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Abstract

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RADIO-ASTRONOMICAL STUDIES OF THE MOTIONS AND SIZES OF SMALL-SCALE INHOMOGENEITIES OF INTERPLANETARY PLASMA

(Presented by Academician N. G. Basov, 2 XII 1967)

Observations, carried out since the beginning of 1965 in the radio-astronomy laboratory of the P. N. Lebedev Physical Institute of the USSR Academy of Sciences, of rapid changes in the intensity (scintillations) of radio emission received on Earth from sources with small angular size (1,2) have been further developed. The scintillations are recorded simultaneously at several points separated from one another by a certain distance. Whereas observations at a single point made it possible to obtain only the magnitude and period of the scintillations, several points make it possible to determine directly the magnitude and direction of the velocity of motion of the diffraction pattern (and consequently of the plasma inhomogeneities), as well as the characteristic sizes, shape, and orientation of the inhomogeneities.

At present there are data on measurements of the solar wind by various methods. However, radio-astronomical studies do not simply supplement the capabilities of these methods, but have a fundamental difference. In particular, with rockets only the proton component of the solar wind is measured, whereas by the radio-astronomical method we obtain the characteristics of the motion of the inhomogeneous electron component. In addition, in contrast to rocket measurements, by the radio-astronomical method regions are studied from very close to very remote distances from the Sun. The formulation of these studies is discussed in paper (3)*. The observation points are located at the vertices of an approximately equilateral triangle with sides of 220 km. The receiving antenna at one of the points is the range cross-shaped radio telescope in Pushchino. Two other radio telescopes, with an effective antenna area of about 1000 m^2 each, are located in the region of the city of Kalinin and the city of Pereslavl-Zalesskii. Recording is carried out at all points simultaneously. Time synchronization is achieved by continuous recording on the chart tape of precise-time signals.

The first simultaneous observations of scintillations at three points were carried out by us in July–September 1966 (4). Since March 1967, continuous observa-

Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

tions of the sources 3C-48, 3C-144, 3C-147, and others have been under way. The similarity method is used for the processing. Only clearly similar sections of the curves obtained at the three points are processed. From characteristic points on these curves, for example from maxima and minima of the amplitude fluctuations, the relative time shifts are determined. From the known geometry of the points and the obtained values of the time shifts, the directions and magnitudes of the velocities of the diffraction pattern relative to the observation points are determined. Here we present results obtained from daily observations of the source 3C-48 in the first half of 1967.

Figure 1 shows the velocity vectors averaged over one day of observations. The apparent position of the source on the celestial sphere relative to the Sun—from day to day; *a*—the phase of approach of the discrete source to the Sun, *b* —the phase of recession. It is seen that, on the average, the obtained directions of motion are close to radial, away from the Sun, with velocity magnitudes of $\sim 200 \div 300$ km/sec.

The dependence of the velocity direction on the distance from the Sun can be traced from the data in Fig. 2, where the deviation $\Delta\theta$ is shown for different positions of the source.

Fig. 1. Values of the velocity vectors of the diffraction pattern on different days of observations (from 15 III to 15 VI 1967). This corresponds to the velocities of inhomogeneities at various distances from the Sun. Source 3C-48. λ 3.5 m. *a*—phase of approach of the source to the Sun; *b*—phase of recession; $\varphi = 21^\circ$—minimum angular distance of the source from the Sun. Each vector is the mean from the data of one day.

positions of the source. The circles indicate the mean values of $\Delta\theta$ for values $\theta > 25^\circ$ and $\theta < 25^\circ$, respectively. In the first case $\Delta\theta = 14 \pm 3^\circ$, in the second case $\Delta\theta = 15 \pm 7^\circ$. Thus, at large distances there is observed a deviation of the direction of motion toward the equatorial region; for small distances (polar regions) there is observed a deviation from the radial direction toward the line of the solar pole.

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* The methodology and apparatus will be described in greater detail in the *Transactions of the P. N. Lebedev Physical Institute of the USSR Academy of Sciences.*

Fig. 3

Figure 3: Fig. 3

Fig. 2. Magnitude of the angle of deviation from the radial direction of motion for different distances φ from the Sun. Source 3C-48. λ 3.5 m. 1967. $+\Delta\theta$–deviations toward the equatorial plane; $-\Delta\theta$–deviation toward the line of the pole.

Figure 3 presents a histogram of the velocities of the diffraction pattern. The mean value of the measured velocities is 233 km/sec. However, it should be noted that the measured velocity and the direction of the diffraction pattern coincide with the true values only in the case when the front of the diffraction pattern is rectilinear and perpendicular to the direction of motion. If the angle between them is ψ_1, then what is measured is not the true velocity V_0 of the diffraction pattern, but the velocity $V = V_0 \cos\psi_1$, i.e., owing to the indicated effect the measured velocity magnitudes are, on the average,

less than the true values. This same circumstance leads to an increase in the dispersion of the measured directions of motion. In determining the velocity of motion of the inhomogeneities, one should take into account the fact that, for inhomogeneities not lying in the plane perpendicular to the line of sight, the measured velocity values are also smaller than the true ones; this can be allowed for by introducing an effective angle ψ_2. The expression for the true value of the velocity V_i of such inhomogeneities, taking the above-mentioned effects into account, has the form:

$$V_i = V / \cos\psi_1 \cos\psi_2. \tag{1}$$

For our observing conditions $\cos\psi_1 \cos\psi_2 \approx 0.7 \div 0.8$, and, consequently, the mean value of the velocity of the inhomogeneities is equal to 280–300 km/sec.

Fig. 3. Histogram of the measured velocity values of the diffraction pattern. Source 3C-48. λ 3.5 m. 1967. $\overline{V} = 233$ km/sec–the mean velocity.

In papers (4,5) it was noted that, when the apparent distance of the source from the Sun decreases, an increase in the velocity of the solar wind is observed. However, according to our data from this series of observations, as is seen from Fig. 4, there is no reliable dependence of this kind. Some increase in velocity is suggested as the source approaches the Sun, but in the second phase (as the source recedes) such a dependence is not manifested. In the same figure, a decrease in velocity is observed in the region nearest the Sun.

On the basis of the results obtained, the linear dimensions of the diffraction pattern (the mean distances L between maxima and minima) and the dimensions of the inhomogeneities are determined unambiguously. The mean value $L = VT$ is equal to 980 km. This corresponds to a size of the inhomogeneities

Fig. 4

Figure 4: Fig. 4

Fig. 4. Dependence of velocity on the date of observations (on the angular distance of the source from the Sun). λ 3.5 m. 1967. V—measured velocity of the diffraction pattern; V_i—velocity of the inhomogeneities. Means over 5 days ($-65^\circ < \Delta\theta < +65^\circ$).

$$(2a = L/2.6)$$

of approximately 380 km. It is now possible to find the electron concentrations (more precisely, their excess over the mean value). Calculations (^{6}) give values $\Delta N \sim 2 \cdot 10^{-2}$ for $\varphi \sim 40^\circ$.

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