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ANGULAR STRUCTURE OF FRII RADIO SOURCES 3C169.1 AND 3C263 AT DECAMETER WAVELENGTHS

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ABSTRACT. The radio galaxy 3C169.1 and the quasar 3C263, located at nearly the same distance with red shift $z>0.6$, have similar morphological and spectral characteristics. The maps of the sources obtained at decimeter and centimeter wavelengths have shown they are FRII radio sources with steep spectra and approximately equal angular sizes. The very first investigation of the sources structure at decameter wavelengths is presented in the report. Observations were made using a network of the URAN decameter interferometers with baselines 42 to 950 km and with maximum angular resolution of arcsec order of magnitude. The models of the image of these sources based on visibility functions measured have been obtained at frequencies of 20 and 25 MHz. They were composed of elliptical components with Gaussian brightness distribution. To facilitate the comparison of these low-frequency models with high-frequency radio images, the latter were converted to the similar models by fitting the Gaussian components to lobes and hot spots selected at the maps. Comparison of the models revealed changes in a structure of the sources caused by the frequency decrease.

Keywords: interferometer, brightness distribution, decameter waves, radio galaxy, quasar.

1. Introduction

Observation of extragalactic radio sources at decameter wavelengths with the URAN interferometers has revealed that their angular structure at low frequencies differs considerably from high-frequency images of the sources. The most obvious reason is a difference in spectra of source components which leads to essential changes of a ratio of their fluxes and results in modification of the source brightness distribution at low frequencies. The most prominent spectral phenomenon is synchrotron self-absorption of radio emission which is observed in the most compact details of the sources such as a core or hot spots. It often leads to disappearance of these compact details in the decameter range. An increase of an angular size of source lobes is other feature of brightness distribution observed at low frequencies. It is related to synchrotron losses in the most aged areas close to the core of the source. The losses make these areas less prominent at higher frequencies but keep them bright enough at lower ones. Such phenomenon has been revealed in radio galaxies studied with the URAN (Megn et al., 1999, Megn et al., 2003). Furthermore, an extended structure has been found out in some quasars at decameters that significantly exceed the source dimensions measured at decimeter wavelengths (Megn et al., 1996, Megn et al., 2006). These components have large spectral indexes and low surface brightness that complicates their detection at higher frequencies. But at the same time they provide considerable part of the total source flux at the decameter wavelengths.

It is generally accepted that radio galaxies and radio loud quasars have common physical nature and differences in their optical/UV properties is a result of orientation of a source axis relative to the line of sight. General radio properties of large-scale structure of radio galaxies and quasars have to be similar. Individual features of the source radio structure can be connected with age and power of the sources, their environment and a redshift.

The radio galaxy 3C169.1 and the quasar 3C263 are convenient pair of the sources to study of common properties and distinctions of the large-scale structure of extragalactic radio sources. These sources have approximately equal flux densities and angular dimensions; they are located practically at the same redshift of $z\approx0.6$ hence possess similar physical conditions in them. The radio sources have a similar spatial structure of FRII type according to their high-frequency maps. The goal of this study was to obtain the angular brightness distributions of these objects at decameter wavelengths, to find a difference from their high frequency images, and also to compare the low frequency radio structures of the quasar and the radio galaxy.

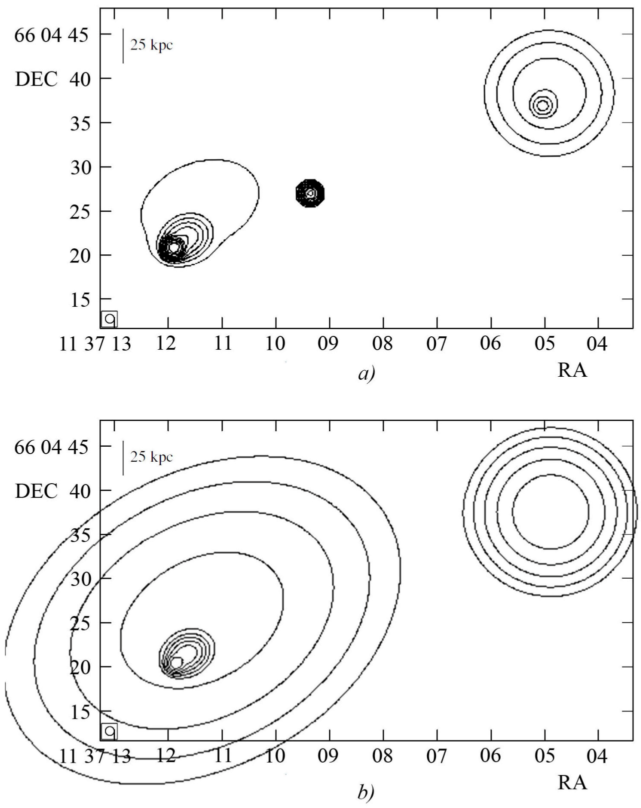

Figure 1: Models of brightness distribution of the quasar 3C263 at decimeter (a) and decameter (b) wavelengths

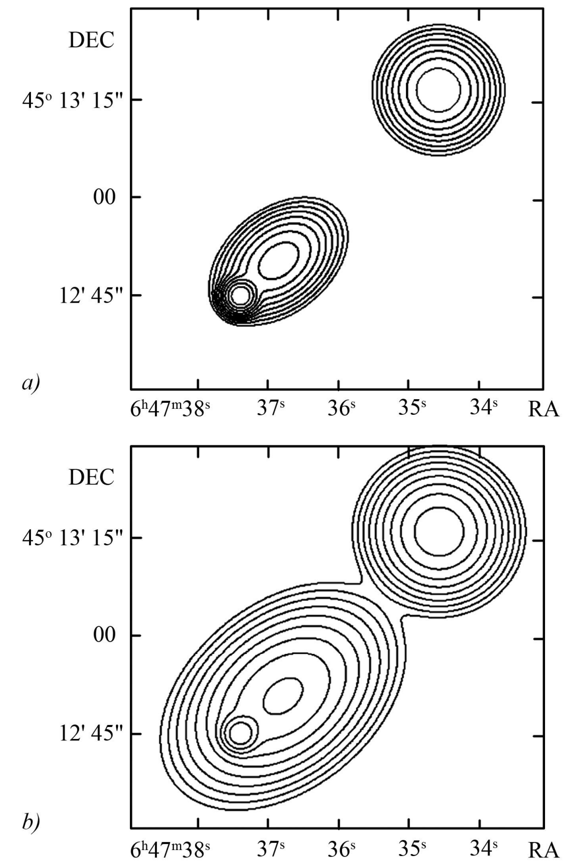

Figure 2: Models of brightness distribution of the radio galaxy 3C169.1 at decimeter (a) and decameter (b) wavelengths

2. Observations and reduction

Radio galaxy 3C169.1 and quasar 3C263 were observed at frequencies of 20 and 25 MHz with the URAN radio interferometers (Megn et al., 1997, Megn et al., 1998) during 2011-2013. The observations were carried out in the range of ±2 hours from the source culmination by seven minutes scans.

The arrays of radio telescopes URAN1-URAN4 have a possibility to receive the signals of two orthogonal linear polarizations to take into account Faraday rotation induced by Earth's ionosphere. Visibility functions were calculated using a software correlator by multiplication of signals recorded at each of the URAN radio telescopes with signal received by the North-South array of UTR-2.

Well-known technique of image reconstruction based on two-dimensional Fourier transform of complex visibilities cannot be used in observations at decameter wavelengths due to lack of a phase information. The method of model fitting using modulus of visibility functions was used instead to obtain brightness distribution of the radio sources.

The models were composed from elliptic components with Gaussian brightness distribution. Parameters of the models were fitted to obtain a good agreement of their spectrum of space frequencies with experimental hour angle dependences of the visibility amplitude (Megn et al., 2001).

At the first stage we used the maps of these objects obtained at higher frequencies to determine a quantity, dimension, form and relative position of the source components. For this purpose we calculate response of the map at space frequencies used in our observations with URAN and then fit simplest models to these calculated visibilities. The fitted model demonstrates how the source looks like from the "URAN's point of view" at high frequencies or at decameter wavelengths if its structure would not change with the frequency. Such models of brightness distribution are shown in the fig. 1a for the quasar 3C263 and fig. 2a for the radio galaxy 3C169.1.

The experimental visibility functions obtained in observations with the URAN interferometers differ significantly from the calculated map responses hence the angular structure of both sources was changed at decameter wavelengths.

At the second stage we fit a low frequency model to experimental data using models calculated above as an initial approximation to restrict the range of desired solutions and to eliminate ambiguities induced by a lack of the phase information. The models of the brightness distribution of the sources at frequency of 25 MHz obtained in this procedure are shown in the fig. 1b and fig. 2b for 3C263 and 3C169.1, respectively.

3. Discussion

To specify features of the source brightness distribution in the decameter range it is more convenient to compare the low frequency model with high frequency one rather than with the map. It allows determining the changes in flux density and dimensions of the source components quantitatively. At high frequencies the main part of the flux of both sources is provided by the hot spots and the cores. At decameter wavelengths the cores radio emission is negligible and not detected with the URAN. The low frequency flux of the hot spots in both sources is much lower than emanation of the lobes that provide the main part of the sources emission at these wavelengths. The angular size of the lobes is enlarged significantly with frequency decrease, especially for south-east lobes, that are located closer to the observer in both radio sources. The farther lobes are increased modestly and hot spots in them, quite observable at the higher frequency, are not detected at the lower one.

Centers of the brightness distribution of the extended components in both objects are shifted to the core of the source. It can be explained by influence of synchrotron losses in the oldest parts of the lobs. These parts were formed at earlier stage of source expansion and they are located closer to the core. The synchrotron losses have reduced energy of this most aged population of relativistic electrons hence their radiation at higher frequencies is weakened comparatively to the lower frequencies. This effect leads to the shift of the brightness centers of the lobes in the core direction at lower frequencies. Position of the hot spots at the decameter wavelengths practically coincides with their coordinates in the decimeter range.

4. Summary

The quasar 3C263 and the radio galaxy 3C169.1 were observed at the decameter wavelengths with the URAN interferometers. The models of the brightness distribution of the sources have been determined at low frequencies. It was found that at higher frequencies these objects have very similar properties. The radio sources have approximately equal angular sizes, flux densities, and ages and they are located at close redshifts. In the decameter range these quasar and radio galaxy also have similar angular structure but it differs significantly from their high frequency images. The compact details associated with the active cores of the sources are not detected. The lobes are enlarged noticeably and their relative brightness is increased compared to the hot spots. The extended structures whose size exceeds significantly source dimensions measured at high frequencies are not detected in both objects.

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