrees, and the high degree of circular polarization ($\rho_c \approx 70\%$) is attributed to gyroresonant absorption at the third harmonic of the gyrofrequency ($H \approx 600$ Gauss at 6 cm). The 20 cm emission delineates coronal loops which join regions of opposite magnetic polarity in the underlying photosphere. It is attributed to optically thick bremsstrahlung of a hot plasma trapped within magnetic loops with semilengths $L \approx 5 \times 10^9$ cm, maximum electron temperatures $T_e(\max) \approx 3 \times 10^6$ K and electron densities $N_e \approx 10^9$ cm^{-3} (or optical depth $\tau \approx 2.5$).

For all cases in which we could compare the positions of radio bursts with optical features, the radio emission originates near the central regions of magnetic loops, rather than at the footpoints. In Figure 1

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The degree of circular polarization of the radio emission can increase to 100% about 10 min to 1 hour before the eruption of solar flares, indicating changes in the structure of the coronal magnetic field which may trigger bursts and provide the source of their energy. Changes in both the sense and degree of circular polarization during solar bursts indicate complex magnetic changes and/or propagation effects within the burst plasma.

In Figure 3 a sequence of 10 s snapshot maps at 6 cm wavelength are provided. They were made before, during and after the impulsive burst (second map). The impulsive burst ($\approx$ 8" in size and < 15% circularly polarized) is spatially separated from both the preburst radio emission and the gradual decay component of the burst (10" in size and 30% left circularly polarized). The absence of circular polarization in the impulsive component suggests that this source is located near the apex of the loop where the longitudinal component of the magnetic field is small, whereas the polarization detected in the gradual decay component suggests an origin in a predominantly longitudinal magnetic field of one polarity, most likely in one leg of the loop.

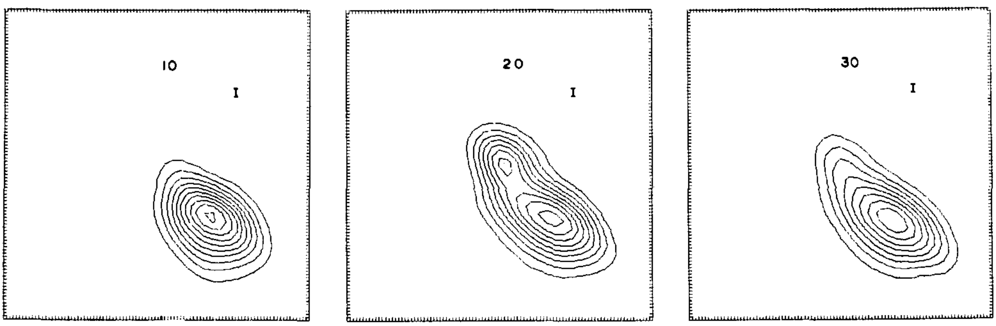

Fig. 3. A series of 10 s snapshot maps before, during and after the impulsive phase (second map) of a 6 cm burst (angular size $\lesssim$ 8").

ACKNOWLEDGEMENTS

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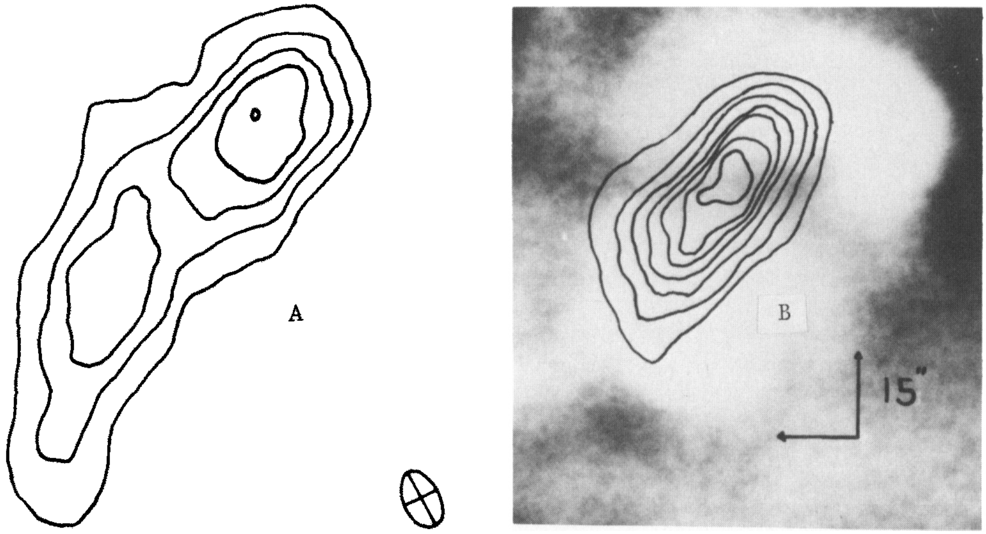

Fig. 1. V.L.A. synthesis map of the preflare (A) and impulsive phase (B) of a burst detected at 6 cm wavelength.

we compare a 10 s snapshot map of the impulsive phase of a 6 cm burst (B) with a map of the preburst radio emission (A: three minutes before the burst) and the flaring Hα kernels (B: at the time of the radio burst). The preburst radio emission was contained within a looplike structure which joins the sites of subsequent Hα emission. The peak brightness temperature of the preburst emission was $T_B \approx 6 \times 10^6$ K as compared with the peak burst brightness temperature of $T_B \approx 4 \times 10^7$ K. The brightness temperature for several ten minute intervals around one hour before the burst was only $T_B \approx 2 \times 10^6$ K, which is typical of quiescent emission of both plage and sunspot-associated sources at 6 cm. The loop plasma was therefore "warmed up" before the release of burst energy (i.e. preburst heating).

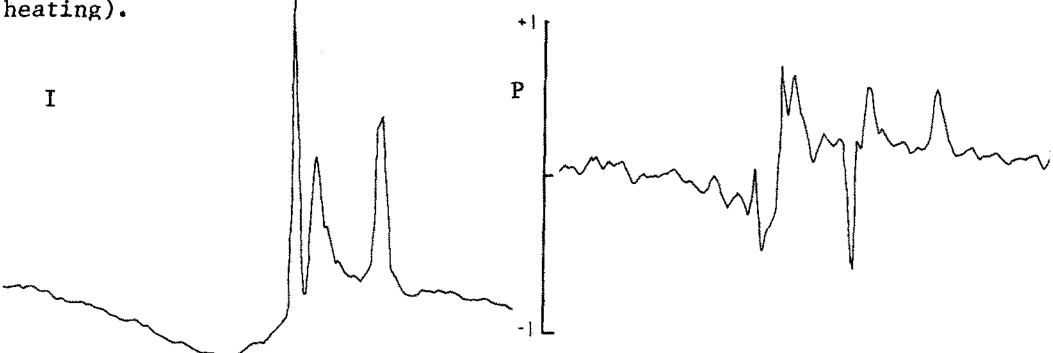

Fig. 2. Total intensity (left) and polarization (right) profiles of a multiple spike burst at 20 cm wavelength. Polarization changes occur before burst emission as well as from burst to burst within the same source of $\approx$ 15" in size.

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DISCUSSION

Kuijpers: You said that the bursts which were observed were resolved. I believe that at present you cannot say that. About a year ago we carried out a VLBI experiment using two instruments with a resolution of 0.06 arc sec to settle the problem of whether the energy release in a solar flare takes place in small pockets (Kuijpers, Tapping & Graham, this volume). This experiment needs to be followed up to observe large flares with VLBI techniques before we can settle this.
(Part of discussion lost due to break in recording).

Kuijpers: ... that in the impulsive phases it might be that might be several small regions in which acceleration takes place. Secondly, one should be cautions with averages over 10 seconds.

Lang: It is the case in solar radio astronomy that the bigger the dish used the more one sees. The VLA can see structures much smaller than the ones we resolve i.e. of order tenths of arc sec and they do not detect any signal. So I am surprised that the VLBI observations detects any signal from solar flares. Have you detected signals from solar active regions with resolution of, say, 0.1 arc sec?

Kuijpers: Yes, I think so.

Lang: Well, that is surprising because I know of many experiments which have tried unsuccessfully to detect structure on those angular scales.

Kuijpers: What I got from those results is that they did not have much flaring activity.

Lang: That's possible. But Marshall Cohen and Bernie Burke(?) both tried and did not see anything.

Dupree: I would like to make a comment. I was involved in the Burke attempt with the VLBI. We never had an optimum configuration and a flare. The only flare which occurred as we were changing tapes. There was no occasion when there was a substantial flare which we should have seen.

Lang: I agree that we cannot rule out the possibility that when a strong flare occurs you will see small-scale features.

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