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RELATIONSHIP OF SOLAR RADIO EMISSION AT λ=1.43m AND OPTICAL PROCESSES IN THE SUN

Sh. Makandarashvili, N. Oghrapishvili, D. Japaridze, and D. Maghradze

Radio frequency observations supplement optical studies and in some cases they are the only way of obtaining information on the physical conditions for radio waves and their propagation. Solar radio emission appears in two forms, "quiescent" and "sporadic." Their distinctive features are well known. Solar radio observations at meter wavelengths (λ = 1.43 m, ν = 210 MHz) have been made at the Abastumani Astrophysical Observatory using a solar radio telescope throughout five solar cycles (since 1957). This article is a study of the long-term observations of solar radio bursts and sunspots. It is found that there is a correlation between the amplitudes of the radio bursts, the number of spots, and the regions of the spots.

Keywords: *Radio emission: radio bursts: sunspots*

1. Introduction

Studies of solar radio emission play an important role in research on the processes taking place in the sun. Comparisons of radio frequency and optical data make a valuable contribution to our understanding of physical processes taking place in the sun's atmosphere, and they make it possible to study processes taking place in different layers of the solar atmosphere. The method of epoch superposition yields the sequence of events in the optical and

E. K. Kharadze Abastumani Astrophysical Observatory, Ilia State University, Georgia; E-mail: natela.oghrapishvili@iliauni.edu.ge; darejan.japaridze@iliauni.edu.ge; davit.maghradze.2@iliauni.edu.ge; admin@reservetour.com

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radio ranges during solar flares [1].

The propagation velocity of perturbations which generate a band of frequencies, the energy release rate, and other information about physical conditions in the solar corona can be determined from the character of the spectrum [2-5].

The advantage of radio observations is high resolution in the upper layers of the corona, since the propagation velocity of radio waves obviously depends on the density of the surrounding medium. This is especially true of the 210 MHz emission band, which corresponds to $\lambda = 1.43$ m.

Comparison of data obtained in different spectral bands is an important method for studying various events in the sun's atmosphere. In the visible range, which contains a large portion of the sun's radiation, the variability of flares is very small. Our knowledge of solar activity has expanded greatly as a result of improvements in and coordination of optical and radio frequency observations [6-9].

Emissions at different wavelengths are produced at different depths of the solar atmosphere. Therefore, by changing the wavelength it is possible to study different depths of the sun's atmosphere.

Our attention is drawn to the fact that solar radio emission appears in two forms, "quiescent" and "sporadic." Their distinctive features are well known [10-12]. As a rule, they are localized in active regions of the solar disk. Flares are considered the main feature of solar activity and are, therefore, a major object of study. The intensity of sporadic radio emission at meter wavelengths can exceed the emission from the quiet sun by several thousand times [13].

The radio emission from the quiet sun is thermal emission from the solar atmosphere. The power of this emission is estimated using the temperature of the sun's corona. Radio emission from the perturbed sun is, however, related to features of the sun's surface layers [14]. It has been found that noise bursts are associated with large groups of spots in the photosphere, especially those located in the central part of the solar disk [15]. The probability of radio emission increases when the area of the entire group is greater, as well as when the area of the largest spot in this group increases [14]. Flares, like the background emission, have a high degree of polarization, up to 100% with a magnetic field that shows up either in the source region of the radio emission or as the radio waves propagate in the corona [16].

The duration of noise bursts can range from a few hours to several days over a wide range of frequencies (50-300 MHz) [17]. As a whole, it is this phenomenon, observed at meter wavelengths, which leads to an increased level of noise emission.

The relation of noise bursts to other solar features, such as flares, has been discussed in various ways. Some authors assume that all chromospheric flares precede or take place at the same time as noise storms [18]. Others believe that noise bursts are observed only when strong, second or third order chromospheric flares are observed on the sun [19,9,16].

Over 50 years of active radio frequency observations at the Abastumani Astrophysical Observatory (Georgia), there have been as many as 200 cases indicating a distinct relationship between the occurrence of noise bursts and the sun's activity cycle [20-21].

2. Observational data and measurement techniques

Solar radio observations at meter wavelengths ($\lambda = 1.43$ m, $\nu = 210$ MHz) have been made at the Abastumani Astrophysical Observatory since 1957 using a solar radio telescope.

We have used observational data from 1957-2008 that contains 5 solar cycles (maxima during 1957-1958, 1969-1970, 1980-1981, 1990-1991, and 2000-2001).

The data are presented in the form of time dependences of intensity. Universal time and the intensity in units of 10^{22} W/m^2/Hz are plotted on the abscissa and ordinate, respectively. The internal noise is less than 0.01 times the signal from the quiet sun. When solar radio emission is recorded, the galactic background is subtracted. When a large burst of solar radiation with an intensity many times greater than the level for the quiet sun, the sensitivity of the radiometer varies greatly.

Extensive data collected in recent years indicate clearly that there is a close relationship between radio bursts and sunspots or groups of spots. The groups of spots accompanying solar radio bursts are often of E or F types (according to the conventional classification of sunspots). It has also been found that a spot or group of spots with opposite polarity may be the source of a radio burst.

Some characteristics of radio bursts, such as their duration and intensity, are closely related to the 11-year solar activity cycle. These all vary with changes in solar activity.

Here we pay special attention to three cases from the set of data which indicate a close relationship between the occurrence of radio bursts and the sun's activity cycle; we have compared these with optical observations.

Figure 1 shows a plot of solar radio emission and an image of sunspots on December 24, 1973. This figure corresponds to the first type of radio emission [8], i.e., a radio burst produced in active regions of the sun and observed optically. On this day the Wolf sunspot number reached 260, and the area of the sunspots was as high as $1.500 \cdot 10^{-3}$ of the solar hemisphere.

Figure 2 shows a plot of the solar radio emission and an image of sunspots for July 27, 1981. The sunspots were observed with the photosphere-chromosphere telescope at the Abastumani Astrophysical Observatory. The Wolf number was 170 and the overall area of the sunspots was $3.35 \cdot 10^{-3}$ in the units mentioned above.

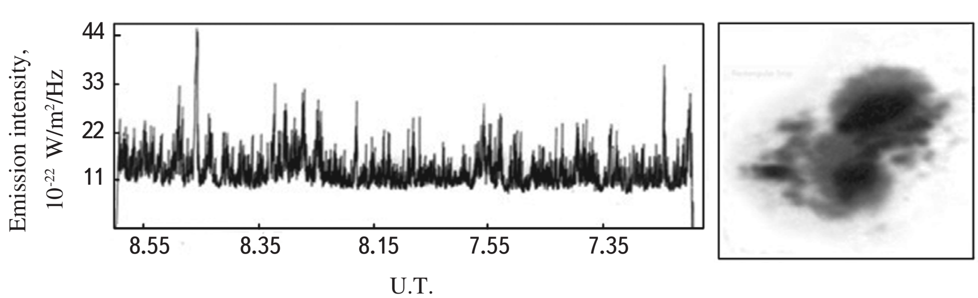

Fig. 1. A plot of solar radio emission data obtained on December 24, 1973. The observation times are given on the abscissa (Universal time) and the intensity of the radio emission, on the ordinate (in 10^{-22} W/m^2/Hz). A image of sunspots on that date is at the right.

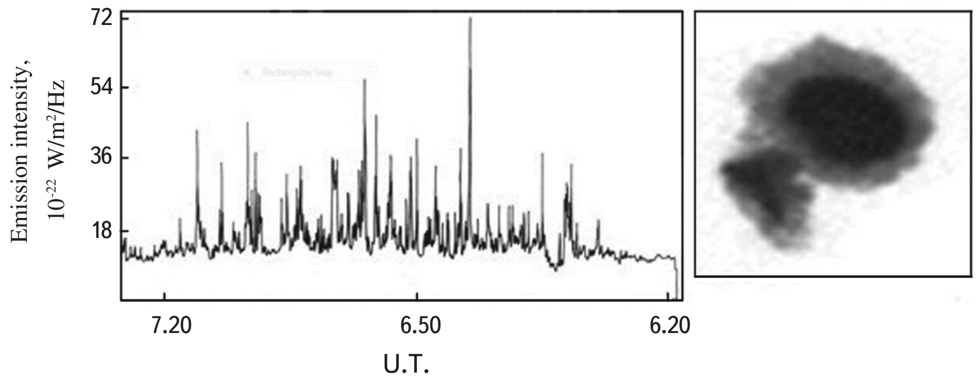

Fig. 2. Solar radio emission and a picture of sunspots on July 27, 1981.

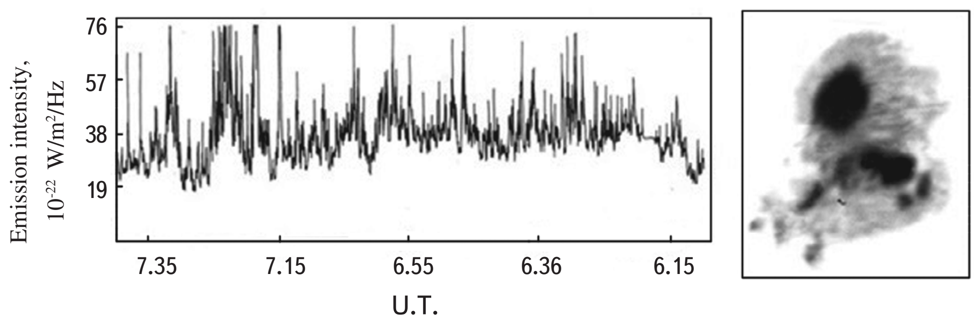

Fig. 3. Solar radio emission and a picture of sunspots on November 12, 2001.

Figure 3 shows a plot of the solar radio emission and an image of sunspots for November 12, 2001. The plot shows that this was a very intense radio burst and it fluctuated over 20-100x10^{-22} W/m^2/Hz. On this day an especially large group of sunspots was recorded on the eastern edge of the sun near the north pole.

3. Discussion and results

Many researchers [7,10] have obtained similar results in different frequency bands based on interference and polarization observations. The variation in the continuum components of radio bursts is closely related to the area occupied by the sunspot group. Solar radio flares of the first time, however, have a rigid relationship to oscillations in the magnetic field strength of sunspots.

A comparison of the radio flux at 10.7 cm with the number of sunspots for solar cycles 19-21 shows that the radio flux depends on the magnetic field associated with the sunspots. The radio flux at 10.7 cm and its relationship to the number of sunspots and other parameters has been reported for each of these cycles. These data show that the radio flux at 10.7 cm seems to be stochastic for cycle 19 and chaotic for cycles 20 and 21 [22,23]. The solar radio emission provides valuable information on the structure and dynamics of the sun's atmosphere above a temperature minimum. In an effort to provide maximum detail in the picture of the quiet sun and active regions with the aid of the radio regions, researchers have examined new observational and theoretical results on the quiet sun and active regions over the entire range of radio waves from millimeter to decameter wavelengths. In principle, the radio frequencies can provide us with as much information as the rest of the spectrum of the solar atmosphere. Further refinement and improvements for the mechanism of noise bursts will require optical observations of chromospheric flares and spots with magnetographs. Observations of this kind will make it possible to determine the magnetic field strength of the large spots, as well as the variation in their area over time intervals of hours [24-29]. Based on an analysis of the observational data, we have found that in most cases radio bursts are produced in a group of spots with a complicated structure and during growth of large spots. In addition, the maxima of radio flares and the peak magnetic flux of large groups of sunspots coincide to within a day. On the other hand, a strong magnetic flux in a group of spots is a precursor of a strong chromospheric flare.

This analysis of the experimental data shows that the maximum duration of radio noise is 7-10 days and that flares appear earlier and disappear later than the elevated radiation background.

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