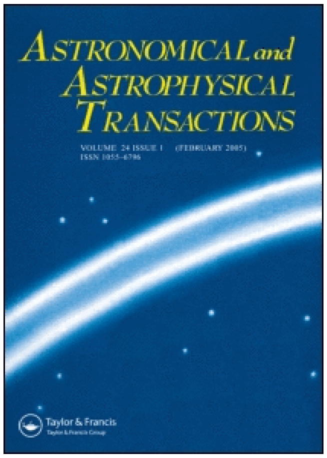

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Evolutionary features of the variations in the fluxes of selected extragalactic radio sources at 102 MHz, 22 GHz and 36 GHz

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Observations of galactic and extragalactic radio sources have been made at the DKR-1000 radio telescope at 102 MHz and at the 22 m Crimean Astrophysical Observatory radio telescope at 22 and 36 GHz. Here, the results of observations of six sources are presented. Time series analysis of the sources reveals quasiperiodic flux variability with timescales from 5 to 8 years. Variations are probably connected with the global evolution of the sources. A new outburst in the 3C 454.3 source, which started in May 2005 at 36 GHz was found. The variability of 3C 454.3 was found to be cyclic, with a mean period of 6.6 years at 22 and 36 GHz.

Keywords: Extragalactic radio sources; Evolution of flux variability

1. Introduction

The observations of millimetre-wave variability of extragalactic radio sources may give important information about active processes in their inner parts. Millimetre-wave observations of extragalactic radio sources were started at the 22 m Crimean Astrophysical Observatory radio telescope in 1973. Since 1973, over 10000 observations of some 140 sources have been obtained. The data shown here are from 1990 to 2005, and combined with our earlier published data they form a 32 year database.

As extended monitoring programmes have demonstrated, there are unpredictable outbursts, quiescent periods, minimum flux levels and secular trends. It follows from analysis that the flare evolution can be divided into three phases: a rapid flux increase; a plateau when the flux was relatively constant; and a slow intensity decrease. No significant differences between the flare evolutions in the various optical classes of radio sources were found.

The Odessa Observatory of the Radioastronomical Institute, Ukraineian National Academy of Sciences, has a long-term flux monitoring programme for extragalactic radio sources.

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The observations, at 102 MHz, are made at the DKR-1000 radio telescope of the Pushchino Radio Astronomy Observatory of the Astrospace Centre of the Lebedev Physical Institute. About 20 sessions of observations over 80 compact and extended radio sources have been obtained in 1984–1985, 1988–1992 and 1996–1998.

The apparent variability of radio sources at metre wavelengths is often caused by ‘scintillation’ due to the inhomogeneous nature of the local interstellar medium. However, many of the sources showed anomalous flux variations at metre wavelengths that do not appear to be due to interstellar scintillation.

In this paper, we present a comparison of the data from the two independent observational programmes, on the DKR-1000 and RT-22 radio telescopes.

2. Observations and data in use

2.1 *RT-22 observations*

The observations were carried out with the 22 m Crimean Astrophysical Observatory radio telescope. For our measurements, we used two similar Dicke switched radiometers of 22 GHz and 36 GHz. Until the end of 1981 the receiver with a radio-frequency preamplifier was used at 22 GHz. The properties of the receivers and the telescopes are presented in table 1.

The antenna temperatures from sources were measured by the standard ON–ON method described by Efanov *et al.* [1]. Before measuring the intensity, we determined the source position by scanning. The radio telescope was then pointed at the source alternately by the principal and reference (arbitrary) beam lobes formed during beam modulation and having mutually orthogonal polarizations. The antenna temperature from a source was defined as the difference between the radiometer responses averaged over 30 s at two different antenna positions. Depending on the intensity of the emission from sources, we made a series of 6–20 measurements and then calculated the mean signal intensity and estimated the root-mean-square error of the mean.

The gain of the receiver was monitored using a noise generator every 2–3 h. The orthogonal polarization of the lobes allowed us to measure the total intensity of the emission from sources, irrespective of the polarization of this emission. Absorption in the Earth’s atmosphere was taken into account by using atmospheric scans made every 3–4 h. The errors of the calculated optical depths are believed to be less than 10%.

The errors of the measured flux densities include the uncertainties of, firstly, the detected mean value of the antenna temperature of the sources, secondly, the calibration-source measurements, thirdly, the noise generator level measurement and, fourthly, the atmosphere attenuation corrections, but the main contributions to the quoted errors are due to the first two terms.

The flux density scale of observations was calibrated using DR 21, 3C 274, Jupiter and Saturn. The adopted parameters of the calibrators are listed in table 2.

Table 1. Parameters of the receiving systems.

Frequency (GHz)	Aperture efficiency	Half-power beam width	Beam separation	Sensitivity (t = 1 s) (K)	Detection level
22	0.43	$2.6'$	$18.3'$	0.20	0.08
37	0.40	$1.6'$	$8.3'$	0.15	0.06

Table 2. The flux density values and beam size correction factors C of calibration sources.

Source	f (GHz)	S (Jy)	C
DR 21	22.2	19.0	1.023
DR 21	36.8	18.06	1.050
3C 274	22.2	21.68	1.059
3C 274	36.8	15.04	1.104
Jupiter	22.2	1373	†
Jupiter	36.8	4348	†
Saturn	22.2	887	†
Saturn	36.8	2730	†

†Flux densities are given for a distance of 1 AU. Beam correction factors are variable because of the variation in the distance of planets.

2.2 *DKR-1000 observations*

With the DKR-1000 radiotelescope at a frequency of 102 MHz a long-term observational programme of the variability of extragalactic radio sources was carried out. The observations covers the periods 1984–1985 and 1988–1992. In total throughout this period, 15 cycles of observations were carried out.

Bochkarev and Ryabov [2, 3] used their own procedure for obtaining 'light' curves of relative variations in the flux density by using 'calibration' sources. The sources which did not change their flux between observational cycles were used as calibration sources. Thus, for all the examined sources, 'standard' flux variations relative to their average magnitude were obtained throughout all the observational period. Observations were made all day long and therefore it was necessary to exclude the effects of the season and day due to variation in the state of the ionosphere. This problem was solved successfully and eventually, variations in source fluxes 'free' of ionospheric influence were determined.

As a result, variations in source fluxes were noted from cycle to cycle within 25% of their mean level throughout all the observational period. The results obtained demonstrate the presence of refraction scintillations in radio sources are 1–3 months.

All the extended sources showed flux stability throughout all these observational periods. These sources were used as reference sources to estimate variations in the fluxes of the compact sources 3C 2, 3C 103 and 3C 228 of particular value are the observational findings of the 'light curve' variations in flux density. Each of these can yield valuable information on the character of their own variable radio sources, inhomogeneities and turbulence state of the interstellar medium in various regions of the local interslellar medium.

3. Discussion

Figure 1 shows the flux–density variations at 102 MHz, 22 and 37 GHz. The RT–22 and DKR–1000 data combined with our data published earlier were supplemented by observations by other astronomers [4–8].

The 3C 111, 3C 216, 3C 273, 3C 279, 3C 380 and 3C 454.3 radio sources have been most extensively observed at high and low frequencies. They were in various stages of activity.

The data obtained by monitoring were best at high frequencies. We have calculated the relative units of flux density for comparison of the observations of the sources at RT-22 and DKR-1000.

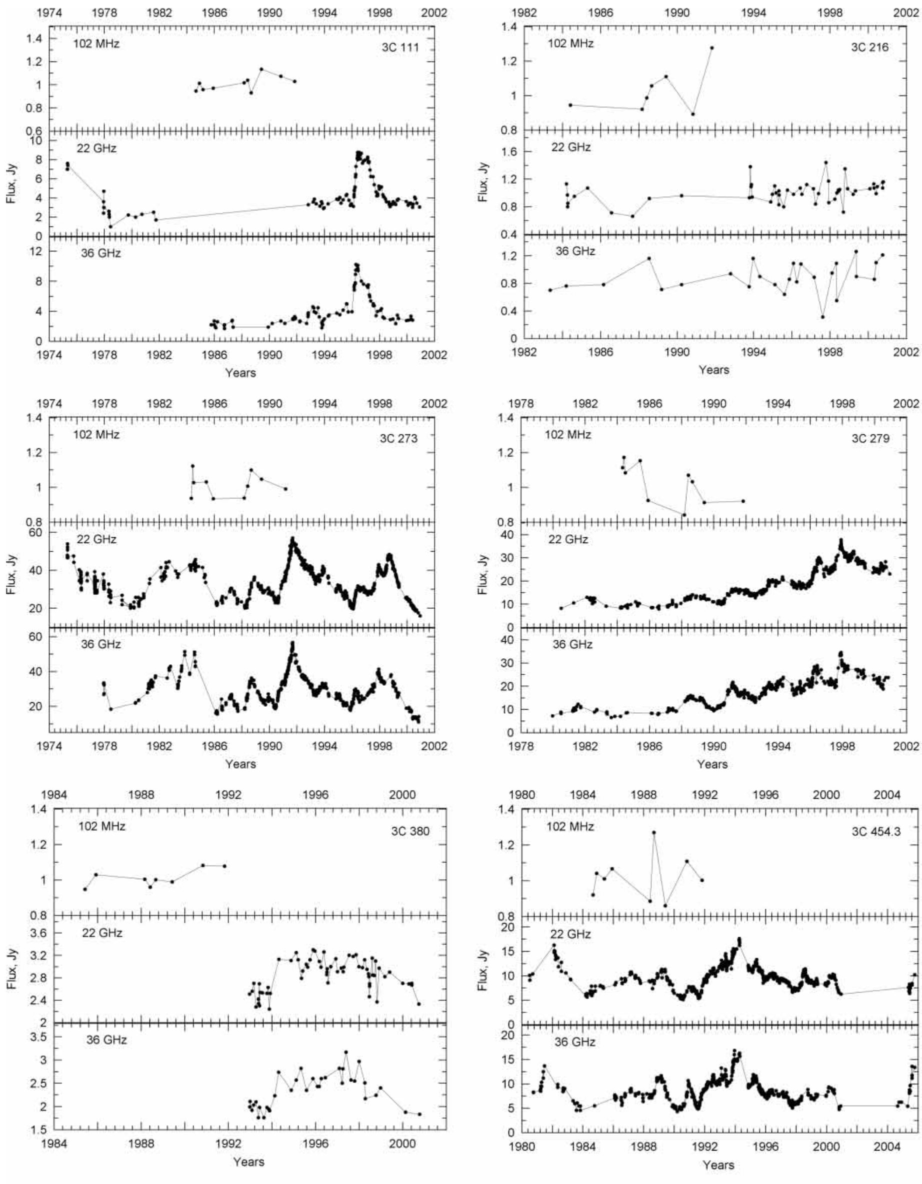

Figure 1.

Unfortunately, the monitoring of sources was not extensive. In this connection, it is possible to suggest the variation in the flux density only at low and high frequencies. At the same time, if there is a variation at low frequencies, it should arrive with a time delay at high frequencies.

3.1 *3C 111*

During 1984–1992 there was no variation at high and low frequencies. Analysis of radio light curves of 3C 111 at a frequency of 36 GHz during the period 1986–2001 revealed a 6.5 year cycle of variability.

3.2 *3C 216*

There are variations in the flux density in various periods. At low and high frequencies, the flux density had increased in the late 1980s. Probably the preceding maximum was delayed by approximately 2–3 years from high to low frequencies. Unfortunately, the observations at various frequencies are too few to analyse in detail the intensity variations at those frequencies.

3.3 *3C 273*

This source is one of the best-observed extragalactic object on RT-22. Bursts were observed in 1975, 1984, 1987, 1989, 1992 and 1998. At the same time at low frequencies, the flux density increased in 1984 and 1987. Unfortunately, the observations at low frequencies are too few to analyse in detail the yearly delay in the variations in flux density from high to low frequencies. Analysis of the radio light curves of 3C 273 at a frequency of 22 GHz during the period 1974–2001 revealed 5.7 and 7.9 year cycles of variability. Analysis of the radio light curves of 3C 273 at a frequency of 36 GHz during the period 1977–2001 revealed 3.4, 5.4 and 7.1 year cycles of variability.

3.4 *3C 279*

This source has been the most observed source at different frequencies. We observed variations in the radio intensity at high frequencies. Since early 1981, the flux density at high frequencies has increased, having reached its highest value in 1982. Then, the source flux density decreased until 1984. At low frequencies, the flux density increased in 1984–1985 and then the flux decreased until the 1996. Probably this variation in the flux density is the result of the activity of the source at high frequencies with a shift every 2 years. Analysis of the radio light curves of 3C 279 at a frequency of 22 GHz during the period 1980–2001 revealed 5.9 and 20.5 year cycles of variability. Analysis of the radio light curves of 3C 279 at a frequency of 36 GHz during the period 1979–2001 revealed 6.4 and 27.9 year cycles of variability.

3.5 *3C 380*

This source showed an increase in flux density for the period from 1986 until 1996. Small bursts were recorded at high frequencies. However, in that period, when the source was observed simultaneously on RT-22 and DKR-1000 the flux density almost did not vary. Analysis of the radio light curves of 3C 380 at frequencies of 36 and 22 GHz during the period 1992–2005 revealed a 7.8 year cycle of variability.

3.6 *3C 454.3*

This source has also been the most observed source at different frequencies. Bursts were recorded at high frequencies in 1981, 1989, 1991, 1994 and was succeeded by a new outburst which started in May 2005 at 36 GHz and is still in progress. There were no variations in the radio intensity at the low and high frequencies from 1985 to 1988. In 1988 and 1990, the flux density had increased simultaneously at low and high frequencies. Analysis of the radio light curves of 3C 454.3 at frequencies of 36 and 22 GHz during the period 1980–2005 revealed a 6.6 year cycle of variability.

4. Conclusions

Using monitoring of sources at high and low frequencies, the preliminary analysis of the variations in radio intensity shows different changes. Probably for each source depending on its structure and the activity, there is a pattern in the development of bursts from high to low frequencies. There can be various displays of the variations in radio intensity at low and high frequencies.

(i) There is a 2–3 year delay in the variations in flux density from high to low frequencies (source 3C 216 and 3C 279).
(ii) There are quasi synchronous variations in flux density when the bursts are observed at high and low frequencies (source 3C 454.3).
(iii) There are independent displays of the variations in flux density at low and high frequencies when the variability of radio sources at low frequencies is caused 'scintillations' of the flux density of the inhomogeneous region of the local interstellar medium.

A new outburst in 3C 454.3 which started in May 2005 at 36 GHz was found. The variability of 3C 454.3 was found to be cyclic, with a mean period of 6.6 years at 22 and 36 GHz.

A further joint programme of observations of metre, decimetre, centimetre and millimetre waves in order to study the variations in flux density of active galactic nuclei is planned.

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