The catalog of periods of the variability of blazars 3C120, 3C273, 3C279, 3C345 and 3C454.3 at centimeter and millimeter wavelengths

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Abstract. Variations in the radio flux of 3C120, 3C273, 3C279, 3C345, 3C 454.3 are analyzed using long-term monitoring data at five frequencies from 4.8 to 36.8 GHz obtained at the University of Michigan Radio Astronomy Observatory and the Crimean Astrophysical Observatory. A spectral analysis of the light curves at the various frequencies reveals the presence of periodic components. Using method of model calculations for each of the found period tested its ability to reproduce the observed flux variability at different frequencies. On the basis of the model calculations presented the catalog of the most reliable periods of flux variable of radio sources.

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1. INTRODUCTION

The flux of radio sources at centimeter and millimeter wavelengths is monitored for more than 30 years with the 26-m telescope of the University of Michigan Radio Astronomy Observatory (UMRAO) at 4.8, 8, and 14.5 GHz and 22-m telescope RT-22 Radio Astronomy Laboratory of Crimean Astrophysical Observatory at 22.2 and 36.8 GHz. The observational data with RT-22 were carried out using modulating radiometers with a fluctuation sensitivity of 0.04 K [1, 2]. The source antenna temperature was measured in an ”ON-ON” regime, when the antenna temperature recorded during the installation of radio alternately at one and the second horn charts orientation [4]. The values of antenna temperature, corrected for absorption of radiation in the Earth’s atmosphere, converted to a flux density of observational data calibration sources. It also took into account the dependence of the effective area of the antenna from the corner seats radio [2]. The method of observation and data processing with RT-26 UMRAO are given in [3].

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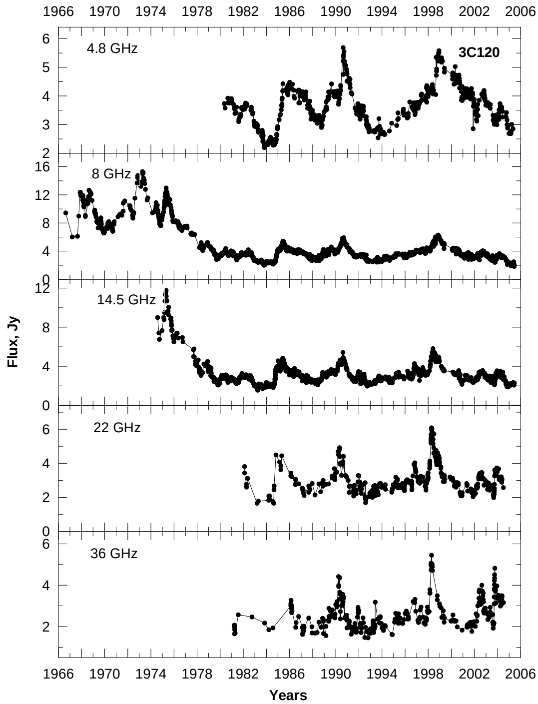

FIGURE 1. The light curves of 3C120 at the five frequencies.

2. METHODS OF THE DATA PROCESSING

Based on the resulting millimeter- and centimeter-wavelength database, we carried out a harmonic analysis of the flux-variation curves using different methods of filtering data in the assumption that the observed flux variability are a superposition of different processes and the periods of the activity. The data were averaged within time intervals of a week (Figs. 1, 2, 3, 4, 5). Figures 1-5 presents the light curves at the five frequencies. The number of ”gaps” in the data was small, which made it possible to apply the usual method of interpolation. Using bar chart of time intervals between the data was chosen the optimal interpolation interval of 0.04 years (14.6 days).

In the next step of data processing were carried out to identify the trends in the data and procedure of flattening for the purpose of identify the long-term changes of the flux of the radio sources. The trends for 3C279 and at 14.5 and 8 GHz for 3C120, as well as at 36.8 GHz and 22.2 GHz for 3C345 described by polynomials 4-6 degree [4]. Then all data were released from the trends and smoothed by moving average polynomial. It reduced probability of ”dispersion” of target frequencies by close frequencies. To select the frequency with high spectral densities used Parzen window. For detection of short-change flux, the data were approximated by trigonometric polynomials, which are then subtracted from the number of smoothed data, forming a series of ”o-c” data [4].

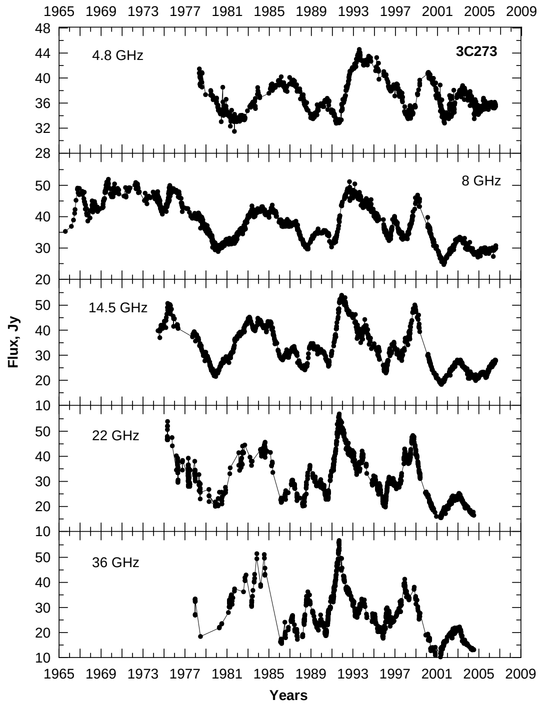

FIGURE 2. The light curves of 3C273 at the five frequencies.

The conducted stages of the data processing have created the basis of application of Fourier spectral analysis for search of the periodicities in the flux variability of the radio sources. To calculate the periods we have been used: a software package for statistical research StatSoft Statistica 8 and the ISDA program, widely used in studies of variable stars. The simultaneous use of two programs allows you to compare the results of the data processing and check the reproducibility of the observations based on simulation.

3. ANALYSIS OF OBSERVATIONS AND INTERPRETATION

A spectral analysis of the light curves at the various frequencies reveals the presence of periodic components. On the basis of the periods were constructed models of curves of flux variability for the studied sources.

3.1. 3C120

The time interval of 3C120 data at 14.5 GHz were 25 years, at 8 GHz - 33 years and at 4.8 GHz - 19 years. The results of analysis of the flux variation data at the five

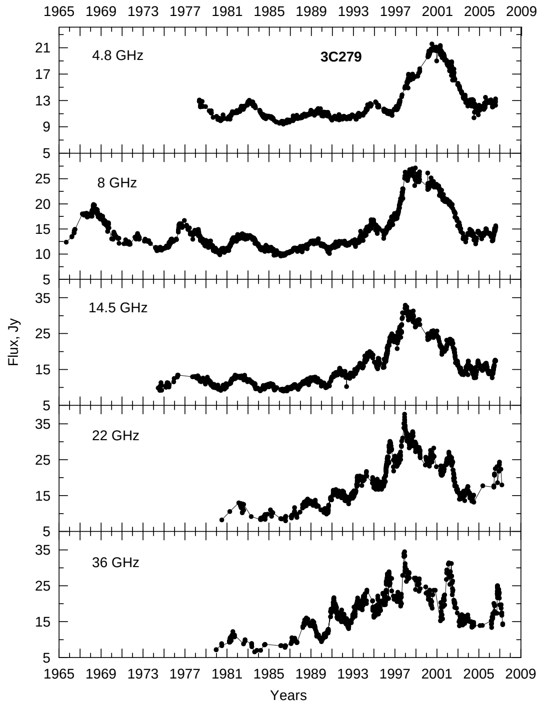

FIGURE 3. The light curves of 3C279 at the five frequencies.

TABLE 1. The results of analysis of 3C120 flux variation.

Frequency, GHz	Data interval	Periods, Years (Statistica v.8)	Periods, Years (ISDA v.3)	Periods o-c, Years (Statistica v.8)	Periods o-c, Years (ISDA v.3)
14.5	1974 - 1999	12.32 4.92	 5.00±0.042	1.25	1.28±0.003
8	1966 - 1999	16.60 4.15	12.98±0.254 4.42±0.029	1.74 1.27	1.73±0.004
4.8	1980 - 1999	9.48 4.74	10.83±0.310 5.50±0.080	1.04 0.85	1.21±0.004 0.85±0.002

radio frequencies (Fig.1) are presented in Table 1. A well expressed flux variation with a period of about 10-13 years and 4-5 years are present at different frequencies. The results of the calculation of periods by ”o-c” are 0.85-1.73 years. The similar periods of 1.28-1.25 (14.5 GHz), 1.73-1.74 (8 GHz) and 0.85 (4.8 GHz) can be the development of one process of radiation at different frequencies. The periods of 5.00, 4.42 and 5.50, at 14.5 and 8 GHz are also close to each other.

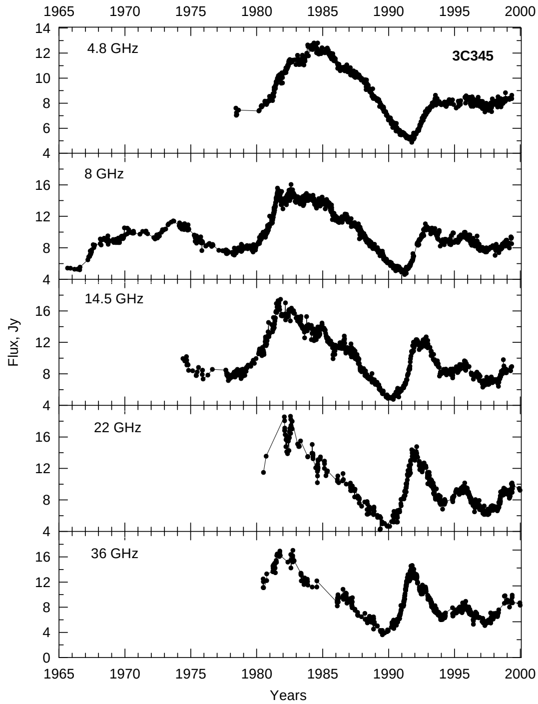

FIGURE 4. The light curves of 3C345 at the five frequencies.

TABLE 2. The results of analysis of 3C273 flux variation.

Frequency, GHz	Data interval	Periods, Years (Statistica v.8)	Periods, Years (ISDA v.3)	Periods o-c, Years (Statistica v.8)	Periods o-c, Years (ISDA v.3)
14.5	1974 - 1999	8.29	8.22±0.136	2.26	2.33±0.011
8	1966 - 1999	11.09	18.21±0.556 8.34±0.105	2.21 3.32	2.30±0.079
4.8	1978 - 1999	 4.74	17.79±0.76 8.60±0.178	1.28 0.78	1.26±0.039 0.80±0.016

3.2. 3C273

The time interval of 3C273 data at 14.5 GHz were 25 years, at 8 GHz - 33 years and at 4.8 GHz - 21 years. The results of analysis of the flux variation data at the five radio frequencies (Fig.2) are presented in Table 2. The periods of about 8.6-8.2 year is present at 4.8, 8 and 14.5 GHz. The short periods are 0.78-3.32 years. The similar periods of 2.30-2.33 year are present at 14.5 and 8 GHz. The periods of 0.8-1.26 year are present at 4.8 GHz.

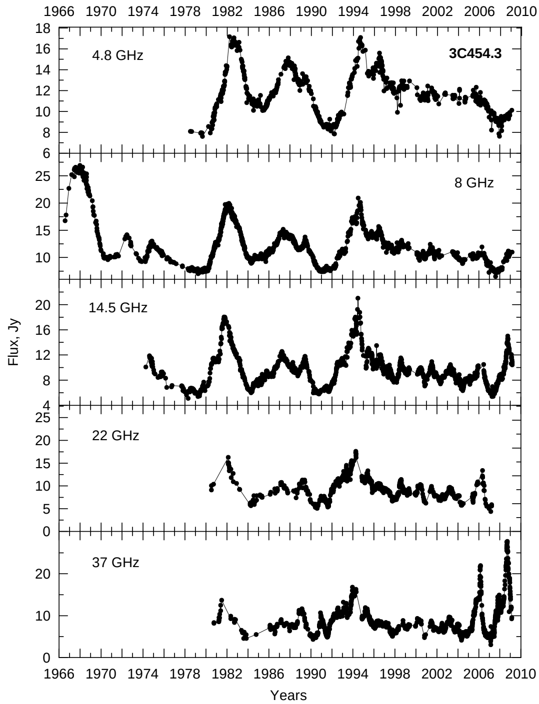

FIGURE 5. The light curves of 3C454.3 at the five frequencies.

3.3. 3C279

The time interval of 3C279 data at 14.5 GHz were 25 years, at 8 GHz - 33 years and at 4.8 GHz - 21 years. The results of analysis of the flux variation data at the five radio frequencies (Fig.3) are presented in Table 3. The light curves of 3C279 are differed from the other radio sources uptrend overlaid with the short-period fluctuations of the flux density. The period of about 4-6 years are present at 4.8, 8 and 14.5 GHz. The long-term periods of 21, 16 and 10 years are present at 8 GHz. The period of 15-16 year is present at 8 and 14.5 GHz. The short-period of 1.85-3.27 year is present.

3.4. 3C345

The time interval of 3C345 data at 36.8 and 22.2 GHz were 24 years, at 14.5 GHz - 25 years, at 8 GHz - 34 years and at 4.8 GHz - 21 years. The results of analysis of the flux variation data at the five radio frequencies (Fig.4) are presented in Table 4. The long-term periods of 10-18 years are present at all frequencies. The short-period of 1.00-1.97 year is present. The similar period of 1.80-1.75 year is present at 14.5 and 8 GHz [5].

TABLE 3. The results of analysis of 3C279 flux variation.

Frequency, GHz	Data interval	Periods, Years (Statistica v.8)	Periods, Years (ISDA v.3)	Periods o-c, Years (Statistica v.8)	Periods o-c, Years (ISDA v.3)
14.5	1974 - 1999	8.00 4.90	8.42±0.143 5.14±0.053 3.07±0.019	2.41 1.85	2.32±0.011
8	1966 - 1999	 16.64 4.12	21.02±0.665 16.00±0.384 10.44±0.164 5.16±0.100	3.27	3.12±0.015
4.8	1978 - 1999	 5.21	15.77±0.597 5.38±0.713	2.01	1.94±0.009

TABLE 4. The results of analysis of 3C345 flux variation.

Frequency, GHz	Data interval	Periods, Years (Statistica v.8)	Periods, Years (ISDA v.3)	Periods o-c, Years (Statistica v.8)	Periods o-c, Years (ISDA v.3)
36.8	1980 - 2004	7.24	8.87±0.164	1.35 1.00	1.37±0.041 1.00±0.022
22.2	1980 - 2004	7.20	8.84±0.158	1.12 0.69	1.13±0.027 0.70±0.010
14.5	1971 - 2004	15.40	18.43±0.552 9.40±0.144	1.80 1.33	1.81±0.054 1.34±0.030
8	1965 - 2004	13.28	12.65±0.201 6.27±0.050	1.97 1.79 1.27	 1.75±0.039
4.8	1978 - 2004	13.28	16.75±0.528	1.44 1.08	1.27±0.031

3.5. 3C454.3

The time interval of 3C345 data at 14.5 GHz were 25 years, at 8 GHz - 33 years, at 4.8 GHz - 21 years. The results of analysis of the flux variation data at the five radio frequencies (Fig.5) are presented in Table 5. The long-term periods of 12-13 years and 6 year are present at all frequencies. The short-period of 0.97-2.52 year is present.

4. FLUX MODELING VARIABLE OF RADIO SOURCES

The results of period's calculations with different methods were tested by simulation on the "reproducibility" of the observed flux variability. The results of model calculations of recovery observed flux variability of sources are shown in Figure 6, 7, 8. The best possible fit with observational data of the periods defined by the program ISDA v.3.

TABLE 5. The results of analysis of 3C454.3 flux variation.

Frequency, GHz	Data interval	Periods, Years (Statistica v.8)	Periods, Years (ISDA v.3)	Periods o-c, Years (Statistica v.8)	Periods o-c, Years (ISDA v.3)
14.5	1974 - 1999	12.6	12.41±0.306	1.40	1.52±0.046
		6.3	6.50±0.086	1.05	1.00±0.020
8	1966 - 1999		13.64±0.270	2.52	2.45±0.092
		6.62	6.65±0.068	1.82	
4.8	1978 - 1999		12.35±0.371	1.68	1.70±0.071
		6.85	6.30±0.096	1.26	0.97±0.023

5. RESULTS

It can be concluded that the best curves of flux densities are described by models constructed on the basis of the periods calculated using the ISDA.

Our results are generally consistent with previously published works of the study of the variability of Blazars [6, 7, 8, 9, 10, 11]. At the same time they provide a more detailed picture allowing one to analyze the applicability of certain physical models.

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