FLUX DENSITY MONITORING OF EXTRAGALACTIC RADIO SOURCES. OBSERVATIONS AT 22, 37 GHz AND 102 MHz WITHIN THE RESEARCH PROGRAMS FOR THE RT-22 CrAO AND THE ODESA OBSERVATORY "URAN-4" IRA NASU

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Observations of the millimeter wave emission variability of extragalactic radio sources may give an important information on active processes in their inner parts. The millimeter wave observations of extragalactic radio sources were started with the 22-m radio telescope of the Crimean Astrophysical Observatory in 1973. Since 1973, over 10 000 observations of 140 sources have been obtained. As the extended monitoring programs have demonstrated, there are unpredictable outbursts, quiescent periods, minimum flux levels, and secular trends. As it follows from the analysis, the flare evolution can be divided in three phases: (1) a rapid flux increase; (2) a plateau when the flux relatively constant; (3) a slow intensity decrease. Significant differences in the flare evolution in various optical classes of radio sources were not found. The Odesa Observatory of the Institute of Radio Astronomy of NAS of Ukraine (IRA NASU) have performed a long-term flux monitoring of extragalactic radio sources at 102 MHz with the DKR–1000 radio telescope of the Pushchino Radio Astronomy Observatory of the Astro–Space Center of the Lebedev Physical Institute. About 20 observational sessions of over 80 compact and extended radio sources have been carried out in 1984–1985, 1988–1992, and 1996–1998. The variability of radio sources at meter wavelengths is caused by "scintillations" of the flux density of the inhomogeneity of the local interstellar medium. At the same time, many of sources are showed anomalous flux variations at meter wavelengths that do not correspond to the assumption about interstellar scintillations. In this paper, we present a comparison of the data of two independent observations programs. Own activity of radio sources has been taken into account and the flux variability with the time delay at millimeter and meter wavelengths has been considered. It was possible due to the longer time series of the RT-22 observations.

INTRODUCTION

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OBSERVATIONS

RT-22 observations

The observations were carried out with the 22-m CrAO radio telescope. For our measurements, we used two similar Dicke switched radiometers of 22 GHz and 37 GHz. Until the end of 1981, the receiver with a RF pre-amplifier was used at 22 GHz. Characteristics of the receivers and telescopes are presented in Table 1.

Table 1. Parameters of the receiving systems

Frequency, GHz	Aperture effic.	HPBW	Beam separation	Sensitivity [K], ($t = 1\,\mathrm{s}$)	Detection level
22	0.43	$2.6'$	$18.3'$	0.20	0.08
37	0.40	$1.6'$	$8.3'$	0.15	0.06

The antenna temperatures from sources were measured using the standard ON–ON method described by Efanov *et al.* [3]. 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 rms error of the mean.

The gain of the receiver was monitored using a noise generator every 2–3 hours. 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 hours. 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 (1) the detected mean value of the antenna temperature of the sources, (2) the calibration source measurements, (3) the noise generator level measurement, and (4) the atmosphere attenuation corrections, but the main contributions to the quoted errors are due to the first two terms.

The RT–22 flux densities are presented in Fig. 1 [4–7]. 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 2. The flux density values and beam size correction factors C of the 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	[1]
Jupiter	36.8	4348	[1]
Saturn	22.2	887	[1]
Saturn	36.8	2730	[1]

[1] Flux densities are given for the distance of 1 AU. Beam correction factors are variable because of variability of the distance of planets.

DKR-1000 observations

With the radio telescope DKR-1000 at frequency 102 MHz, a long term observational program of variability in extragalactic radio sources is carried out. The observations cover the period 1984–1985 and 1988–1992. During this period, 15 cycles of observations were carried out. The authors used their own procedure for obtaining "light" curves of relative variations in the flux density by using the "calibration" sources [1, 2].

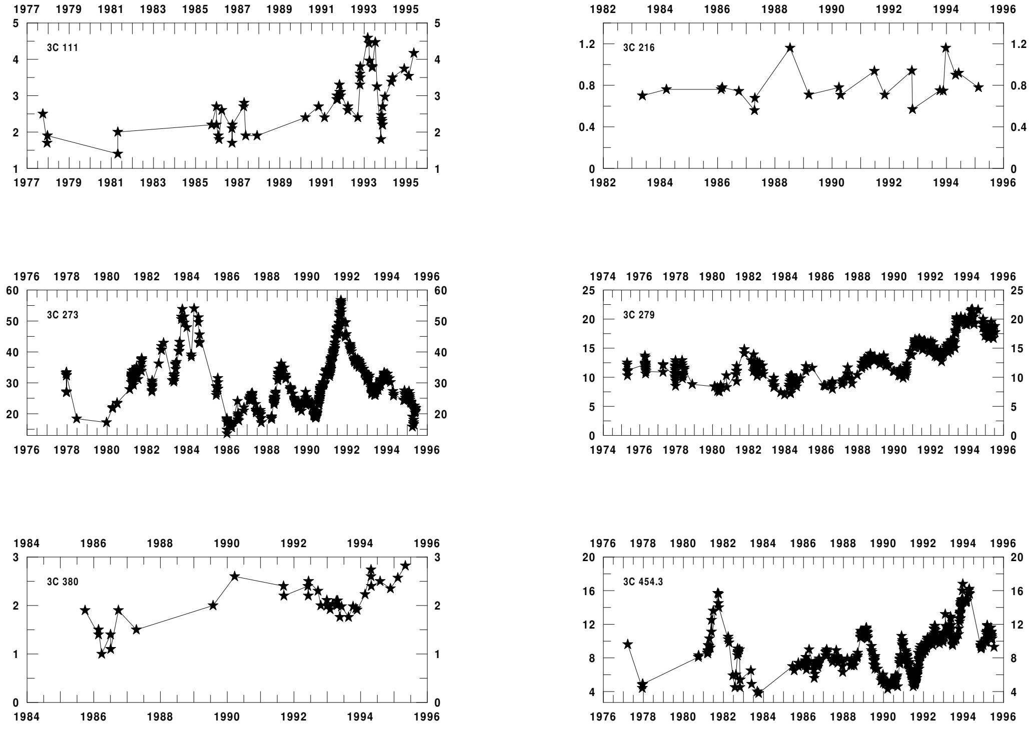

Figure 1. The RT-22 flux density in the observed sources as a function of the time

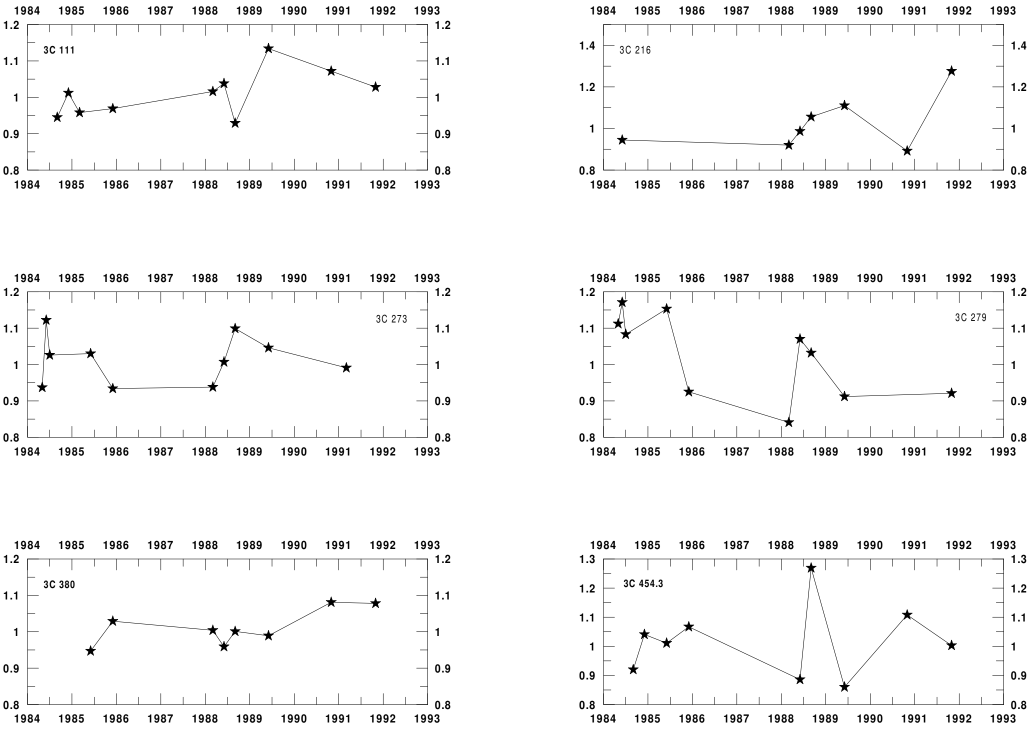

Figure 2. The DKR-1000 flux density in the observed sources as a function of the time

The sources which did not change their flux among observational cycles were used as the calibration ones. Thus, for all the examined sources, the "standard" flux variations relative to their average magnitude were obtained during the whole observational period.

Observations were carried out all days and nights, and, therefore, it was necessary to exclude the influence of seasonal and daily effects because changes in the ionosphere state. This problem was successfully solved, and, eventually, variations in source fluxes are "free" of the ionosphere influence. As a result, variations in source fluxes have been revealed from cycle to cycle within 25% of their mean level during the whole observational period. The results obtained indicate the presence of refractions scintillations in radio sources during 1–3 months. A whole number of extended sources showed a flux stability throughout all these observational periods. These sources were used as the reference ones to estimate variations in fluxes of the compact sources 3C 2, 3C 103, 3C 228. Of particular importance are observational findings of "light curve" variations in the flux density.

Each of them can yield a valuable information on the character of own variability radio sources, inhomogeneities and turbulence state of interstellar medium in these or those regions of LISM. The DKR-1000 flux densities are presented in Fig. 2.

DISCUSSION

The 3C 111, 3C 216, 3C 273, 3C 279, 3C 380, and 3C 454.3 radio sources were most extensively observed at high and low frequencies. They were in a various stage of activity. The data of the monitoring was the best at high frequency. We have calculated the relative units of the flux density for comparison of observations of sources with RT-22 and DKR-1000.

In Fig. 3, the measured flux densities of the observed radio sources are plotted as the relation of the common period of observations of each source with RT-22 and DKR-1000. It gives a possibility to study variations of the flux density at different frequencies.

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

- **3C 111.** During 1984–1982, there was no variations at high and low frequencies. We have not the observations with RT-22 from 1988 until 1990.
- **3C 216.** There are variations of the flux density in different periods, but the times of observations at low and high frequencies do not coincide.
- **3C 380.** The source showed an increase of the flux density for the period from 1986 until 1996. The small bursts are registered at high frequencies. However, in this period, when the source was observed simultaneously with RT-22 and DKR-1000, the flux density practically did not vary.
- **3C 273.** The source is one of the best observed with RT-22 extragalactic object. The bursts were observed in 1983 and 1991. The flux density twice increased. At the same time, we had the DKR-1000 observations for the periods when the flux at high frequencies was at an average level.
- **3C 279.** The source is a most observable source at different frequencies. We observed variations in the radio intensity at high frequency. Since the early 1981, the flux density at a high frequency had increased, having reached its highest value in the 1982. Then, the source flux density has decreased until 1984. At a low frequency, the flux density had increased in 1984–1985, and then the flux has decreased until 1996. Probably, such a variation of the flux density is the result of the activity of source at high frequencies with a shift of two years.
- **3C 454.3.** The source is a most observable source at different frequencies too. The bursts are registered at high frequencies in 1981, 1989, 1991, and 1994. There were no variations in the radio intensity at low and high frequencies from 1985 to 1988. In 1988 and 1990, the flux density had simultaneously increased at low and high frequencies.

CONCLUSIONS

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

1. the two-year delay in the flux density variations from high frequencies to low (source 3C 279).
2. the quasi-synchronous variations of the flux density, when the bursts are observed at high and low frequencies (source 3C 454.3).

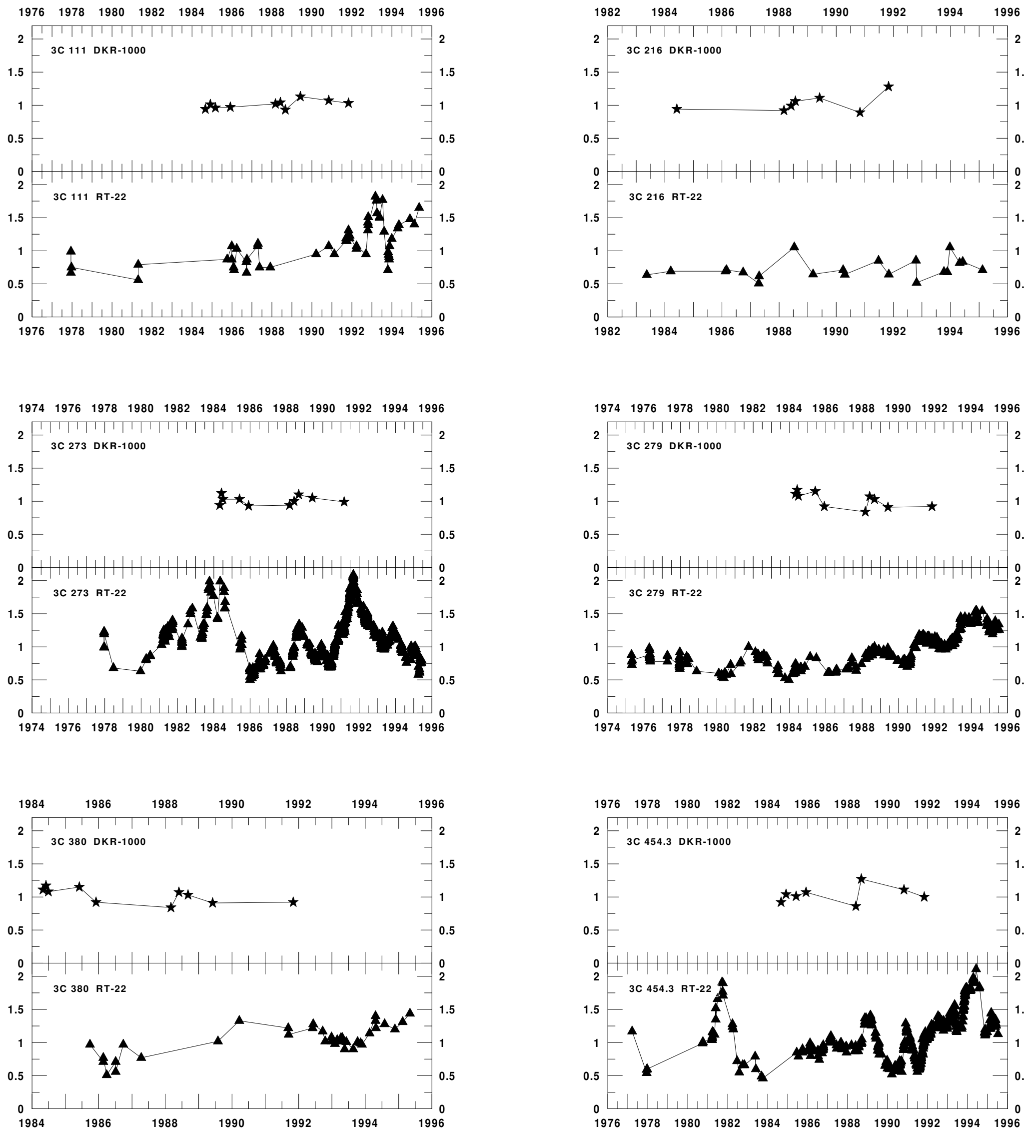

Figure 3. Flux density in the observed sources as a function of the time

3. the independent displays of the flux density variations at low and high frequencies, when the variability of radio sources at a low frequency is caused by "scintillations" of the flux density of the inhomogeneity of the local interstellar medium.

A further joint program of the observations at meter, decimeter, centimeter, and millimeter wavelengths for a detailed study of flux density variations of AGN is planned.

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