ON THE RELATION BETWEEN THE RADIO-EMISSION FLUX OF LOCAL SOURCES ON THE SUN AND THE STRUCTURE OF ACTIVE REGIONS OBSERVED OPTICALLY

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Abstract

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A. R. ABBASOV

ON THE RELATION BETWEEN THE RADIO-EMISSION FLUX OF LOCAL SOURCES ON THE SUN AND THE STRUCTURE OF ACTIVE REGIONS OBSERVED OPTICALLY

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The characteristics of the radio emission of local sources on the Sun that are necessary for the study of solar activity have not been studied sufficiently; moreover, a number of anomalous cases are known that are difficult to explain. In order to obtain more complete data making it possible to broaden the possibilities for interpreting the existing observations, below are given the results of a statistical treatment of daily radio-astronomical observations available at the Moscow International Data Collection Center.

The observations for 1961 and 1963, selected according to the criteria mentioned in ([1,2]), were subjected to treatment. In addition, cases associated with the appearance of sources on the E-limb and their disappearance on the W-limb of the Sun were rejected, with a two-day margin. Equations of the following form were then constructed:

$$F_{\lambda_i} = a_{1\lambda_i} \sum_{k=1}^{n} S_{\mathrm{gl}k} + a_{2\lambda_i} \sum_{k=1}^{n} \left(S_{\mathrm{p}k} - S_{\mathrm{gl}k}\right) + a_{3\lambda_i} \sum_{j=1}^{m} S_{\phi j} + F_{0\lambda_i},$$

where F_{λ_i} is the total radio-emission flux at wavelength λ_i; $S_{\mathrm{gl}k}$ is the area of the main spot of the k-th group, in millionths of the solar hemisphere; $a_{1\lambda_i}$ is the proportionality coefficient associated with the main spot;

Table 1

λ, cm	$a_{1\lambda_i} \cdot 10^9$	$a_{2\lambda_i} \cdot 10^3$	$a_{3\lambda_i} \cdot 10^5$	$F_{0\lambda_i} \cdot 10^{22}$, $\frac{\mathrm{W}}{\mathrm{m^2Hz}}$
1961	**1961**	**1961**	**1961**	**1961**
3.2	24 ± 3	11 ± 2	35	244
8.0	23 ± 2	28 ± 3	63	89

Fig. 1

Figure 1: Fig. 1

λ, cm	$a_{1\lambda_i} \cdot 10^9$	$a_{2\lambda_i} \cdot 10^3$	$a_{3\lambda_i} \cdot 10^5$	$F_{0\lambda_i} \cdot 10^{22}$, $\frac{\text{W}}{\text{m}^2\text{Hz}}$
1963	**1963**	**1963**	**1963**	**1963**
3.2	26 ± 3	13 ± 2	30	236
8.0	24 ± 2	27 ± 2	50	81

n, m are the numbers of groups of spots and plages on the disk of the Sun for the given day; $S_{\mathrm{p}k}$ is the total area of the k-th group of spots, in millionths of the solar hemisphere; $a_{2\lambda_i}$ is the proportionality coefficient associated with the remaining spots of the group; $S_{\phi j}$ is the area of the j-th plage, in millionths of the solar hemisphere; $a_{3\lambda_i}$ is the proportionality coefficient associated with the plage area; $F_{0\lambda_i}$ is the radio-emission flux of the quiet Sun.

By the method of least squares, $a_{1\lambda_i}$, $a_{2\lambda_i}$, $a_{3\lambda_i}$, and $F_{0\lambda_i}$ were found.* All computational work was carried out at the computing center of Leningrad State University named after A. A. Zhdanov on the M-20 computer.

The results of the calculations are given in Table 1. It follows from the table that the ratio of the radio-emission intensities of the two regions of the source—

* The radio-astronomical observations of the Toyokawa station and the optical data published in the bulletin *Solar Data* were used.

groups of spots associated with the main spot and with the remaining spots of the group—depends on λ: at $\lambda = 8.0$ cm these intensities coincide within the limits of error, while at $\lambda = 3.2$ cm their ratio is of the order of two. This leads to a noticeable difference in the contribution to the total radiation of the region from the main spot and from the rest of the group.

The noted feature may be caused by different contributions of the bremsstrahlung and magneto-bremsstrahlung mechanisms to the radiation of different parts of the source, since the magnetic-field strengths H of the main and peripheral spots are different (H increases with increasing spot area). The field strength sufficient for the efficiency of the magneto-bremsstrahlung mechanism depends on λ (it decreases as λ increases); therefore, at $\lambda = 8$ cm this mechanism is effective for all spots of the group, whereas at $\lambda = 3.2$ cm it is effective only for the main spot.

Fig. 1

The results presented agree well with observations of single sources and make it possible to reduce the discrepancy between data in different publications. For example, in ([3]) spectra of 10 sources are presented, including two anomalous

Fig. 2

Figure 2: Fig. 2

ones: the radio-emission flux at 3.2 cm in them proved to be greater than at 8 cm. Calculation of the ratio S_{gl}/S_p, as should have been expected from the results given above, gave for them the values 0.92 and 0.87, in contrast to the same quantity for the others, which varied from 0.65 to 0.14.

In ([4]) the results of observations of 60 separate sources at $\lambda = 3.2$ cm and $\lambda = 7.5$ cm are given. Use of these data to construct the relation between $F_{3.2}/F_{7.5}$ and S_{gl}/S_p gives the dependence shown in Fig. 1, likewise in good agreement with the conclusions given above.

Several spectra of single sources with identical S_p, but different S_{gl}, could be constructed from the results of observations at the Toyokawa and Ottawa stations. For all of them, as follows from Fig. 2 (1—$S_{\text{gl}}/S_p = 0.92$; 2—0.50; 3—0.30), the dependences of the type found above for the spectrum on the ratio S_{gl}/S_p are fulfilled. The stronger dependence of the flux on the magnetic field at $\lambda = 3.2$ cm than at $\lambda = 8$ cm should be reflected in the dimensions of the source, which is confirmed by observations during eclipses, according to which at $\lambda = 3.2$ cm the extent of the source is smaller than at $\lambda = 10$ cm ([5]). In addition, it follows from what has been said that, when observed with sufficiently high angular resolving power, the source above a complex group of spots should consist, at some wavelengths, of at least two parts. Such cases have been described in the literature ([5]).

Fig. 2

The above-mentioned strong dependence of $F_{3.2}/F_{7.5}$ on $S_{\text{pl}}/S_{\text{p}}$ can be compared with the relation, indicated in (4), between the ratio $F_{3.2}/F_{7.5}$ and the probability of occurrence of a proton flare, and one may expect that such a flare can be predicted from optical observations determining the ratio $S_{\text{pl}}/S_{\text{p}}$. A preliminary test of 18 flares confirmed this assumption in 14 cases.

Leningrad State University
named after A. A. Zhdanov

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Note: Figure translations are in progress. See original paper for figures.