OBSERVATIONS OF FLUCTUATIONS IN THE INTENSITY OF RADIO EMISSION FROM THE QUASI-STELLAR SOURCE 3C-48 ON INHOMOGENEITIES OF THE INTERPLANETARY PLASMA

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OBSERVATIONS OF FLUCTUATIONS IN THE INTENSITY OF RADIO EMISSION FROM THE QUASI-STELLAR SOURCE 3C-48 ON INHOMOGENEITIES OF THE INTERPLANETARY PLASMA

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1. The application of the "probing" method (1) in the study of near-solar plasma led to the discovery of the scattering of radio waves coming from the Crab Nebula in the outer regions of the solar corona (2,3). Plasma inhomogeneities of near-solar space were detected, receiving the name of the supercorona of the Sun. Inhomogeneities of the "quiet" supercorona were traced up to $(50 \div 60)R_\odot$ from the Sun, and in individual cases up to $100R_\odot$ (4). In (2), in addition to the scattering effect, irregularities of the radio-interference pattern were noted for the first time in recordings of a discrete source, which testified to dynamical processes in the supercorona; and whereas previously only ionospheric fluctuations of the intensity of a discrete source had been observed, in paper (2) cases of non-ionospheric intensity oscillations were first noted. The time of variation of the intensity (the "scintillation" time) was several minutes. Similar scintillation phenomena were later observed in Australia by O. B. Slee (5). Theoretical analysis showed that we are dealing with large-scale inhomogeneities moving with velocities of the order of several thousand kilometers per second; this is a case of observing scintillations on inhomogeneities of a "disturbed" supercorona.

However, radio scintillations on inhomogeneities of the quiet supercorona had not been observed until recently. The first cases of scintillation in the quiet supercorona were recently observed by Hewish (England), as reported in (6). He carried out observations at a frequency of 178 MHz and obtained reliable data on radio scintillation. The characteristic scintillation period was 1-2 sec.

At the Radio Astronomy Station of the P. N. Lebedev Physical Institute of the Academy of Sciences of the USSR, soon after the commissioning of the east-west line of the DKR-1000, investigations in this direction were undertaken; use was made of the theoretical works of V. L. Ginzburg (7), V. V. Pisar’ eva (9), and also V. I. Shishov.

Fig. 1. Copies of the record curves

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2. We systematically observed the quasi-stellar source 3C-48 at a wavelength of 3.5 m (f = 86 MHz) and at a wavelength of about 7.5 m (f = 40 MHz) on field B-3 of the DKR-1000 radio telescope, a description of which is given in (^{8}). The effective area of the field is about 1000 m^2 (without preamplifier heads). The time constant of the recorder (EPP-09) is about 1 sec. Observations were carried out on two halves of the field with a correlator switched in at the output. The pencil beam had a width (to 0.5 power) of $12'$ and $27'$ at the indicated wavelengths, respectively. The time for the source to pass through the lobe of the pattern was 1 and 2.1 min. Observations have been conducted from the beginning of February 1965 to the present time; at the beginning of the observations the angular distance α between the Sun and the source was about 80°. The closest distance was on 25 IV and was $\alpha = 21^\circ.20$.

We shall report the principal results obtained at a wavelength of 3.5 m. As the source approached the Sun, in February its fluctuations were not always distinctly observed, whereas in March they were quite clearly seen in an individual record. In the following months the fluctuations were observed distinctly and ceased at the end of June. Figure 1 gives the curves of the original records and shows the points used for the reduction.

Fig. 1. Copies of the record curves of sources with a time constant of about 1 sec. Wavelength 3.5 m.
a –record of source 3C-33, 21 IV 1965, fluctuations are not observed; *b* –record of 3C-48, 21 IV 1965, fluctuations are visible; *c* –record of 3C-48, 2 V 1965, fluctuations are visible. The points used to determine the amplitude and period of the fluctuations are marked by circles.

As a measure of the fluctuations we take the arithmetic mean of the maximum deviations of the intensity from the mean value, divided by the mean intensity,

$$f = \overline{|\Delta I|}/I_0.$$

On 2 II and 3 II, apparently, the onset of fluctuations could already be noted, although their values are very uncertain and amount to about 20%; on 11 II (α = 73°) the scintillations were observed quite clearly, and the value of f reached a large value (30%). Subsequently observations were carried out almost daily. Table 1 gives the values of f, averaged over calendar observing periods of 15 days; α is the mean angle; ρ is the corresponding value of the minimum distance of the line of sight from the Sun.

As can be seen from the table, the value of f increases markedly in February and at the beginning of March; later, in March, April, and May, its changes are comparatively small. From day to day the magnitude of the fluctuations sometimes changes sharply; cases were observed in which f for adjacent days changed by a factor of 2. Thus, for example, on 3 V 1965 $f = 49\%$, and on 4 V 1965 $f = 100\%$. Moreover, the value of f sometimes changed noticeably within one and the same record, i.e., over a time interval of less than 1 min. For example, on 15 IV 1965, during 30 sec, f changed from 70 to 40%. Values of f were constructed for slower and faster fluctuations. On the average, no differences in the course of the curves were found.

3. Let us turn to the characteristic period of the fluctuations. In reducing the observations, no complete correlation analysis was carried out; nevertheless (as is evident, in particular, from Fig. 1), it was possible to count fairly reliably the number of excursions per unit time, which usually followed

fairly regularly, with clearly expressed intensity maxima. The mean time between them we denote by T. In some records—

Table 1

	1-14 II	15-28 II	1-14 III	15-31 III	1-14 IV	15-30 IV	1-14 V	15-31 V	1-14 VI	15-30 VI
f, %	15–20	27	44	48	53	55	58	52	33	32
α, degrees	77	63	51	38.5	27	21.5	24.5	33.5	46	58.5
P, AU	0.97	0.89	0.78	0.62	0.45	0.37	0.41	0.55	0.72	0.82

—other periodic variations seemed to be superimposed on the general pattern of fluctuations. In this case one may speak of the quantities T_1 and T_2. At times it was possible to suspect the presence of three periods. All comparatively reliable values of T in Fig. 2 are presented in the form of a histogram. It is seen that the principal maximum, with a period between 3 and 4 sec, stands out clearly. Between 6 and 7 sec a second maximum is indicated; on individual tapes it is expressed quite distinctly. Finally, a long "tail" of the distribution curve of T is observed in the range 10-18 sec. The question of the dependence of the fluctuation period on the distance α of the source from the Sun was analyzed. Within the accuracy of the observations, the histogram of the distribution of T did not depend on the angle α.

Fig. 2. Histogram of the fluctuation periods of the source 3C-48 at inhomogeneities of the interplanetary plasma. Wavelength 3.5 m. N is the number of cases for the given limits of variation of the value of the period T.

4. Observations at a wavelength of 7.9 m, and later at a wavelength of 7.4 m, were for the most part spoiled by interference from distant radio stations.

Fig. 2. Histogram of the fluctuation periods of the source 3C-48 at inhomogeneities of the interplanetary plasma. Wavelength 3.5 m. N is the number of cases for the given limits of variation of the value of the period T

Figure 2: Fig. 2. Histogram of the fluctuation periods of the source 3C-48 at inhomogeneities of the interplanetary plasma. Wavelength 3.5 m. N is the number of cases for the given limits of variation of the value of the period T

It was not possible to observe fluctuations regularly. A number of cases were noted in which, at a wavelength of 3.5 m, distinct fluctuations were observed, while at a wavelength of 7.9 m, if they occurred at all, they had a considerably smaller value of f. On the other hand, fluctuations were recorded on individual days: for example, on 2 II $f = 50\%$, on 28 IV $f = 30\%$, on 2 V $f = 30\%$. In general, the picture of the phenomenon at this wavelength requires additional measurements.

5. In drawing conclusions from the observations, we shall proceed from a scheme according to which the diffraction pattern of the field distribution produced on the Earth by inhomogeneities of the interplanetary plasma moves with a velocity v equal to the velocity of motion of the interplanetary plasma (the orbital motion of the Earth may be neglected). The velocity v is not known to us precisely, but for estimates one may take $v \simeq 300$ km/sec. Then, for fluctuation times of 3.5, 6.5, and 10–17 sec obtained from the observations, we estimate the corresponding linear scales of the diffraction pattern l: 10^3; $2 \cdot 10^3$; and $(3 \div 5) \cdot 10^3$ km. The relation of the linear size l of the diffraction pattern to the characteristic linear size of the plasma inhomogeneities L is ambiguous and depends both on the root-mean-square phase path $\sqrt{\Delta\psi^2}$ along the ray path and on the distance D between the inhomogeneities and the observing point. In the case $\sqrt{\Delta\psi^2} \leqslant 1$, one may take, in accordance with theory (^{9}, ^{10}), that $l \simeq L$, i.e., the data given above could be interpreted as characteristic sizes of inhomogeneities of the interplanetary plasma. However, from estimates based on data on the scattering of sources (^{11}) one can find

order of magnitude $\sqrt{\overline{\Delta\psi^2}}$. For a wave of 3.5 m, $\sqrt{\overline{\Delta\psi^2}}$ apparently has a value from several units to several tens. In this case the diffraction pattern, according to the works (^{9}, ^{10}), in addition to a component with characteristic size $l = L$, also has a component with smaller dimensions $l \sim L/\sqrt{\overline{\Delta\psi^2}}$. This component probably plays some role in the fluctuation pattern, and consequently, in order to obtain the sizes of the inhomogeneities L, the data presented must be correspondingly increased; in any case, the values of l obtained give a reliable lower limit to the quantities, and their values will prove different after the velocity v has been refined.

6. The spots of the diffraction pattern on the Earth, with dimensions of 500–1000 km, are seen from the location of the scattering inhomogeneities,

situated on average at a distance of 1 AU = $1.5 \cdot 10^8$ km, at an angle $\psi = 0.7'' \div 1.4''$. Since in these cases strong scintillation was observed, with intensity variations up to 100% (with an accuracy of about 20%), it may be concluded that the source has effective dimensions of the order of $0.1''$. The dimensions of the other quasi-stellar source studied, 3C-147, whose scintillation was observed just as clearly as that of 3C-48, are of the same order. To our knowledge, no other methods have achieved such high resolving power in estimating the sizes of radio sources.

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