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Characterization of two solar active regions by activity in the radio range

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RESUMEN

Con base en un análisis estadístico presentamos los resultados de un estudio comparativo de 2 regiones solares actvias. Con el objeto de estimar la estructura del campo magnético coronal, consideramos conjuntamente las fluctuaciones del ruido del continuo de fondo, la clasificación espectral de las explosiones en microondas que tienen lugar en las regiones, la morfología, y la distribución de la actividad en la banda métrica-centimétrica.

PALABRAS CLAVE: Regiones activas, estructuras magnética coronal, radioemisión.

ABSTRACT

Based on a statistical analysis we present the results of a comparative study for two active regions. In order to estimate the coronal magnetic field structure we consider jointly the fluctuations of the noise storm background continuum, spectral classification of the microwave bursts taking place in them, the morphology of the active regions, and the metric-centimetric wavelength band distribution of the activity.

KEY WORDS: Active regions, coronal magnetic structures, radioemission.

INTRODUCTION

A solar active region can be characterized by its optical or x-ray features, sunspot area, Hα flare productivity, and also by its activity in the radio frequencies. These characterizations are based on the properties of the observed parameters in the specific wavelength band. Their relation to the structure of the active region is very complex.

In this paper we use radio observations to describe the structure of two active regions. The appearance of fluctuations in the radioemission was detected as early as two decades ago (Kobrin *et al*. 1973). Different mechanisms were identified as probable sources of radiofluctuations. Zaitsev and Stepanov (1982), considering the coronal structures as magnetic hydrodynamic resonators proved they act as modulators of the radioemission. Stepanov (1983) found that if the instabilities occur in the source itself, the modulation is even deeper and could be of pulsating character.

The appearance of fluctuations in the radioemission could provide some information on the length scale of the magnetic structures as shown for the continuum component of radioemission associated with active regions (Méndez and Rodríguez 1996; Méndez *et al*. 1997).

The solar radioemission bursts give information about the mechanism taking place in the sudden energy release process and in a general sense of the magnetic structure. In the metric band the type III and V events point to open and closed magnetic structures in the associated active region. The classical morphological classification in the centimeter band gives some information about the mechanism but not about the structure of the associated active region. In this paper, we use a centimetric wavelength spectral classification obtained by Rodríguez (1987).

We present results of a comparative study for two active regions considering jointly the fluctuations of the noise storm background continuum, the spectral classification of the bursts taking place in them, the morphology of the active regions, and the metric-centimetric wavelength band distribution of the activity.

MATERIALS AND METHODS

We studied the active regions associated to the sunspots groups 105+106 and 249 from the Solar Data Bulletin (Solnechnye Dannye) of the Main Astronomical Observatory in St. Petersburg (5027+5028 and 5200 NOAA/USAF). Both were active in the 1 to 21 cm and metric radio band, and had a noise storm associated in the 235-280 MHz band. We consider regions 105 and 106 as a single active region, because of the proximity between them; this means they are joined in a single magnetic structure (see Table 1).

We used the regular observations on 235 and 280 MHz by the Havana Radioastronomical Station during May 27 and 28, and October 23 to 25 1988 to study the fluctuations of the noise storm background continuum.

For each day, types I and/or III bursts were removed in order to obtain the noise storm background continuum. A five-hour interval was digitized with a 30-second interval. In order to reduce the noisy structure in the high frequencies, the short periods variations were removed by five-minute running averages in each case. The trend was estimated by 30-minute running averages and subtracted from the five-minute smoothed data. In these way the noise storm background fluctuations were found. Processing the data with FFT, we obtained the power spectra for each day.

The noise storm background continuum is the metric band manifestation of the slowly varying component (S-component). We consider that the fluctuations are due to excited eigenmode oscillations of the magnetic structure associated to the corresponding active regions, similar to those sustaining loop prominences. From the power spectra the proper frequencies of the magnetic structures and consequently their characteristic lengths were estimated using the dispersion relation (Vrsnak *et al*. 1990):

$$\omega^2 + \delta^2 = k\, v_a^2$$

where ω is the observation frequency, δ is the damping factor (= $0.4 \mathrm{x} 10^{-4} \mathrm{s}^{-1}$), v_a is the Alfvèn velocity (= 300 kms^{-1}), and k is the wave vector, (see Méndez *et al*. 1997 and references therein).

The burst spectra in the 1 to 21 cm wavelength band associated to the 105+106 and 249 active regions were obtained from the Outstanding Events report (Solar Geophysical Data, No. 531 and 536, part 2). The bursts were classified in six spectral bands following Rodríguez (1987) in order to investigate the structure of the magnetic field and the mechanism taking place in the sudden energy release process in the microwave band associated to active regions. The association with the active region was established by temporal simultaneity with H_α flares. Radiobursts in the metric wavelength band were obtained from the Solar Geophysical Data.

DISCUSSION AND CONCLUSIONS

The spectra obtained for the 105+106 active regions (Figure 1) present a maximum around 25 min. period, corresponding to structure with a characteristic length of 48.2 10^3 km. The absence of significant components over 800 sec (fo in Figure 1) could be associated to a 32.3 10^3 km lower limit for the magnetic structure length to support a noise storm in the 280-235 MHz range. The absence of the noisy structure for cycles/sampling interval longer than 0.06 in Figure 1 is due to the reduction of the noisy structure in the high frequencies above mentioned.

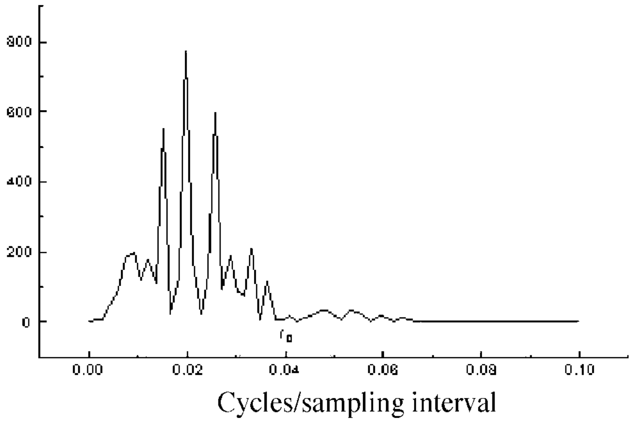

Fig. 1. The power spectra for the noise storm background continuum associated to the 105+106 active region corresponding to May 28, 1988 at 235 MHz. The y-axis is referred to relative amplitude.

The spectra associated to the 249 active region present a high variability for the daily significant frequency maxima. This behavior could be related to the more complex structure of this group, with twice the area of the 106+105 group and more individual umbrae indicators of more resonant structures (Table 1).

Table 1

Group area and spots number for the days spectrally analyzed for the two active regions (data from Solar Data Bulletin).

Active Region 105+106			Active Region 249		
day	Group area	Spots number	day	Group area	Spots number
27	795	54	23	1825	75
28	693	54	24	1686	72
			25	1809	93

The distribution of the radio bursts considering their spectral classification (Table II) is different for the active regions considered (significant level >0.01 in a Kolmogorov-Smirnoff test). It is interesting to note that the classes associated to intense bursts (classes 1 and 4) differ between them. The contribution of class 1 bursts in active region 249 is more important.

The 105+106 active region has an important contribution of class 6 bursts. Class 6 may be associated to thermal emission from approximately isothermal sources, which we believe more likely in down-located closed magnetic structures.

The activity level in the centimetric band is greater for the 105+106 active region. On the other hand, the 249 group is more active in the metric band. These and the previous results point to a 105+106 group magnetic structure more closed in front of a 249 group more developed magnetic structure with magnetic field lines protruding more deeply in the solar corona up to the noise storm generation level. This could be the reason of a more frequently perturbed metric radioemission.

Notice that the probability for spectra associated to great bursts (classes 1 and 4) is approximately the same for both active regions, but the class 1 spectrum has a more important contribution in the active region 249. This region has a probably more extended magnetic structure and it is possible that this spectrum is more likely associated to open magnetic structures.

Thus, qualitatively speaking the active region 249 with fluctuation periods greater that those of the 105+106 active region would have a more extended magnetic structure, protruding deeply into the solar corona to the metric radioemission source region, thus explaining the more frequent perturbations in the metric band.

Table 2

Spectral class distribution (in %) of the bursts in the 1 to 21 cm wavelength band, and the mean value for the occurrence of meter and centimeter bursts per day.

Spectral Class	Active Region 105+106	Active Region 249
1	11	33
2	4	8
3	0	8
4	65	51
5	0	0
6	20	0

	Active Region 105+106	Active Region 249
Centimeter Bursts per day	4.3	1.7
Meter Bursts per day	0.8	3.9

On the other hand, the 105+106 active region has a shorter magnetic structure in accordance with an essentially centimetric activity and an important contribution of the spectral class 6.

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