Multidimensional analysis of X-ray variability of AGN

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Abstract. In this work we analyzed X-ray light curves of active galactic nucleus NGC 4051 obtained using Advanced CCD Imaging Spectrometer of Chandra satellite. Taking into account mainly flaring behaviour of AGNs we have used wavelet analysis for searching of short time lived events on light curves.

1. Introduction

Short time-scale X-ray variability from dozens of seconds to hours in AGNs is explained as the result of different kinds of processes which happen close to the central engine. The possible origins are changes of the accretion rate, flares in accretion disk, motion of hot spots around the black hole and, for longer time scales, motion of hydrogen clouds which obscure the central source, etc.

Here we present results of investigations of short time-scale variability of active galactic nuclei using as example Chandra observations of bright Seyfert type galaxy NGC 4051. All archive data sets (obsid 829, 2983 and 3144) were processed using CIAO 2.3 package.

2. ANALYSIS OF VARIABILITY OF NGC 4051

Seyfert type galaxy NGC 4051 is very bright object with rapid and dramatic changes of flux.

Chandra observations of NGC 4051 were made during AO1, AO2 and AO3 (see Table 1).

In order to investigate the character of variability, we used the wavelet method (Andronov 1999), which is excellent for detection of incoherent or weakly coherent variations. Many papers are devoted to the application of the wavelet method to periodic or multiperiodic processes (Fritz & Bruch 1998).

Long-term variations of NGC 4051 have been smoothed by using the method of the running parabola (Andronov 1997). The optimal value of the filter half-

| Obs.ID | Date          | Exp.ks | Mode |
|--------|---------------|--------|------|
| 829    | 00-03-24/25   | 80.8   | ACIS |
| 2148   | 01-02-06      | 50.5   | ACIS |
| 3144   | 01-12-31/02-01-01 | 91.7 | HRC  |
width $\Delta t = 0.217$ d has been determined from maximization of the “signal-to-noise” ratio. To avoid apparent effects of low-frequency trends on the test–functions at high frequencies, the original data have been detrended, i.e. the running parabola fit was subtracted from the observations. For these detrended time series, the test functions have been computed using the code described by Andronov (1994). For visualization, we used the Weighted Wavelet Z-transform (WWZ) test-function (Foster 1996), which is characterized as having the best contrast among other test functions.

On Fig.1 one can see resulting wavelet maps, power spectra with red noise trend and detrended power spectra for all data sets. Power spectra for different runs show prominent peaks (Fig.2), but they never found again for other runs. However, the same result for time-scale of about 4 ksec have been found by previous investigators (see Papadakis & Lawrence 1993). As a result we can conclude incoherent or only weakly coherent behaviour of variability of NGC 4051.

To study typical time-scales of variability of NGC 4051 we plot the distributions of time-scales derived from wavelet maps for different runs (Fig.3). All plots show two different groups of peaks with time-scale of approximately 5 and 15 ksec. Additional powerful peak (9 ksec) on distribution for the run 3144.

Figure 1. Light curves, wavelet maps and power spectra for detrended light curves of NGC 4051.
corresponds to oscillations which were observed during the large flare on light curve.

\[ \alpha = 1.49 \pm 0.13 \]

\[ P_{\text{OPO}} = 3940.3 \pm 5.9 \text{ s} \]

Figure 2. Initial and detrended power spectrum for run 3144 with peak around 3940 sec.

Figure 3. The distribution of the variability time-scales derived from wavelet maps.
Figure 4. Quasi-coherent events on light curves of NGC 4051.

On the next figure (Fig.4) we show evolution of time scales and amplitudes for the most prominent oscillations detected with wavelet analysis. One can see that mostly long lived oscillations have life time approximately 3-4 times longer than their periods. This fact allow us assume non flare nature of these events.

3. CONCLUSIONS

Using results of wavelet analysis we declare absence of “true” quasi-periodical oscillations in NGC 4051 with coherence time-scale longer than 4 periods. Detected QPO-like events with coherence time-scale shorter than 3 periods must be explained as composition of different flares on light curves. However, several events, observed during 3-4 cycles, could be generated by some quasi-periodical processes in the vicinity of central black hole.

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