RESEARCH OF THE FINE STRUCTURE OF THE RADIO GALAXY 3C 234 WITH RADIO INTERFEROMETER URAN-2

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The brief description and the basic characteristics of the radio interferometer URAN-2 aerial system, included in VLBI decameter system URAN, are presented. The research results of the 3C 234 angular structure with URAN system are submitted. The model of radiobrightness distribution of this source at frequencies of 20 and 25 MHz is obtained. With the URAN-2 radio interferometer compact details in a radio galaxy have been found and their contribution to the general flow of a radio emission at decameter waves is determined. The effect of reabsorption in compact details (hot spots) is found and their true angular size are determined based on the research of the 3C 234 spectrum.

INTRODUCTION

The radio emission research of space radiation sources at the decameter waves known as one is connected with the certain difficulties that is defined both of specificity of this range, and necessity of construction of the big aerial systems insufficient in this range. Thus, obtained high angular resolution can be reached not by separate tools, but with long-baseline interferometric systems, which for today are the most informative method of researches. Having in order of NAS of Ukraine decree the unique VLBI system URAN, we can study the fine structure of space radio sources at the decameter waves with $1''$ resolution.

In 2000 the construction, tests, and adjustment of the URAN-2 radio telescope included in this system have been completed that has allowed us to use it more effectively both in structure interferometer, and for the decision of independent radio astronomical tasks.

THE ARRAY OF RADIO TELESCOPE URAN-2

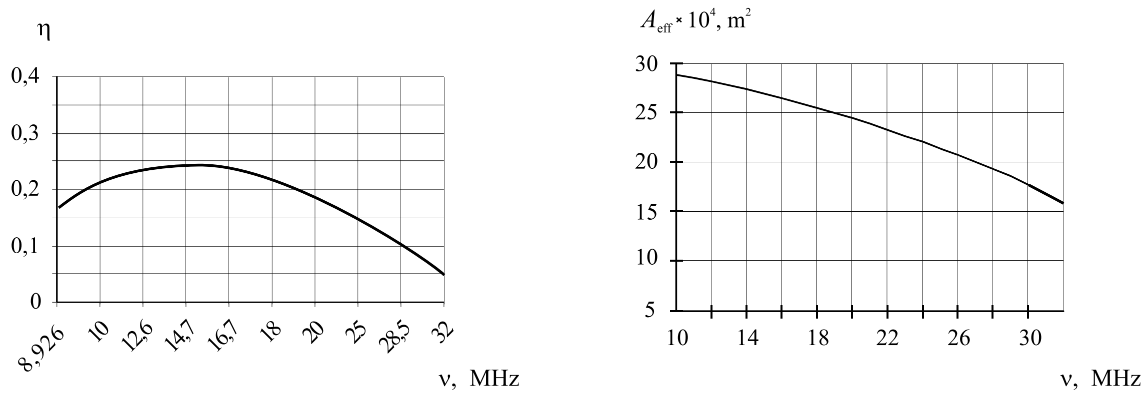
The URAN-2 radio telescope is situated in Stepanovka of Poltava region that is 153 km distance from UTR-2. The URAN-2 aerial in comparison with other aerials of URAN system, provides the highest spatial filtration of signals: on the azimuth A – up to 3.5°, on the corner of place ε – up to 7°. The resolution of an interferometer on declination is provided by the aerial "north-south" of a radio telescope UTR-2 which has the beam 0.5° width in zenith at the frequency of 25 MHz.

The antenna is executed as multielement rectangular horizontal phasing array with the dimensions of 238×118 m. It consists of 512 elements. As an element of a array the two orthogonal vibrators are used, located at an angle of 45° to meridian that enables to receive the two linear (circular) polarizations of a signal and to take into account the influence of Faraday rotation of a polarization plane in interplanetary plasma and ionosphere of the Earth.

For management by the directional diagram the time phasing method with the time delay lines for compensation advancing of signals in the dipoles is applied. It allows us to receive the signals practically for the most of the top hemisphere angles both in a wide band of frequencies, and simultaneously at the several different frequencies.

The phasing system executed under multi-storey circuits, provides discrete management of a beam on two angular coordinates such as $l = \cos\varepsilon \cdot \sin A$ and $m = \cos\varepsilon \cdot \cos A$ in the sector of ± 1 for each of two linear polarizations: 128 positions of a beam at the l coordinate and 64 positions of a beam at the m coordinate.

The basic characteristics of the URAN-2 array are shown in Fig. 1.



a) array efficiency b) effective area

Figure 1. Dependencies of the array efficiency η and the effective area A_{eff} on the frequency for zenith direction

RESEARCH OF THE ANGULAR STRUCTURE OF THE RADIO GALAXY 3C 234

In the interferometer composition the URAN-2 provides an angular resolution about $4''$ at sensitivity about 12 Jy, that allows us to investigate the fine structure of a brightness distribution of many radio sources.

One of the sources which was investigated lately with a radio interferometer URAN-2 and which had the expressed compact details, was radio galaxy 3C 234, classified as classical double FR II object with a steep spectrum. The structure of radio galaxy at the millimeter waves was represented rather complex and interesting, consisting of strongly extended jets at which edges the hot spots were observed. The spacing of the centers of hot spots was $110''$. At the centimeter and decimeter wavelengths the angular structure of radio galaxy has been also determined in details well enough, but already in a meter range its structure has not been established. In the most long-wave band *i.e.*, the decameter one, the observations were carried out with two facilities of the system URAN – URAN-1 and URAN-2 with D baselines of 42 and 153 km, respectively. The interferentional signals were formed by multiplication of signals of the URAN antennas with a signal of the antenna "north–south" of the UTR-2 radio telescope.

During the observations using both facilities the oscillation of dependencies of visibility function on a hour angle $\gamma(T_0)$ was presented. It is evidence of the interference in response to a minimum of two components of model of brightness distribution occurs at decameter waves. The oscillations observable using the UTR-2 radio interferometer indicated that the compact details (to sizes of which URAN-1 is not sensitive) are observed in 3C 234 structure. The high frequency of these oscillations specified of the significant angle distance between these details in space.

In connection with well-known difficulties of the observations at the decameter waves range and the "habits" of URAN system, during observations of a source only the modules of visibility function were measured. It does not allow us to use the methods of radiomaps construction by means of return Fourier transform used at high frequencies. So, the interpretation of the received experimental data was carried out by the model approximation method with a set of elliptic Gaussian components with different angular sizes and relationships of flows. It was applied χ^2 criterion in the degree of proximity measures of model to experiment.

To determine the initial conditions for search of models of 3C 234 radiobrightness distribution at decameter range, at the beginning it was necessary to define the model for frequency of 8 400 MHz. A dependence $\gamma(T_0)$ for this model would coincide precisely with calculated $\gamma_c(T_0)$ based on radiomap at the same frequency. The one general model of the brightness distribution was searched for four instanced values D/λ (URAN-1 – 3525 and 2820; URAN-2 – 12 692 and 10 153 at the frequencies of 25 MHz and 20 MHz, respectively). As a result the optimal model at the frequency of 8 400 MHz has been determined as five-component, consisting of two compact details and three extended, the greatest of which covers the central area of a galaxy, including its nucleus.

For the further refinement of this model by the computering technique with reference to the obtained in the decameter range experimental data, the optimal four-component model of brightness distribution consisting of two compact and two extended details adjoining to them has been obtained. The parameters of the derived model for the frequencies of 25 and 20 MHz are listed in Table 1, and the model is shown in Fig. 2 in the background of the galaxy radiomap derived with VLA at the frequency of 8 400 MHz.

It will be interested to carry out the analysis of the radio galaxy 3C 234 spectrum and in particular its components, and as far as possible to specify the true sizes of compact details. The maximum of radiation at

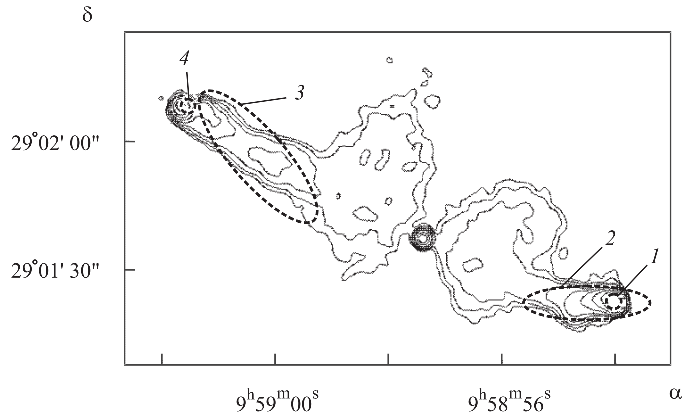


Figure 2. Model of 3C 234 brightness distribution derived at the frequency of 25 MHz (dotted curves) in the background of the 3C 234 radiomap (see Table 1)

Table 1. Parameters of the models of 3C 234 radiobrightness distribution at decameter waves[1]

ν, MHz	Component	$\Delta\alpha_i''$	$\Delta\delta_i''$	S_i/S_0	$\Delta\theta_i''{}_{max}$	$\Delta\theta_i''{}_{min}$	ψ°
	1 (S–W)	0	0	0.22±0.03	<2.3	<2.3	–
20	2	6.1±4.0	−0.4±13	0.33±0.06	35.7±6.0	9.2±2.6	0±40
	3	83.7±6.0	34.2±20	0.4±0.05	37±10	10.9±4.5	51.8±25
	4 (N–E)	96.3±2.2	46±14	0.05±0.02	<2.3	<2.3	–
	1 (S–W)	0	0	0.25±0.03	<2.3	<2.3	–
25	2	6.1±4.6	−0.4±12	0.33±0.06	29.6±6.5	7.6±2.8	0±36
	3	83.7±3.5	34.2±13.5	0.36±0.05	37±6	10.9±2.6	51.8±27.5
	4 (N–E)	98.8±1.3	45.6±7.7	0.06±0.02	<2.3	<2.3	–

the frequency about 50 MHz is observed for the compact components spectra. The various mechanisms are examined which could responsible for the falling of the spectral density of radiation lower than the frequency of a maximum. As a result was found out that the spectra of compact components coincide in the best way with the derived spectrum calculated for reabsorption. This one has enabled us to determine the own true angular sizes of the compact components at the decameter wavelengths: towards the North–East is $0.27''$; towards the South–West is $0.55''$ [2].

Thus, the two compact details of the radio galaxy 3C 234 have been allocated with the radio interferometer URAN-2 that has allowed us to establish a complete brightness distribution at the decameter wavelength, namely: it was found out that the radioimage of 3C 234 in the centimeter and decimeter wave bands in the certain extent is kept in the decameter range. It first of all touches on two compact components, their relative coordinates and angular sizes, and also the coordinates of the centers and orientation of the axes of two extended components located near to compact ones. The basic changes in brightness distribution of a source during the frequency reduction up to decameter waves consist of some times increasing of the angular sizes of extended components. The more essentially is an absence of an appreciable radio-frequency radiation of the most extended component of the high-frequency radioimage covering the central area of a galaxy with its nucleus and providing a significant part of a source total radiation at high frequencies.

[1] $\Delta\alpha_i''$ and $\Delta\delta_i''$ are the coordinates of the centers of components in arcsec ($\Delta\alpha_{\rm SW} = \Delta\delta_{\rm SW} = 0$); S_i/S_0 is relative magnitude of the components radioemission spectral density; $\Delta\theta_i''{}_{max}$ and $\Delta\theta_i''{}_{min}$ are the maximal and minimal angular sizes of components in arcsec; ψ is an angle of orientation of the main axis of components in grades (towards the West).

[2] The sizes seen on the Earth's surface and which are already dispersion-stricken in the interstellar and interplanetary medium are measured from the radio interferometric observations of compact details, but from spectral measurements their true sizes are determined when the reabsorption effect is available.