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We discuss the capabilities of VLBI studies of irregularities of the solar-wind plasma using multi-element radio interferometric facilities. We analyze the data obtained during international VLBI experiments at decimeter wavelengths (92 and 18 cm) in 1994–1996 and supposed that the irregularities have a “stream” structure. The “streams” are strongly elongated in the solar-wind direction (longitudinal size of about a few hundred thousand kilometers) and have the transverse size of about 0.5–2.0 thousand kilometers. The irregularities inside a single “stream” are almost isotropic. We discuss the restrictions imposed on operation of decimeter VLBI systems due to effects of the interplanetary medium.

Cosmic media of the solar system are studied now using mainly the scintillation method based on measuring scintillations of intensity of the radiation received from discrete space radio sources and the method of dispersive interferometry of coherent radiation at multiple frequencies, which is received by a spacecraft located outside the medium under study. The use of these methods encounters certain limitations. The scintillations arise due to relatively small-scale irregularities of the medium. The scale of such irregularities should not exceed the size of the first Fresnel zone $\sqrt{\lambda R}$, where $\lambda$ is the wavelength and $R$ is the distance to the irregularities. This means that irregularity scales of the interplanetary medium giving rise to scintillations are not larger than 400 km if the irregularities are located at a distance of about 1 AU and the wavelength of the occulting radiation is relatively large: $\lambda = 92$ cm. Moreover, the scintillations saturate if the radiation from a space radio source is subject to strong phase fluctuations upon propagation through the medium studied (e.g., in the solar vicinity). The dispersive interferometry method can only provide information on the state of the studied medium in a narrow region along the spacecraft trajectory and thus can only be used occasionally during the spaceflight.

In recent years the interplanetary medium has been studied by the method of very long baseline interferometry (VLBI). In this case, the source radiation, reaching the interferometer antennas located hundreds or thousands kilometers away from each other, propagates through irregular media over different paths with different phase and group velocities. Since an interferometer measures the degree of mutual coherence of radio emission from the source received at spatially split places, the phase of the interferometric response $\Phi$ can be used for direct measurements of the spatial structure function

$$D(d) = \langle (\Phi(x) - \Phi(x - d))^2 \rangle$$

of the phase fluctuations arising due to the effect of interplanetary-plasma irregularities. Here $d$ has the meaning of the projection of the interferometer base onto the wavefront plane, brackets correspond to the averaging over the realization ensemble, and the coordinate $x$ is reckoned along the interferometer base.

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Since \( d \) amounts to thousands of kilometers in VLBI and even hundreds of thousands of kilometers in the case of a space interferometer, there is an opportunity to directly study the spatial characteristics of irregularities of the solar-corona and interplanetary plasmas with spatial scales that cannot be studied by the scintillation method.

Weak irregularities change the phase of interferometric response. If strong irregularities exist in the occulted medium, phase distortions of the response are transformed into frequency ones. Thus the phase portrait of the interference response allows study of the weak irregularities, while the information on the characteristics of the strong irregularities can be obtained using the spectrum of the response and its location on the plane of mutual frequency–time shifts. In this case, the width and shape of the spectral line of interference radiation indicate the state of turbulent near-solar medium.

Therefore, the VLBI method allows one to study spatiotemporal structure of medium- and large-scale irregularities of the near-solar plasma and interplanetary medium occulted by extra-Galactic radio sources and offers an opportunity to extend the range studied to both very weak and intense irregularities. VLBI observations become more informative if simultaneous observations using a few bases of different lengths and orientations are performed. In this case, it is also possible to judge the irregularity shape (anisotropy).

This paper is a short overview of VLBI studies of irregularities of the near-solar plasma. We also describe here the results of our studies of the physical characteristics of interplanetary-plasma irregularities, which were obtained during international VLBI experiments in 1994–1996.

The first experiment on occultation of the near-solar turbulent plasma by signals of 30 cm wavelength from the interplanetary spacecraft “Venera-15” was performed on June 27, 1984 using the Crimea–Moscow region base of length 1200 km [1]. Antennas of diameters 70 and 25 m and the VLBI hardware complex of the Radiophysical Research Institute (NIRFI) [2] were involved in this experiment. The measurements were performed at elongation 3°. A pronounced broadening of the interference-signal spectrum amounting, on average, up to 8 Hz was observed. Such broadening arises due to coronal-plasma irregularities. Moreover, the line width was detected to change from 7.9 to 9.5 Hz over 20 min. The spectral line of the interference oscillation was approximated by a Laments profile. According to [1], this corresponds to the spectral index 3 of the spatial power spectrum of irregularities in the scale range below 1,000 km.

In 1989–1990 the same team performed experiments on radio interferometric studies of the near-solar plasma occulted by quasar radiation at a wavelength of 18 cm using the locations Eupatoria, Ussuryisk, and Medvezhyi Ozera. The spectral characteristics of the plasma turbulence and the anisotropy of its irregularities were studied in these experiments. The results of these observations confirmed the conclusions of [1]. No pronounced anisotropy of irregularities on the scale of a few thousand kilometers was observed at elongations 10 – 15° [3].

Space radio sources at small angular distances from the Sun were also observed by instruments with relatively small bases. These observations were aimed at studying irregularities of the solar-corona plasma. Thus, in contrast to our experiments, these observations were sensitive to smaller irregularities on the scale of a few tens of kilometers.

Such an experiment was described in [4]. The studies were performed in October, 1985 at frequencies 1665 and 4885 MHz. The source 3C279 was observed at elongation 0.6 – 3.3° from the Sun using the NRAO VLA antenna array. The lengths of baselines of the array (7 to 35 km) determined the irregularity scales subject to study by the interferometric complex. The authors conclude of the existence of highly anisotropic irregularities of the near-solar plasma.

The authors of [4] compared the results of their observations to the data of earlier experiments [5–9] in which the anisotropy of coronal scattering was studied. These works were mainly aimed at studying the angular scattering of the Crab nebula at elongations larger than 1.3 ° using the Culgoora and Clark Lake radio heliographs. In addition, VLA observations were also performed [10, 11]. In these experiments, the spatial coverage of the VLA allowed one to obtain two-dimensional information on irregularities on the scale of 0.2 to 2 km at angular distances 1.2 to 2.5 ° from the Sun.

Combining the results on the analysis of the dependences of the viewing function amplitude on length