VARIABILITY OF THE EXTRAGALACTIC RADIO SOURCES 3C120, CTA102, DA55 AND OJ287 ON CENTIMETER WAVES AND ITS CONNECTIONS WITH THE DATA OF VLBI OBSERVATIONS

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ABSTRACT. By data of the long-term monitoring (30-40 years) fluxes of extragalactic radio sources 3C120, CTA102, DA55 and OJ287 received on the RT-26, University of Michigan present results of data processing with use the wavelet analysis. Received analysis of trend and short-time components of the flux density changes in the studied frequencies 14.5, 8 and 4.8 GHz. For each time components on all frequencies found values of main periods and time of their existence, integrated power spectra for the phases activity for radio sources was built. From the results of VLBI observations in sources with long jets (3C120 and CTA102) detected quasi-periodic structures brighter components. Their appearance is linked to the dynamics of the interaction of shock waves in the jet emission from the cores. Quasi-periodic structures in the jet can be formed as a result of a return standing wave.

Introduction

Radio galaxy 3C120. Main characteristics: z ~ 0.033, the distance to the object ~142 Mpc. The observations were made at a frequency 14.5 GHz 33 years (1978–2011), 8 GHz 45 years (1966–2011) and 4.8 GHz 29 years (1980–2009). Diagram of the flux density at 3 frequencies for the common observation periods is presented in Fig. 1.
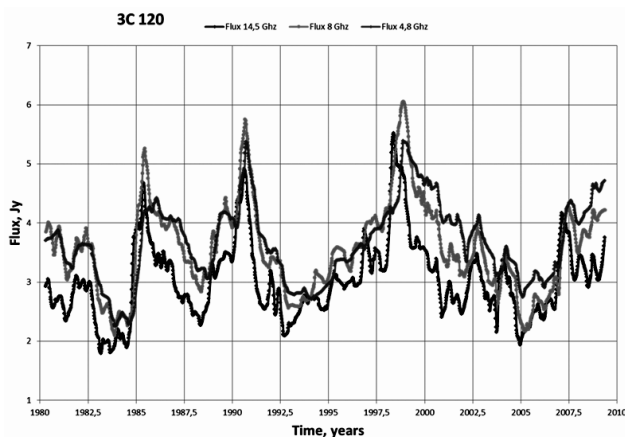

Figure 1: Graph of the fluxes at frequencies of 14.5, 8, 4.8 GHz, for the radio galaxy 3C120.

Quasar CTA102. Main characteristics: z ~ 1.037, the distance to the object ~6942 Mpc. For the source CTA102 data were obtained at frequencies of 4.8, 8 and 14.5 GHz for the 12-year period of observation (1999–2011).

Quasar DA55. Main characteristics: z ~ 0.859, the distance to the object ~5489 Mpc. For a source DA55 used data obtained at frequencies 4.8, 8 and 14.5 GHz for the 12-year period of observation (1999–2011).

Radio Source OJ287 refers to blazars, which are rapidly variability across the electromagnetic spectrum. Main characteristics: z ~ 0.306, the distance to the object ~1576 Mpc. We used the results of 30 years' observations (1979-2010) at frequencies 4.8, 8 and 14.5 GHz.

Observations

Investigation results monitored the 14.5, 8, 4.8 GHz fluxes of 3C 120, CTA 102, DA55, OJ 287 with the 26 m antenna of the University of Michigan Radio Astronomy Observatory. Details of the calibration and analysis techniques are described in Aller et al. (1985).

We used the average values of the fluxes of sources at regular intervals samples every 7 days.

With the use of a polynomial moving average (half-width of the interval 5 points), there was a decrease of noise and remove the casual bursts . Total flux densities of a radio source 3C120 are shown in Fig. 1. Allocation of short-component signals against the main period performed using Fourier filtering (O – C) (Gaydyshev, 2001). The change in the flux of sources at different frequencies has been observed mainly in time shift from the larger to the smaller frequency. The individual phases of activity sources can show the coincidence peaks at all frequencies.

FOURIER-analysis

In order to determine the periods Lomb-Scargle periodogram for data with an uneven readings on the time axis was built (Smolentsev, 2010). The spectral densities were calculated using the spectral Bartlet window. Examples of Fourier and wavelet spectra are shown in Fig. 2 and Fig. 3.
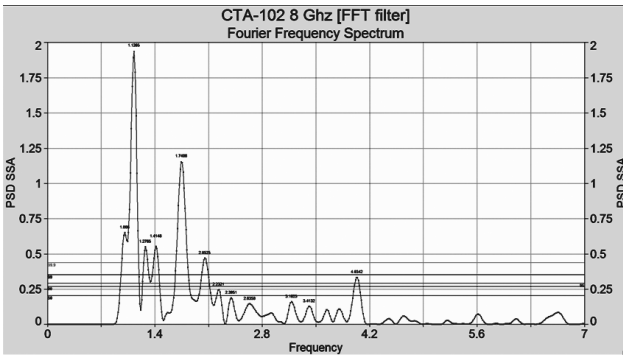
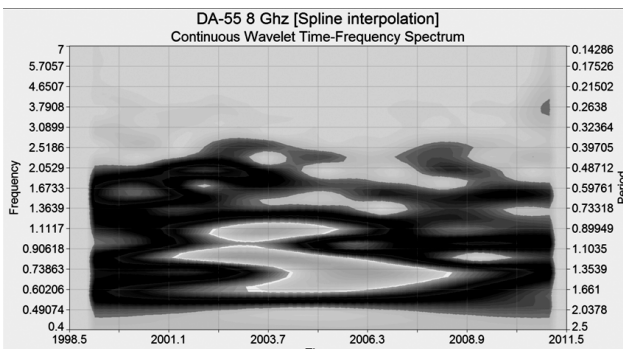Figure 2: Periodogram for the source CTA102 at a frequency of 8 GHz.

Figure 3: Continuous wavelet spectrum of the source of the «O – C» data for DA55, at 8 GHz.

WAVELET-analysis

Two-parameter analyzes function of one-dimensional wavelet transform is well localized in time and frequency. This distinguishes it from the ordinary Fourier analyzing function covers the entire time axis. Thus, it is possible to see the detailed structure of the process and the evolution of the harmonic components of the signal in time [4]. We used a continuous wavelet transform based on Morlet function. The example of the wavelet spectrum is shown in Fig. 4. On the wavelet spectra of the harmonic components of the signal are visible as bright spots, pulling in a strip along the time axis. The calculation of the integral wavelet spectra in the frequency range allows us to study the spectral variation of the signal power over time [3].
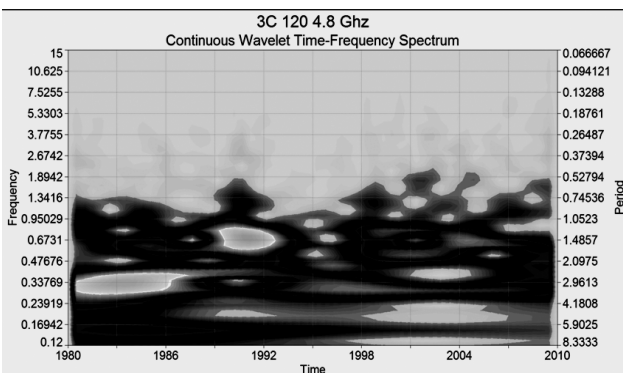

Figure 4: Continuous wavelet spectrum filtered series «O – C», for the source 3C120, at a frequency of 4.8 GHz.

Periods and phases of activity sources

3C120. The trend components.

The source 3C120 has a long-term 11 – 13-year-component at all frequencies. At 8 GHz found 24-year period. Phase of activity (bursts of spectral power) at the source 3C120 for the trend component observed at a frequency of 14.5 GHz – 1985, 1990 and 1998, at a frequency of 8 GHz – 1969 and 1974, at a frequency of 4.8 GHz -1990 and 1998 years.

Short periods (O – C). Periods about 2 and 5 years are also present at all frequencies. Similar values of periods 1.6 year (14.5 GHz), 1.3 year(8 GHz) and 1.6 year (4.8 GHz) may be a manifestation of the same process going on different frequencies. For the short-period component of this source activity phases were observed at a frequency of 14.5 GHz – 1990, 1992 and 1998, at a frequency of 8 GHz – 1990, 2004 and 2007, at a frequency of 4.8 GHz – 1990 year.

CTA102. The trend components.

The main period of the flux radio source is about 3 years. 2006 marked the largest phase of activity for the trend component at all frequencies.

Short periods (O – C). Source STA102 has components with periods 0.5 – 1 year. For the short-period component, activity phases were observed at a frequency of 14.5 GHz – in 2000, 2006 and 2009 years, at a frequency of 8 GHz – in 2009 and 2010 years , at a frequency of 4.8 GHz – in 2000.

DA55. The trend components.

There is long-period component of 6 – 8 years at all frequencies. For long-term component of the activity phases were of 14.5 GHz – in 2007 year, at a frequency of 8 GHz – 2004 and 2007 years, at a frequency of 4.8 GHz – in 2010.

Short periods (O – C). At all frequencies components 1 – 2 years and 3 years appear. Phase of activity for this components was observed at a frequency of 14.5 GHz – 1999, 2001, 2003 and 2010 years, at a frequency of 8 GHz – 2002, 2003 and 2005 years and at a frequency of 4.8 GHz – 2002 and 2010 years.

OJ287. The trend components.

At 8 and 14.5 GHz, the presence of 7 – to 8-year- long-period component. At frequencies of 4.8, 8 and 14.5 GHz 10 – 13-year component is shown. The peculiarity of this source in the presence of a trend at all frequencies. The period of this trend is likely to exceed 25 years.

Short periods (O – C). The source is the presence of 3-year component at frequencies 4.8, 8 and 22 GHz. At all frequencies the period of 1.6 to 1.1 years is changed. This change is the most evident in the frequency of 14.5 GHz. Phase of activity was at a frequency of 14.5 GHz – 1985 and 2010 years, at a frequency of 8 GHz – 1985 and 1989 years and at a frequency of 4.8 GHz – 1985 and 1989 years.

«Spectra periods»

For each year of observations graphics "spectra periods" were built to assess the contribution of individual periods in the activity of the radio source. In Fig. 5 shows an example of such a graph.

The use of a "spectrum of periods" allows comparisons with VLBI observations to determine the nature and dynamics of the processes in the jets.
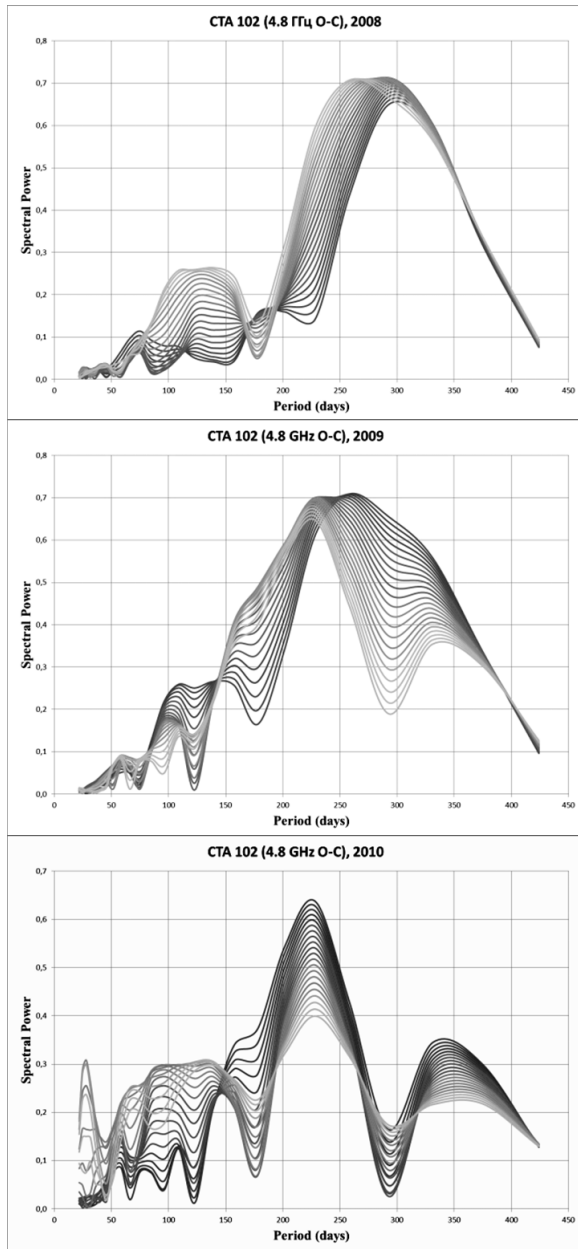
Figure 5: The graph shows the contributions of the individual periods in the activity of the radio source CTA 102 at a frequency of 4.8 GHz (O-C) for 2008–2010 years.

On the existence of quasi-stationary structures in the jets

In comparing the data on the availability of bright VLBI component in the jet being celebrated moving with time component and quasi-stationary structures bright knots occurring on the same distances from the cores. Such phenomena occur in sources with long jets 3C120 and CTA 102 (Fig. 6). Appearance of these nodes in the jets of brightness can be explained by a model of a standing backward wave.

Conclusions

Data processing based on wavelet analysis indicates the presence of a variable fluxes radio sources CTA102, 3C120, DA55 and OJ287 long-period and short components.
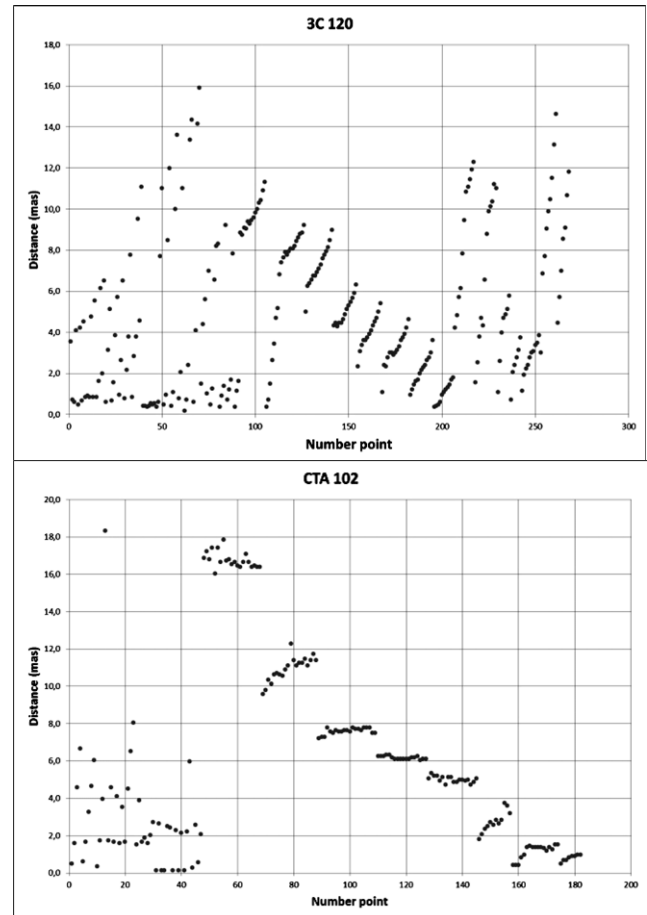

Figure 6: Quasi- stationary space structure of bright knots in the jet of 3C120 and CTA102.

Investigations the time of their existence, the main phases of activity and form the "spectra of periods." "The trend" component of the activity of radio fluxes formed by the long-term oscillations with a period in the range of 8 – 13 years or more. At the coincidence of the maxima of the trend component with maximum short-change flux with periods ranging from fractions to 3-year phase of the observed increased activity system «core- disk-jet». For each year of sources observations in all studied frequencies defined "spectra periods" determined by the contribution of the core and the jet activity. VLBI data show that the sources of 3C120 and STA102 with the activity of the cores are periodically increased flow from the jet. For sources DA55 and OJ287 core activity almost always prevails over the jet activity. In the VLBI data registration bright knots occur on the same distances from the core. This quasi-stationary structures found in jets from sources 3C120 and CTA 102.

References

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