RADIO-ASTRONOMY

ANALYSIS OF THE VARIABILITY AND THE SPECTRUM OF PERIODS OF EXTRAGALACTIC SOURCE OJ 287 IN THE RADIO WAVES

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ABSTRACT. We analyzed long-term monitoring of data flux of extragalactic source OJ 287 obtained at frequencies of 14.5 GHz (1974-2011), 8 GHz (1971-2011), 4.8GHz and (1979-2010), on the RT-26, University of Michigan, USA. Variability of the flux of the radio source was investigated by applying wavelet analysis. There were identified long-period (in the range of 3.6 to 13.6 years) and short (in the range from 1.2 to 1.8 years) components at all studied frequencies and it was determined the time of their existence. The "spectra periods" for each year of observation were built to assess the contribution of individual periods in the formation of the most powerful phase of activity of the radio source. The dynamics of the manifestations of active periods at different frequencies was observed. The obtained data was compared with the results of MOJAVE VLBI monitoring for the period of 1995-2012 years at a frequency of 15.4 GHz. It allowed to investigate the structure of emissions during periods of manifestation activity maxima.

Introduction

According to current views, in the center of active galactic nuclei are supermassive black holes weighing 10^6-$10^{10} M_{\odot}$. The material falling into a black hole, has got an angular momentum and forms the accretion disc. Part of the disk material falls into the black hole, and the other part of the disk material is accelerated by strong magnetic fields and forms a jet that is ejected perpendicular to the plane of the accretion disc.

Extragalactic source OJ 287 refers to blazars, that is, his jet is directed toward the observer. Blazars exhibit variability across the electromagnetic spectrum. In the article [1], the authors suggest that blazar OJ287 contains a system that consists of two black holes. The secondary black hole rotates around the primary the more massive black hole with a period of ~12 years.

The main characteristics of OJ 287: z~0.306, the distance to the object ~1576 Mpc. We used data from observations at frequencies of 14.5 GHz (1974-2011), 8 GHz (1971-2011) and 4.8 GHz (1979-2010). Earlier, we published an article on the four sources, including the OJ 287 [2]. In comparison with the previous one, in this article there was expanded an application of wavelet analysis.

Observations

We investigated the monitoring data on the frequencies 14.5 GHz, 8 GHz and 4.8 GHz flux blazar OJ 287, received a 26-meter radio telescope of the Observatory of Michigan (USA). Details of the calibration and analysis techniques are described in [3].

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 [4]. Total flux densities of a radio source OJ 287 are shown in Fig. 1. Sixth-degree polynomial was subtracted for each frequency.

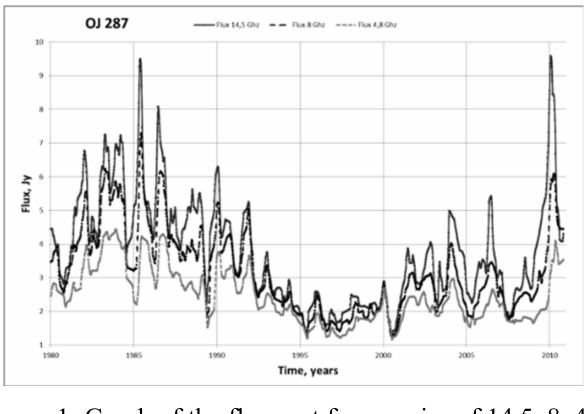

Figure 1: Graph of the fluxes at frequencies of 14.5, 8, 4.8 GHz, for the blazar OJ287.

FOURIER-analysis

In order to determine the periods Lomb-Scargle periodogram for data with an uneven readings on the time axis was built [5]. The spectral densities were calculated using the spectral Bartlet window. Example of Fourier spectra is shown in Fig.2.

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. We used a continuous wavelet transform based on Morlet function. The example of the wavelet spectrum is shown in Fig. 3 and 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.

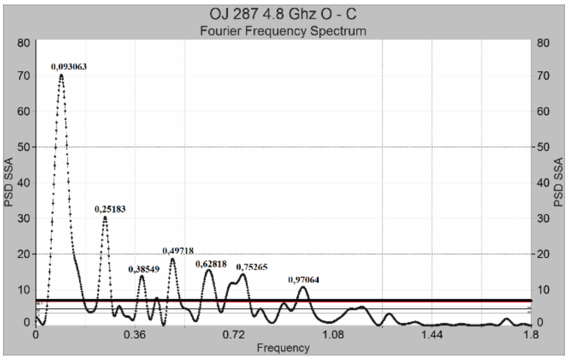

Figure 2: Periodogram for the source OJ287 at a frequency of 4.8 GHz.In the figure the frequency of 0.093063 corresponds to the period 10.7 years, the frequency of 0.25183 4-year period, the frequency of 0.38549 – 2.6 years, the frequency of 0.49718 – the period of 2 years, the frequency of 0.62818 – the period of 1.6 years, the frequency of 0.75265 – 1.3 years, the frequency of 0.97064 – 1 year.

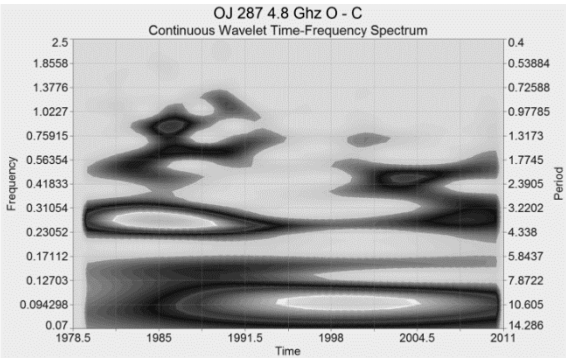

Figure 3: Continuous wavelet spectrum for the source OJ287 at afrequency of 4.8 GHz.

The main periods

Monitoring data of the source OJ287 at three frequencies were processed using wavelet analysis.Among the periods are allocated long-period and short-period.

The trend component. The source OJ 287 at frequencies of 14.5 and 8 GHz has got periods of 7-8.7 years and 13.6 years. At a frequency of 4.8 GHz is detected the period 10.9 years.

Short-period component. Of short-period component at the source there noted the existence of the period of 3.6-4.4 years at frequencies 4.8 and 8GHz. There Fig. 4, in the time interval since 1976 till 1990, shows a spot in the form of a "jellyfish", which is formed by two periods – 1.2 and 1.6 years. Such a "jellyfish" is visible on the wavelet spectra at all three frequencies, but the highest spectral power is observed at a frequency of 14.5 GHz. In the period since 2004 till 2011 at all three frequencies there appeared period of 1.8 years.

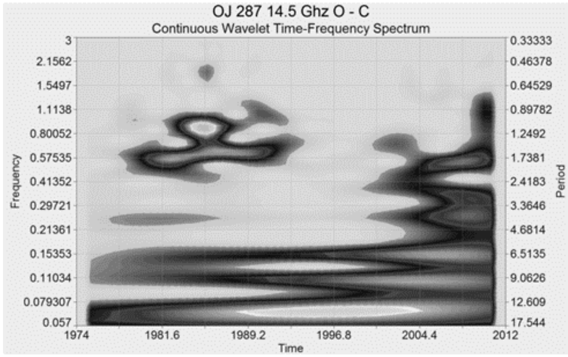

Figure 4: Continuous wavelet spectrum for the source OJ287 at a frequency of 14.5 GHz.

Phases of the activity

The distribution of the total energy of the signal on the scale can be traced through the global wavelet spectrum, which corresponds to the power spectrum, smoothed on every scale Fourier spectrum of the analyzing wavelet. Thus, the global spectrum reflects the relative contribution of the different scales in the total energy and detects the energy distribution of process scales.With the global wavelet spectrumare identifiedthe main periods of activity of the flux of the radio source at the studied time interval (Fig. 5).

Phases of activity for the source observed at a frequency of 14.5 GHz – 1985, 1989 and 2010, at a frequency of 8 GHz – 1985 and 1989 and at a frequency of 4.8 GHz – 1985 and 1989.

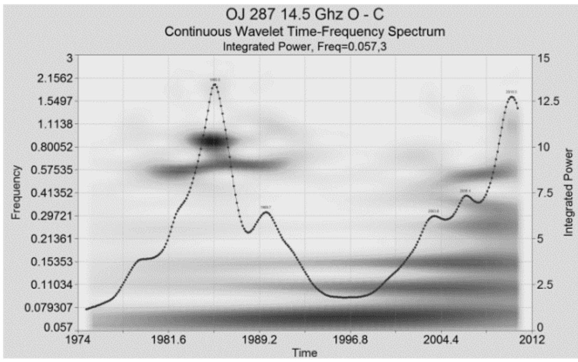

Figure 5: Graph of the integral wavelet spectrum (time – the spectral power) for OJ287.

"The spectra periods"

For each year of observations graphics "spectraperiods" were built to assess the contribution of individualperiods in the activity of the radio source. In Fig. 6 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.

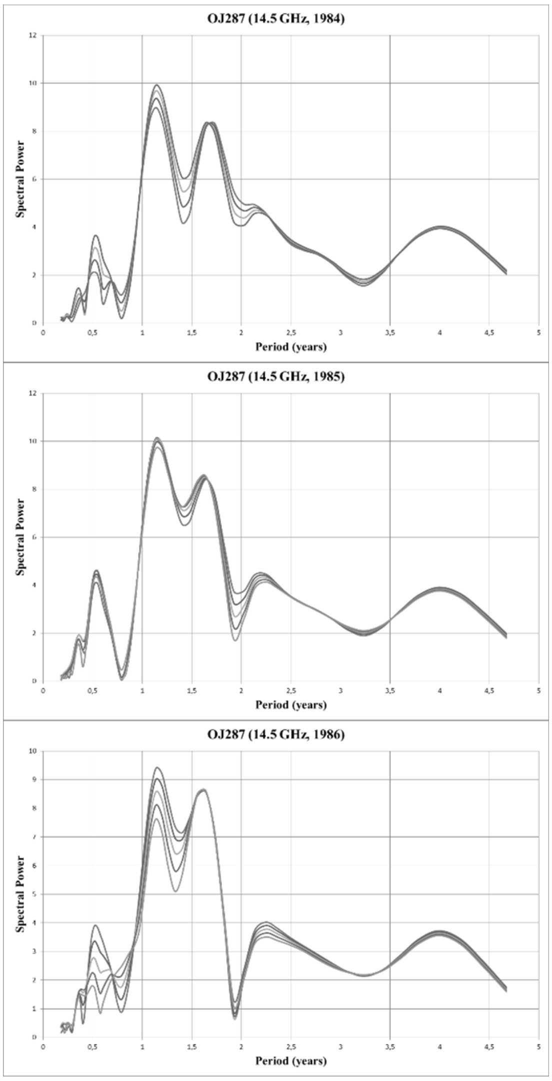

Figure 6: The graph shows the contributions of the individual periods in the activity of the source OJ287 at a frequency of 14.5 GHz for 1984-1986 years.

Stationary components in the jet

In the study of the bright components in the jet on VLBI data at a frequency of 15.4 GHz (Fig. 8) [6] there has been observed that there are gradually receding components and the component which episodically occur on the same distance from the core. In the articles of some authors [7],[8],[9] one discussed the existence of a stationary components in the jets which are in the fixed position. These knots brightness were explained as standing shock wave caused by the interaction of the jet with the environment.

Conclusions

Data processing based on wavelet analysis indicates the presence of radio source OJ287 short-and long-period component, the time of their existence, the main phases of activity."The trend" component of the activity of radio fluxes formed by the longterm oscillations with a period in the range of 7 – 13.6 years.At coincidence of peaks of the trend component with maximum flux density of short-period changes with periods ranging from 1.2 to 4.4 years,

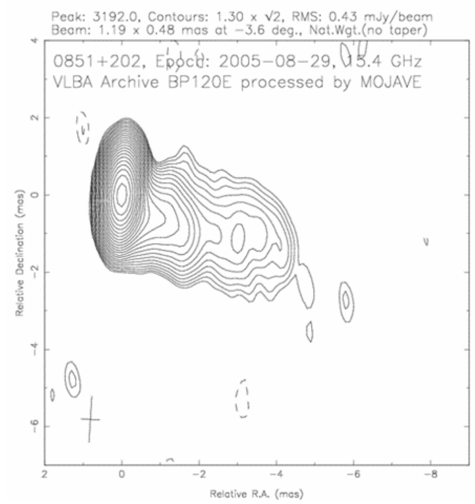

Figure 7:Radio card for Blazar OJ287 at a frequency of 15.4 GHz for the epoch 2005-08-29. This image is obtained from the MOJAVE database.

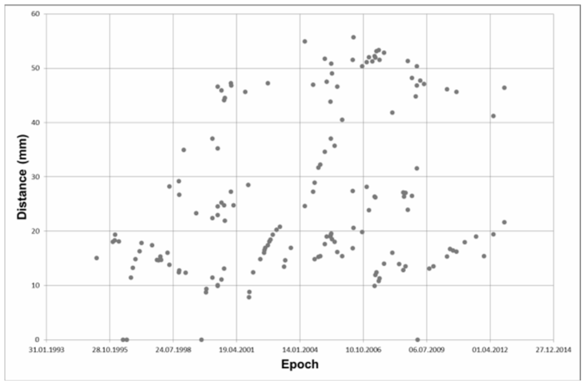

Figure 8: The motion of the jet components relative to the core.

there are marked phases of increased activity.The obtained data were compared with the results of MOJAVE VLBI monitoring for the period 1995 -2012 years at a frequency of 15.4 GHz, allowing to investigate the structure of emissions during periods of manifestation activity maxima.In the jet there marked the existence of certain structures that move with the times and of the bright knots, occurring at the same distances from the core.

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