RADIO VARIABILITY OF THE QUASAR 3C 273 ON THE CENTIMETRIC WAVES -WAVELET-ANALYSIS

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ABSTRACT. 3C 273– has been intensively investigated for many years, since opening of quasars in 1963. Since 1965 on radio telescope RT-26 of Michigan University on frequencies 14.5, 8 and 4.8 GHz long monitoring of this radio source have been carried out. Flux variability of a radio emission on studied frequencies consists a trend on which fast flux changes with characteristic time from 1 to 5 years are imposed. Fourier's methods and the wavelet-analysis that allowed investigating in details changes harmonious component of signals over time are applied. On a trend component the main period makes 8 years. With Fourier filtration have been received «O – C» data, for allocation high-frequency component in studied signals. By the results of calculations of wavelet-spectrums the periods of 3.5 and 2.3 years are revealed. On the basis of calculation of integrated wavelet-spectrums in a frequency range on «O – C» this «spectrum of the periods» characterizing main phases of activity of a source are defined. On the basis of the program written on IDL, supplementing the wavelet-analysis, delay change between fluxes on separate studied frequencies for each of periodic components has been defined eventually. The average delay for the 8 years periodic component in the range of frequencies of 4.8-8 GHz is about 1 year. In the range of frequencies 8 – to 14.5 GHz the average size of a delay was about 0.5 years. The average delay for all intervals of frequencies for the 3 years periodic components has appeared equal 0.3 years.

Introduction

3C273 – is the brightest quasar. It was opened in 1959. Main characteristics: red shift of Z ~ 0.16, visible magnitude V ~ 13, distance to object ~ 735 Mpc, mass of the central object of m ~ 886 million M_{SUN}, the linear extent of jet makes ~ 62 Kpc, the visible size – 23 ”. Luminosity of the object changes in all a wave band from radio waves to range scale within about several days or ten days. Observation on VLBI has revealed own movements of some component in jet of 3C273 [1].

Data processing

On the basis of the carried-out daily observations average values in 7 days with a non-uniform grid of counting are defined. According to the histogram of distribution of time intervals between counting the interpolation interval in 0.02 years (7,3 days) has been chosen. With using a polynomial moving average (half width an interval of 5 points) reduction of noise has been reached and random emissions have been removed [2]. By means of trigonometrical interpolation data have been provided to an even step on time. The initial schedule with the combined frequencies is presented on fig. 1. The allocation of short periodic components of signals, which were imperceptible against the main period, has been carried out by Fourier filtration «O – C» [3].

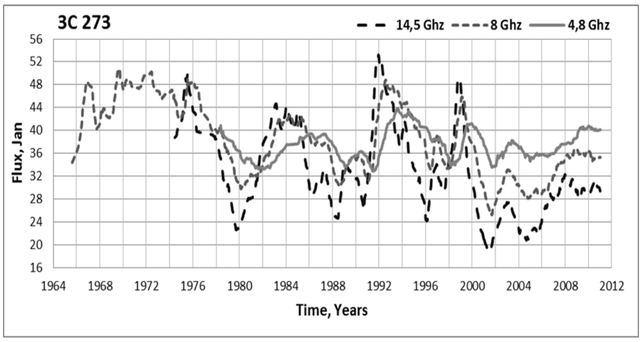

Figure 1: Monitoring of flux density quasar 3C 273 on 14.5, 8, 4.8 GHz.

FOURIER-analysis

For determination of values of the periods calculated Lomb-Scargle periodogram for data with non-uniformly located counting on time [4]. Frequencies with big spectral density, i.e. the frequency areas consisting of many close frequencies which make the greatest contribution to periodic behavior of all rows, were calculated with use of a Bartlett spectral window. Examples of Fourier and wavelet spectra are given on fig. 2 – 3. On all frequencies the most powerful period is close to 8 years. For «O – C» data the most appreciable periods with the values close by 2 and 3 years are found.

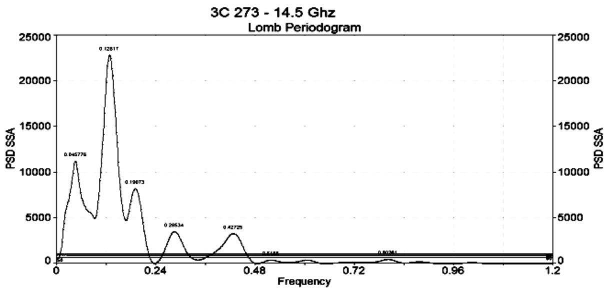

Figure 2: Periodogram for frequency of 14.5 GHz.

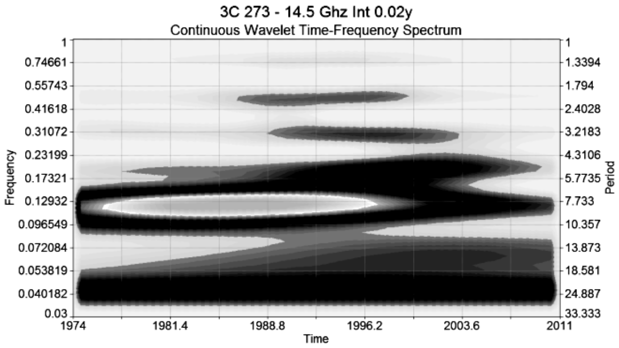

Figure 3: A continuous wavelet-spectrum of the initial smoothed data, frequency of 14.5 GHz.

WAVELET-analysis

Two-parametrical analyzing function of one-dimensional wavelet-transformation is well localized both in time and on frequency. That is distinguished from Fourier's usually applied transformation which analyzing function covers all time base. Thus it is possible to see detailed structure of process and evolution of a harmonious signal component in time [5]. Continuous wavelet-transformation on the basis of function Morlet was used. The example of a wavelet-spectrum is given on fig. 4. On wavelet-spectra harmonious components of a signal are visible in the form of the bright spots which are extending in strips along an axis of time.

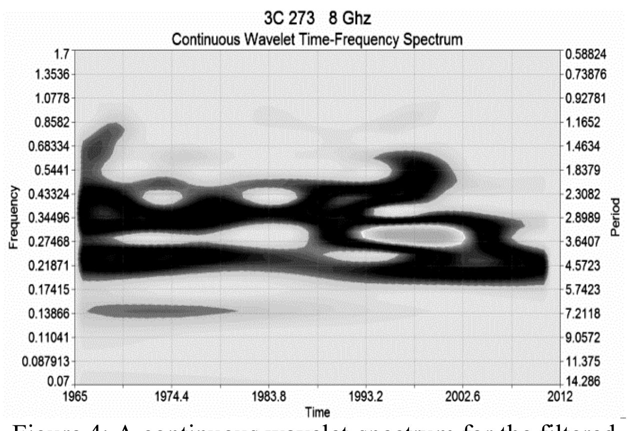

Figure 4: A continuous wavelet-spectrum for the filtered data «O – C», frequency of 8 GHz.

The analysis of ranges has shown existence in studied signals 8 years periods, and also the 3and 2 years periods, shorter periods with values are allocated about a year uncertainly and specification demand. Short time 2-3 years harmonicas are shown not on all length of a signal, and on its separate sites. Calculation of integrated wavelet-spectra in a frequency range for the filtered data has allowed studying change of spectral capacity of signals eventually. Activity phases (splashes in spectral power) were noted on frequency of 14.5 GHz – 1991.15, 1998.71 years; on frequency of 8 GHz – 1967.34, 1976.51, 1991.37, 1998.90; on frequency of 4.8 GHz – 1980.44, 1991.07, 1999.40. For each maximum on a global spectrum were constructed graphs of « spectrum of the periods», allowing to estimate a contribution of the separate periods to phases of activity of a radio source. On fig. 5 it is set an example such plot.

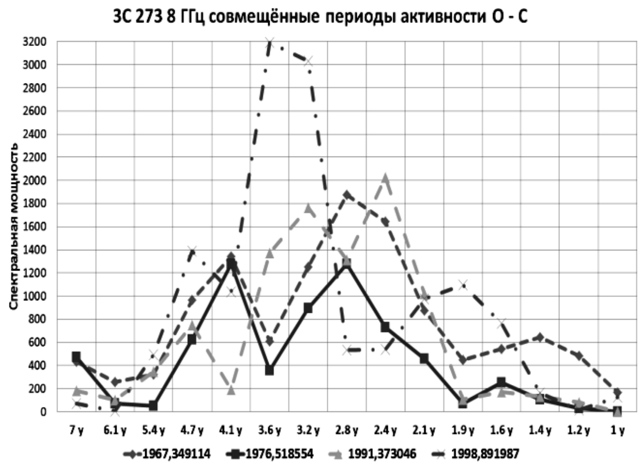

Fig. 5. On graphics contribution to of the separate periods to phases of activity of a radio source on frequency of 8 GHz are shown. For example, in a phase of activity of 1998.9 the most powerful period was of 3.6 years.

Use of «specter of the periods» allows to carry out comparison to data of VLBI observations and to define nature of dynamics of processes in jets. On the basis of the revealed regularities, it is possible to extend them to the entire period of the observation when sessions of VLBI of measurements were not.

Time delay between frequencies

For definition of delays between signals on different frequencies, calculation of direct and return wavelet-transformation was used [6]. This procedure is necessary for allocation of narrow-band signals of the found harmonicas and their comparison. Value of the strip wavelet-filter was fixed close ~ 3 and 8 years. The width of a window of the periods made 2 years. The capacity of fluctuations is non-uniformly distributed throughout the period of observation, there is their strengthening and the subsequent attenuation. For the period of 8 years this interval is in a range of 1979-2002, for the 3 years period

– in a range of 1986-2002. Then the time differences were found maximum and minimum of flux density for different spectral components. Values of positive half-cycles are designated by a dagger, negative are designated by a circle. On fig. 6 and 7 schedules of delays between frequencies for two allocated harmonicas are shown.

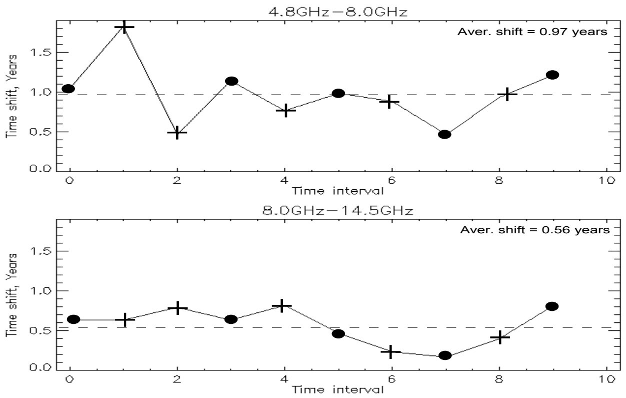

Figure 6: Delays between frequencies for a 8 years' period

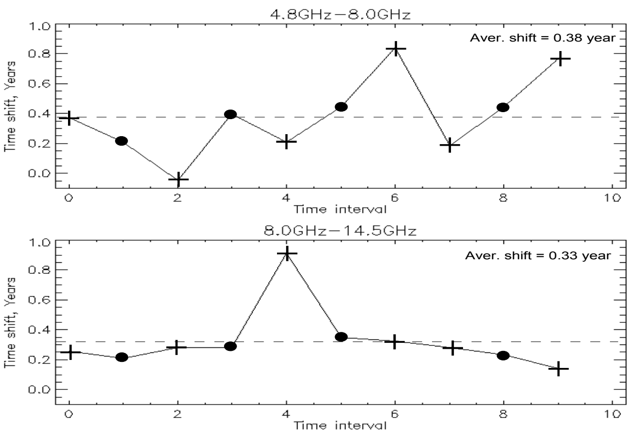

Figure 7: Delays between frequencies for a 3 years period

Conclusions

In this work, with using of a method of the wavelet-analysis existence of the 8 years' period on all studied frequencies that will be is consistent with results of other researches is defined. Fourier filtration method has allocated fast-variable components of signals with the periods of 3.5 and 2.3 years. Duration of the 3 years' period on frequency 14.5 GHz – 14.7 years, 8 GHz – 12.5 years, 4.8 GHz – 16.3 years. At a 8 years duration of manifestation on frequency 14.5 GHz – 14.3 years, 8 GHz – 15 years, 4.8 GHz – 13 years. On frequencies of 14.5 GHz and 8 GHz, probably, the period close to 5 years exist. Construct integrated wavelet-spectra in a frequency range for data «O – C». Activity phases of a source on frequency of 14.5 GHz are constructed – were shown in 1991.15, 1998.71 years. On frequency of 8 GHz in 1967.34, 1976.51, 1991.37, 1998.90 years. On frequency of 4.8 GHz – 1980.44, 1991.07, 1999.40 years. For each maximum on a global spectrum the schedules which allow to estimate a contribution of the separate periods to phases of activity of a radio source are constructed. The received results of delays between various frequencies of radio emission in a source 3C273 for the various periods allow to carry out further the detailed analysis of their physical reasons. For "trend" components with the period ~ time shift on frequencies in the range of 8 – 14.5 GHz twice are less than 8 years, than on lower frequencies (an interval of 4.8-8 GHz). Delays of high-frequency fluctuations do not show about 3 years change with frequency of generation. The average delay for the 8 year components in a range of 4.8-8 GHz is equal to 1 year, in a range 8 – 14.5 GHz a delay is about 0.5 years. An average delay for the 3 years components in all range of frequencies about 0.3 years. Long time changes of a radio flux 3C273 can be connected with quasiperiodic changes of rate of an accretion on a core [6]. 2 and the 3-year periods can be described by model of a shock wave in jet [7]. Variability models on the basis of a magnetic dynamo also well describe emergence of the short periods [8].

References

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