2nd Advances in Solar Physics Euroconference
Three-Dimensional Structure of Solar Active Regions
ASP Conference Series, Vol. 155, 1998
C. E. Alissandrakis, and B. Schmieder, eds.

Sunspot-associated Sources, a Peculiar Source and a Halo-like Source as Basic Components of the 3D Structure of a Large Active Region from RATAN-600 and SSRT Observations

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Abstract. The 3D structure of a large, complex active region (AR 6471, from January 24 to February 09, 1991) was observed and modelled. The microwave observations were obtained in the wavelength range 0.8 – 32 cm with the RATAN-600 radio telescope (1D fan-beam, 7″ resolution at 0.8 cm) and at 5.2 cm with the Siberian Solar Radio Telescope (SSRT; 2D synthesis maps, 20″ resolution). Photographs and magnetograms of high quality were used for comparison. AR 6471 had a bipolar magnetic structure, with an S-shaped magnetic neutral line and produced many Hα flares.

1. Introduction

Observations of active regions in the microwave range give unique information on their three-dimensional structure (Alissandrakis 1994; Gelfreikh 1998). This is because, on the one hand, the microwave emission offers good diagnostics of the magnetic field and, on the other, the observations probe the solar atmosphere from the low transition region to the low corona. We present here a preliminary analysis of spectral observations with two radio instruments and discuss the various components of the emission.

2. Observations and modelling

Active region 6471 had a complex structure, shown in Figures 1 and 2. Figure 1 shows RATAN-600 one-dimensional scans (total intensity, I, and circular

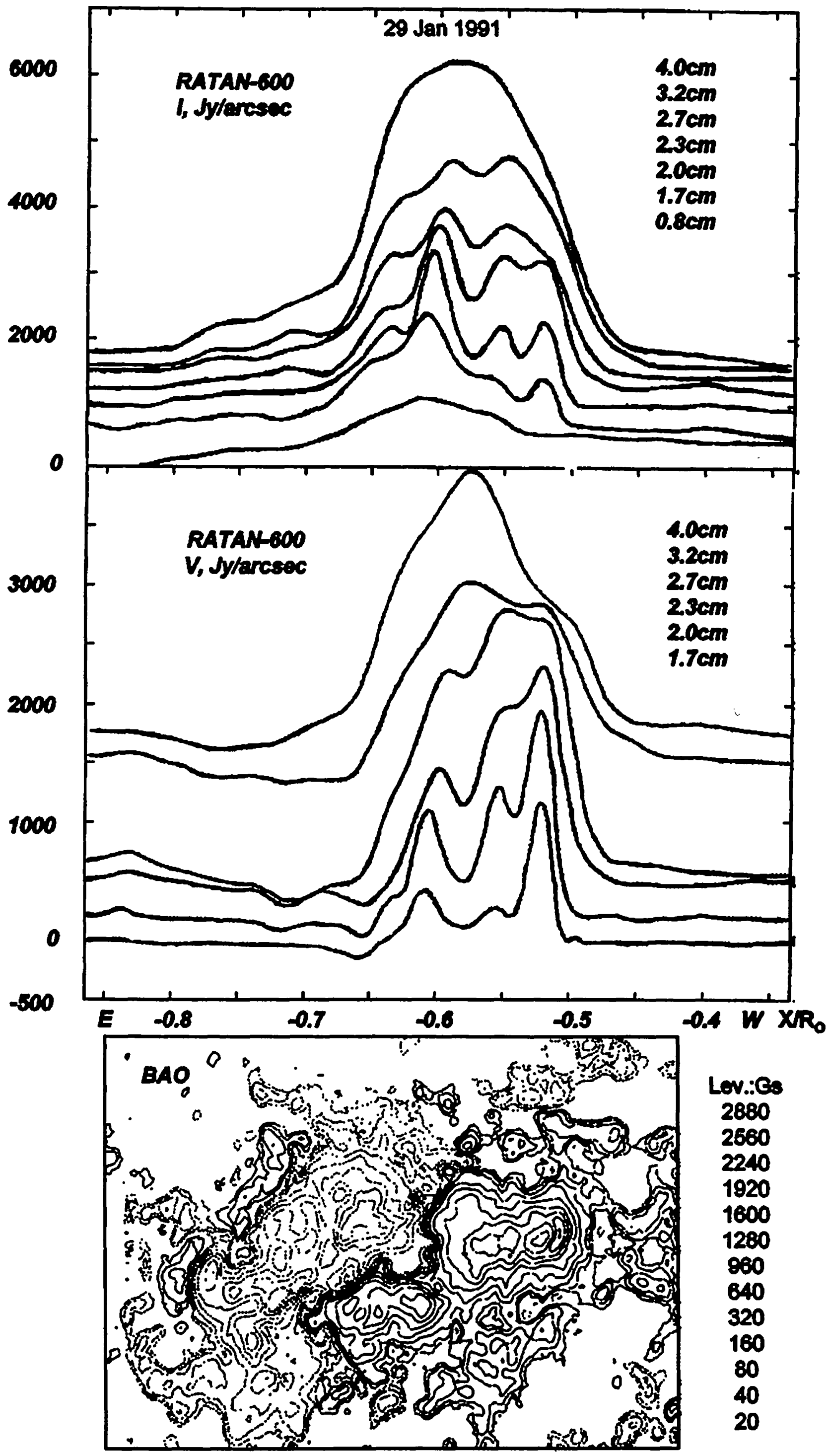

Figure 1. One-dimensional RATAN-600 scans of active region 6471 in total intensity (I) and circular polarization (V), together with a magnetogram from the Beijing Astronomical Observatory

polarization, V) in the short microwave range (0.8 – 4.0 cm), together with a magnetogram from the Beijing Astronomical Observatory. Figure 2 shows a RATAN-600 scan at 1.7 cm, with five identified gaussian-shaped components (labeled A to E and plotted in the figure). Two-dimensional maps in I and V, obtained with the SSRT (Alissandrakis et al. 1992) are also shown.

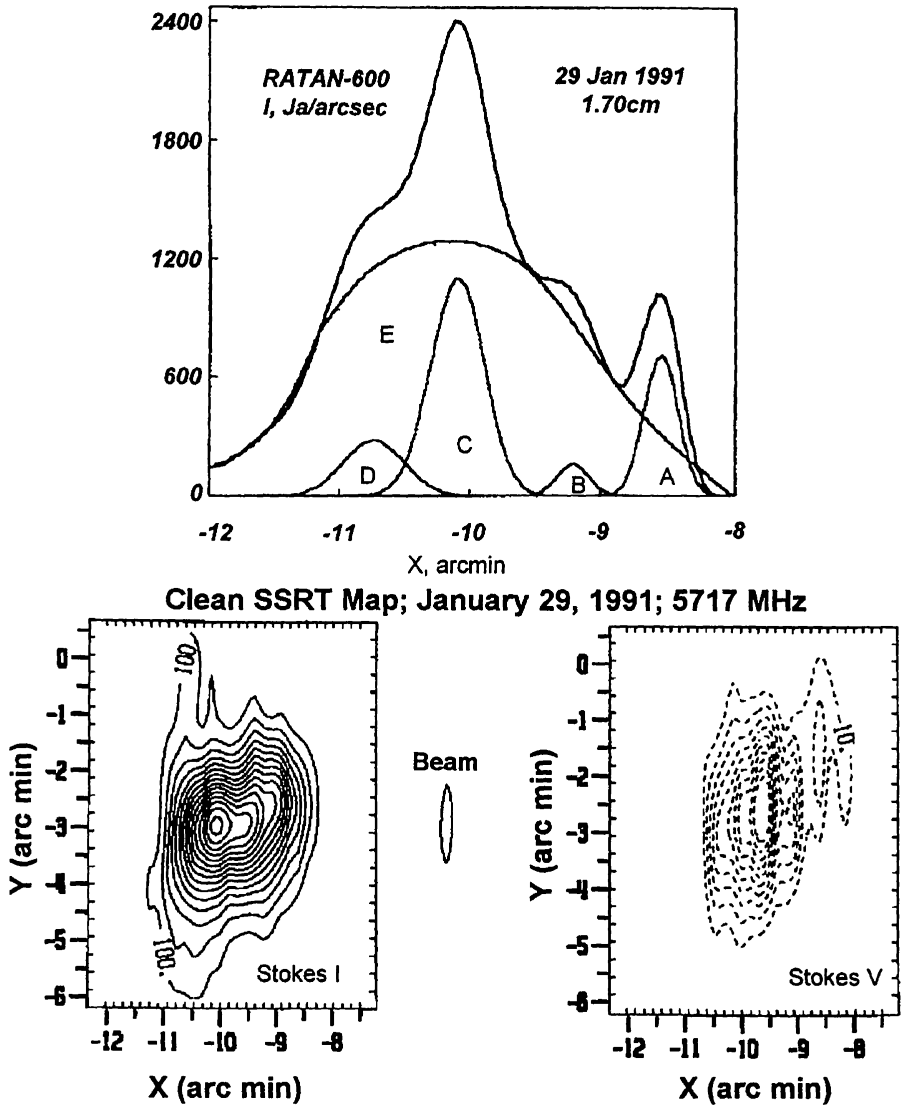

Figure 2. A RATAN-600 I scan at 1.7 cm together with SSRT I and V maps at 5.2 cm. The individual components of the active region emission (A to E) are also shown

The active region consisted of three sunspot-associated components (sources A, B and D) in the 1.7 – 3.2 cm wavelength range, which were 100% circularly polarized at 1.7 cm. This is in accordance with model calculations (Figure 4) for thermal gyroresonance emission at the second and third harmonics of the gyrofrequency (Alissandrakis et al. 1980), in regions of strong magnetic field ($\sim$ 2500 G at the base of the corona). No such emission was detected at 0.8 cm.

A "peculiar" (Akhmedov et al. 1986) source (C) was observed as a compact (20″) and very bright ($T_b = 5\,10^6$ K at 3.2 cm) component of the emission; it was located near the neutral line of the magnetic field, in a region where the gradient of the longitudinal component was maximal. In the 0.8 – 3.2 cm wavelength range, this source was modelled in terms of gyrosynchrotron emission from very hot (10 to $100\,10^6$ K), low lying coronal loops with moderate magnetic field (300 to 500 G).

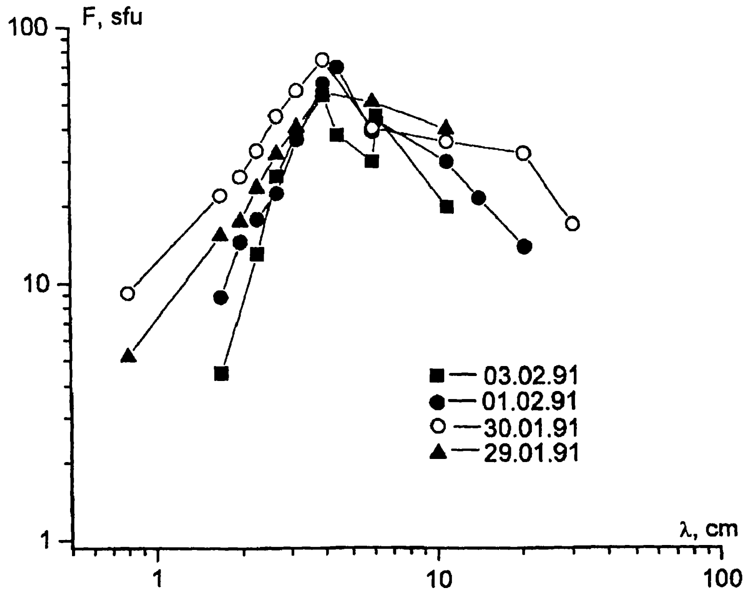

Figure 3. Flux density spectra of the halo source from January 29 to February 3, 1991

The halo-like source (E in Figure 2) was observed in the 0.8 – 4.0 cm range as a wide background of low brightness, compared with the brightness of the compact sources. However, in the 5 – 30 cm range this source became dominant, with maximum flux of about 50 – 60 sfu at 5 – 8 cm. Moreover, even in the 5.2 cm SSRT maps (Figure 2), the bright components A – D are not prominent and a large-scale component dominates.

The halo source was modelled (Figure 4) as the combined emission of thermal and non-thermal (subrelativistic) electrons, filling a large coronal magnetic loop (magnetosphere of the AR). It is important to note that non-thermal electrons can loose energy by excitation of plasma waves in the region where they are trapped. The very efficient scattering of microwaves by plasma waves (Kaplan and Tsytovich 1972) explains the next observed facts (Korzhavin 1994):

(i) invisibility of low lying, bright, sunspot-associated and peculiar sources at 5 cm and longer wavelengths due to the large opacity of overlying halo medium.

(ii) decrease of the emissivity of non-thermal halo electrons themselves at 5 – 8 cm and longer wavelengths, which results into a halo flux density spectrum with maximum at 5 – 8 cm.

(iii) high stability in time of the halo emission at longer wavelengths, compared with high variability at shorter wavelengths (Figure 3) and high flare activity of the AR 6471 due to saturation effects (the higher the number of non-thermal electrons, the higher the radio wave scattering).

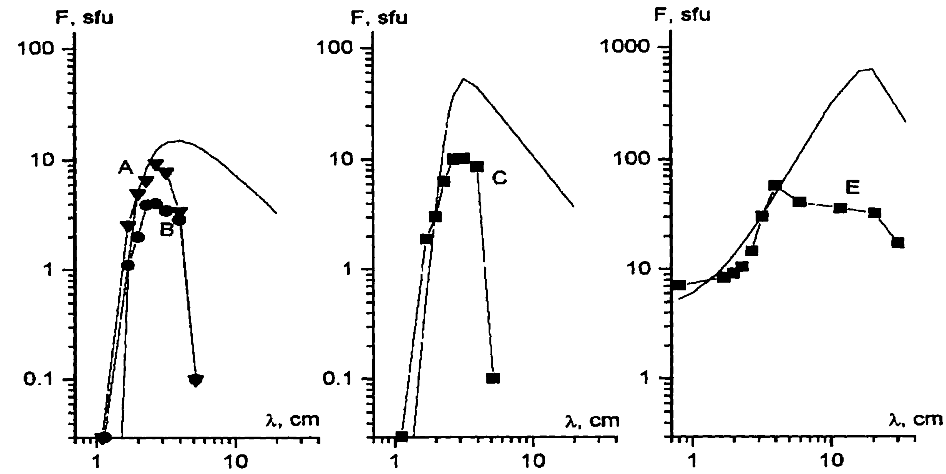

Figure 4. Observed and computed flux spectra of individual sources. *A* and *B* are sunspot-associated, *C* is the "peculiar" source and *E* the halo source. For sources *A*, *B* and *C* the estimated upper limit of the observed flux is 0.01 sfu at 0.8 cm and 0.1 sfu at 5.2 cm

3. Conclusions

Although the origin of the sunspot-associated microwave emission is well established, the mechanism(s) responsible for peculiar and halo sources are still not well understood. The present model computations, which invoke a combination of thermal and non-thermal processes, reproduce reasonably well the high frequency part of the spectrum but still depart from the observations at longer wavelengths.

Acknowledgments. This work was partly supported by INTAS grants 94-4625 and RBRF 96-02-19279 as well as the "Astronomy" program. ANK gratefully thanks the LOC of ASPE-97 for financial support.

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