PROPERTIES OF SOURCES OF THE SLOWLY VARYING COMPONENT OF 2 cm SOLAR RADIO EMISSION

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To study the nature of the local sources of solar radio emission connected with active regions, it is important to investigate the structure of such sources and their emission spectra. These problems are being investigated in detail by a group of workers of the Radio Astronomy Department of the Pulkovo Observatory led by G.B. Gelfreikh. The Pulkovo large radio telescope used for the observations allows them to investigate the solar radio sources at the whole cm-wavelength range with a high resolution reaching 40 sec of arc at the 2-cm wave. Observations are taken at 2·0, 3·2, 4·4, 6·6, and 9-cm waves. The author observes at the 2-cm wave.

The results of the observations at the 2-cm wave with a high resolution permit, in the first place, to draw the reliable conclusion that the radio source over the active region is not a homogeneous formation. It turned out that the structure of the radio source depends on the structure of the magnetic field of the active region and optically observed structures – spot groups and calcium plages connected with the magnetic field. Up to now a clear indication on the existence of radio sources over separate spots in one group was made by Pulkovo radio astronomers only by making use of the data obtained in the polarized emission during the Sun eclipse on April 20, 1958 (Korolkov *et al.*, 1960). The same result for an unpolarized emission was obtained by a number of observers during the Sun eclipse on May 20, 1966.

In particular, G. Apushkinsky and V. Nagnibeda got this result at 0·8 cm, 3·3 and 10-cm wavelengths from the record of the eclipse of the source connected with the spot group no. 57 *(Solnechnye dannye)* in the Southern hemisphere of the Sun. The one-dimensional brightness distributions were taken from the record of the opening and the closing of the radio source (Apushkinsky *et al.*). Having one-dimensional distributions in two directions corresponding to the opening and the closing of the radio source, it is possible to draw two-dimensional images of the radio source (Figure 1). It is seen from the picture that the radio source consists of two main details corresponding to two groups of spots of different polarity. Some bright small detail stands out on a less bright background. (The brightness temperatures of a bright detail are equal 4×10^6, $0{\cdot}6 \times 10^6$, and $0{\cdot}08 \times 10^6$ °K at the waves 10, 3·3 and 0·8 cm respectively.)

Our observations with the Pulkovo large radio telescope show a complicated structure of an enhanced radio emission over active regions too. A comparison of

Kiepenheuer (ed.), Structure and Development of Solar Active Regions, 575–580. © *I.A.U.*

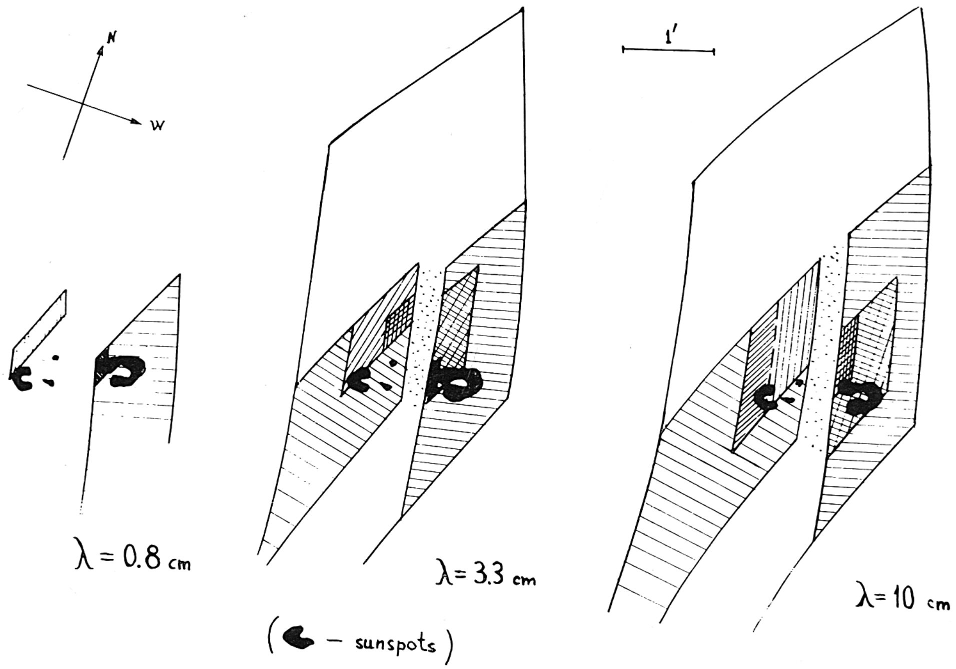

FIG. 1. *Two-dimensional images of the radio source, May 20, 1966.*

records of enhanced radio emission and curves of calcium-plages brightness distribution provides some interesting results. Such distributions were obtained from calcium spectroheliograms on the microphotometer with a split, corresponding to the antenna pattern. The radio-emission intensity over the calcium plages repeats in many respects the plage curves, increasing in the region of the spot groups. But over the spots themselves, in the place where the magnetic field of the spot penetrates into the Sun's atmosphere, the radio-emission intensity increases sharply, forming a bright radio source. In Figure 2 are shown radio sources associated with spot groups no. 144 and no. 145 (using the numeration of the bulletin *Solnechnye dannye*) observed in September 1966. Plage-brightness distributions are also given there.

First of all, it is necessary to point out that the radio sources over the spots have a small width, not more than 0′.7. Separate narrow sources are clearly seen over the main and tail spots of the bipolar group no. 145. It all means that the radio source probably is not high over the photosphere as, according to the recent paper of Livshitz *et al.* (1966), the magnetic field of the spot disperses strongly already on the height of 2000–3000 km. On the other hand, this fact points to the high brightness temperature of the emission of such sources, which differs sharply from the brightness temperature of the surrounding background. Indeed, the brightness temperature of

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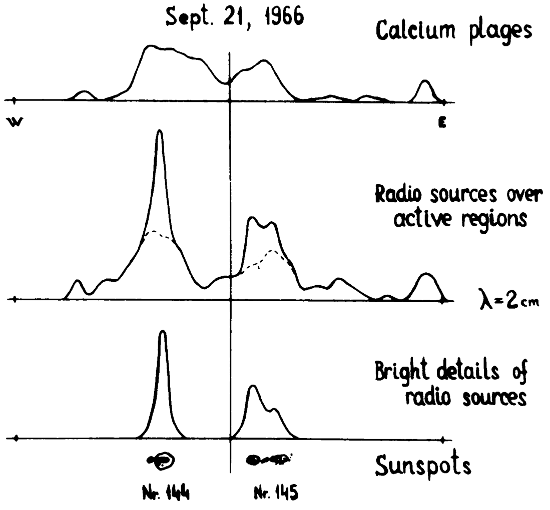

FIG. 2.

the bright detail of the radio source over the group no. 144 reached $2\text{–}2{\cdot}5 \times 10^5\,°K$, whereas the background temperature is scores of thousands of degrees. It means that the mechanism of radio emission of the bright part of the source and the background are different. To assume the thermal nature of the radio emission of the local sources it is necessary to explain the existence of strongly heated regions at a small height over the photosphere, which is probably rather difficult to do.

It is interesting to note that the flux from the nucleus of the source over the group no. 144 falls when the source moves to the limb of the Sun, but the size of the source decreases. Thus the brightness temperature remains constant all the time. This fact can be explained by assuming that we deal with a flat source of a considerable optical thickness.

In solving the problem of the radio-emission mechanism an important role is played by the spectrum of this emission, especially at short cm wavelengths. It follows from the observations in Pulkovo that the solar local radio sources have various spectra (Akhmedov *et al.*, 1966), though most of them possess a marked decrease of the flux in the 3·2–2·0 cm wavelengths. Radio sources over the groups no. 144 and no. 145 have such a spectrum (Figure 3). It is seen from the figure that in the 3–9 cm wavelengths the spectrum is approximately flat, but at the 3–2 cm wavelengths the flux decreases sharply. In our opinion, this fact excludes the presence in the radio emission of a source with an essential contribution of the bremsstrahlung of the thermal electrons demanding for its explanation a gyro-radiation of the thermal electrons at the gyro-frequency and its harmonics. This mechanism also explains the decrease of the radio-emission flux at all wavelengths when the source of the group no. 144 moves to the limb of the Sun.

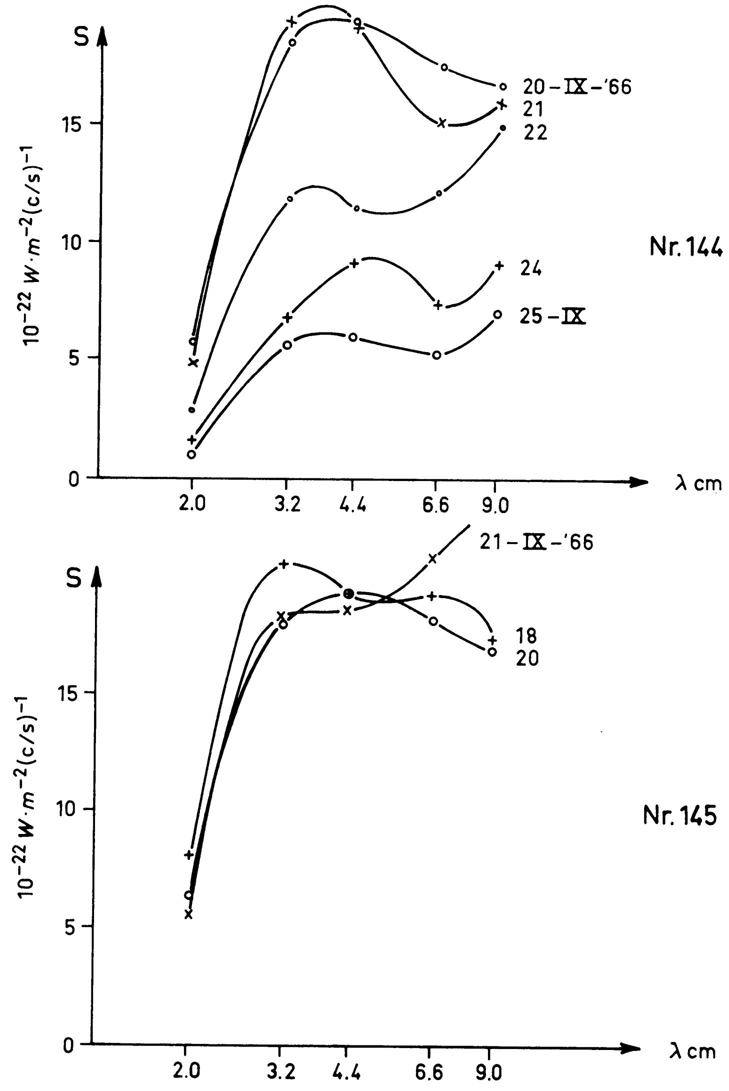

FIG. 3. *Radio-source spectra.*

It follows from our observations that at the 2-cm wavelengths the share of the radio emission connected with the calcium plage in the total flux of the radio source is rather great, falling markedly with the increase of the wavelength (in the cm range). On the other hand, only in high-resolution observations in unpolarized emission it is possible to separate the bright nucleus of the source connected with the spot. This can be seen from the record obtained on September 21, 1966, with 0.′7 and 4′ width beam (the latter being obtained by smoothing) (Figure 4). Therefore the spectrum of

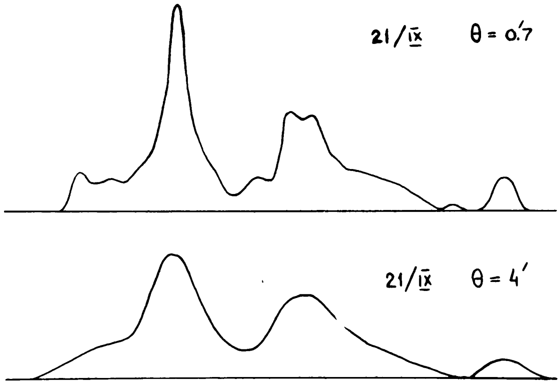

FIG. 4.

such a source plotted on the basis of observations with insufficiently high resolution, will have an extra short-wave part. This probably was the case in the paper of Tsuchiya and Nagane (1967).

The following conclusions can be drawn from the above:

(1) In the distribution of the brightness of the radio source the complicated structure of the active region is well seen: (a) it is connected with the spot component which for bipolar groups of great longitude gives two sources; (b) the component is connected with calcium plages.

(2) The small size of bright details of the radio source implies that their height over the photosphere cannot be large, and the high brightness temperature demands the existence of strong heated regions at this height.

(3) The observed radio-emission spectrum of bright details of the radio source at the cm wavelengths (3–10 cm) requires for its explanation a gyro-radiation of the thermal electrons and excludes the essential influence of the bremsstrahlung.

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DISCUSSION

De Jager: The very steep decrease of spectral intensities for $\lambda \lesssim 2$ cm is surprising. What is the absorption mechanism?

Nagnibeda: The steep decrease of intensity for $\lambda < 3$ cm is the observed fact. Such a spectrum of the slowly varying component of solar emission was explained by Zhelezniakov ('*The Radio Emission of the Sun and the Planets*', 1964) on the basis of gyro-resonance radiation of the thermal electrons. He showed that the steep decrease of the intensity for $\lambda < 3$ cm might be explained by the decrease of the height of emission layers with frequencies $\omega \simeq 2\omega_{\varkappa}$, $3\omega_{\varkappa}$ ($\omega_{\varkappa} =$ gyro-frequency) and its passage from the corona to the chromosphere and the decrease of the τ because of insufficient magnetic-field strength.

Krüger: Have you made any distinction between the spectra originating in the bright cores of the sources of the s-component and its surroundings?

Nagnibeda: Yes, the spectrum of the bright core is steeper than the spectrum of its surroundings at the 2–3·2-cm wavelengths.

Krüger: I should like to draw attention to a paper of Zlotnik, who calculated spectra of the s-component basing on thermal bremsstrahlung and gyro-resonance emission. This paper will appear in the *Soviet Astronomical Journal*.