QUASIPERIODIC LOW-FREQUENCY FLUCTUATIONS OF THE RADIO EMISSION OF THE SUN

Astronomy

1968

SovietRxiv

Abstract

Full Text

UDC 523.164:524.7

Astronomy

QUASIPERIODIC LOW-FREQUENCY FLUCTUATIONS OF THE RADIO EMISSION OF THE SUN

O. I. Yudin

(Presented by Academician V. L. Ginzburg on 26 VII 1967)

The chromosphere of the Sun is a medium that is complex and inhomogeneous in its structure, in which the parameters determining its structure fluctuate about certain mean values. In it, along with spatial fluctuations, motions of chromospheric masses of various scales are observed ([1]), the most intense of which cause changes in the flux of the Sun' s radio emission in the centimeter wavelength range. Emission at wavelengths $\lambda \sim 3$ cm comes from layers of the chromosphere located at heights from $5 \cdot 10^3$ to 10^4 km above the photosphere, and, consequently, its changes are caused by processes in this region.

To study the influence of weak fluctuations of chromospheric parameters on changes in the flux of the Sun' s radio emission, a quasi-null method of registration at a wavelength of 3.3 cm was used ([2,3]). Since 1964, at the radio-astronomical testing ground of our institute, "Zimenki," studies have been carried out of the statistical characteristics of fluctuations in the signal level from the Sun. The signal at the output of the radiometer was proportional to the temperature difference ΔT at its input,

$$\Delta T = T_{A\odot} - T\,,$$

where $T_{A\odot}$ is the temperature at the input of the radiometer with the radio-telescope antenna pointed at the Sun; T is the temperature at the second input of the modulation radiometer, produced by a noise generator. As a result of prolonged observations it was established that, when active regions appear on the Sun, fluctuations of the signal level at the output of the radiometer increase from 0.05 to 1.0% of $\overline{T}_{A\odot}$. The frequency of recurrence of these events is 70-80%. In all, over 3.5 years, about 200 cases of an increase in the fluctuations of the signal were observed. Such phenomena had been observed earlier as well ([4]-[6]) and were explained only by the influence of the troposphere.

In view of this, special experiments were carried out by us to separate effects of solar origin from fluctuations caused by other causes—instability of the ap-

Fig. 1

Figure 1: Fig. 1

paratus, tropospheric propagation, etc. The use of the quasi-null method of receiving the radio emission of the Sun made it possible to reduce by an order of magnitude the random changes in the signal level at the radiometer output, ΔT_α, caused by fluctuations of the gain coefficient. Measurements showed that $\Delta T_\alpha < 0.05\%$ of $\overline{T}_{A\odot}$. To exclude the influence of other factors, observations were carried out on two radio telescopes installed initially at one site and then separated by a distance of 500 m from one another. Comparison of the records of changes in the flux of the Sun' s radio emission on both radio telescopes showed that the fluctuations observed when the activity of the Sun increases remain correlated even with separated reception. The mean coefficient of mutual correlation of the records from two antennas for the active Sun is 0.5, and for the quiet Sun 0.1. By this method the influence of instrumental effects was completely excluded.

To reduce the influence of tropospheric inhomogeneities on fluctuations of the signal, observations were carried out when the height of the Sun above the horizon was great–

more than 15—20°. It is known ([7]) that, for small-scale inhomogeneities, the correlation radius of the spatial field of fluctuations of the radio-emission flux that has passed through an inhomogeneous layer of thickness L is equal to $\sqrt{\lambda L}$. In our case $\sqrt{\lambda L} \ll 500$ m, which makes it possible not to regard the field of these inhomogeneities as the source of the observed fluctuations. Large-scale inhomogeneities with dimensions $l > 500$ m may, in principle, cause correlated fluctuations at the outputs of radio telescopes separated by a distance $d < l$. However, for such an explanation of the observed changes in the radio-emission flux of the Sun, it is necessary that the appearance in the atmosphere of large-scale inhomogeneities of the refractive index be associated with the emergence of active regions on the Sun. There are no experimental or theoretical grounds for such an assertion. Thus, in our opinion, there are sufficient grounds to believe that the correlated part of the radio-flux fluctuations at the output of two separated radio telescopes represents signal variations associated with processes in the solar chromosphere.

Fig. 1. Spectra of realizations: G_1–spectra of the disturbed Sun; G_2–spectrum of the quiet Sun; G_3–spectrum of the noise generator. a–18 X 1966, 9 h 20 min –11 h; b–25 III 1967, 8 h 20 min–9 h 30 min; v–30 V 1967, 15 h 12 min–16 h 10 min.

By the spectral-correlation method, using a computer, an analysis was carried out of the signal fluctuations $T_{A\odot} - T_{\text{ng}}$. From the experimental auto- and cross-correlation functions, energy spectra were calculated in the frequency range from 10^{-3} to 10^{-4} Hz. In fact, we obtained the sum of the spectra of fluctuations of

Fig. 2. Histogram of modulation periods

Figure 2: Fig. 2. Histogram of modulation periods

two signals, $T_{A\odot}$ and T_{ng}. Therefore the spectrum of interest to us–the spectrum of fluctuations of the solar radio-emission flux–is the difference between the spectra of the observed signal $T_{A\odot} - T_{\text{ng}}$ and the spectrum of fluctuations of the signal from the noise generator T_{ng}. The latter was determined experimentally from records of the difference of the emissions of two noise generators connected to the input of the radiometer ($T_{\text{ng}} - T_{\text{ng}}$). In the spectra of the signals $T_{A\odot} - T_{\text{ng}}$, maxima were found whose intensity correlates with changes in solar activity. In the spectra of T_{ng} no such maxima are observed; the spectrum in the analyzed frequency range is uniform to within the measurement errors.

Figure 1 gives instantaneous spectra of noise records of the active Sun (G_1), in which the intensity of the quasiperiodic components is 2-4 times greater than the intensity of these components in spectra of the quiet Sun (G_2). For comparison, the instantaneous spectrum of fluctuations of the power of the noise generator (G_3) is also shown here. The vertical lines indicate the limits of the 95% confidence interval ($\pm 2\sigma$). The spectrum of the quiet Sun was obtained by averaging over 6 realizations, which reduced the random error. Relative quantities are plotted on the ordinate axis.

The spectra obtained indicate the presence of quasiperiodic modulation of the Sun's radio emission, observed even for the quiet Sun and enhanced when centers of activity appear on the Sun. Such quasiperiodic components in the spectra of fluctuations of the solar radio-emission flux have been detected for the first time. The frequencies of the modulation periods vary from one record to another.

Fig. 2 shows a histogram of the quasiperiods of modulation observed at various times from October 1966 to May 1967. The periods of the detected oscillations coincide with the periods of vertical oscillations of the layers of the photosphere and lower chromosphere discovered by Leighton ([8]). The results obtained allow us, in our opinion, to assert that the quasiperiodic modulation of the solar radio-emission flux is caused by processes in the upper chromosphere. This conclusion does not contradict modern ideas about the structure and dynamics of the solar chromosphere. By way of discussion, two possible mechanisms of this phenomenon may be indicated: quasiperiodic modulation of the Sun's radio emission by vertical motions in the chromosphere, and modulation caused by the spicular structure of the chromosphere ([9]).

Fig. 2. Histogram of modulation periods

In conclusion, I consider it my duty to express my gratitude to M. M. Kobrin for formulating the problem, to M. S. Durasova, G. A. Lavrinov, and A. K. Chandaev for their great assistance in carrying out the experimental work and in processing the observational materials, and to V. V. Zheleznyakov for useful discussion of the results.

Research Radiophysics Institute
at Gorky State University
named after N. I. Lobachevsky

Received
23 VII 1967

CITED LITERATURE

1. S. B. Pikel' ner, *UFN*, **88**, 505 (1966).
2. M. S. Durasova et al., *Geomagnetism and Aeronomy*, **6**, No. 5 (1964).
3. M. S. Durasova, O. I. Yudin, *Solar Data*, No. 7, 72 (1966).
4. J. Kazes, J. L. Steinberg, *C. R.*, **240**, 499 (1955).
5. J. Kazes, *C. R.*, **245**, No. 7, 782 (1957).
6. J. Aarons, J. P. Castelli, *IRE Trans. Antennas and Propagat.*, **9**, No. 4, 390 (1961).
7. V. I. Tatarskii, *Theory of Fluctuation Phenomena in Wave Propagation in a Turbulent Medium*, Izv. AN SSSR, 1959.
8. R. B. Leighton, R. W. Noyes, G. W. Simon, *Astrophys. J.*, **135**, 474 (1962).
9. O. I. Yudin, *Izv. vyssh. uchebn. zaved., Radiophysics*, **10**, No. 8 (1967).

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