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Simultaneous UBVRI Light Curves of the Seyfert Galaxy NGC 4151 During the Extraordinary Brightening in 1989-1996

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Introduction. The nucleus of the Seyfert galaxy NGC 4151 is known to be variable in the optical on different timescales: from minutes to tens of years. A new cycle of activity of the nucleus is investigated from 1989.

Observations. 1500 measurements were obtained simultaneously in each of the UBVRI bands at Crimean Astrophysical Observatory with the 1.25-m telescope in an aperture of 20 arcsec during 96 nights between 1989 February 11 and 1996 June 14. The estimated accuracy of each measurement is no more than $0.^m01$.

UBVRI Light curves in each filter showed an increase of the nuclear brightness from 1990 February. Until 1996 June the unusual historically extraordinary long–term brightening was going on. Amplitudes and averaged gradients of the brightness variations during 7.3 years of our observations decreased from the U to I band. The amplitude amounts to $2.^m0$, $1.^m5$, $0.^m9$, $0.^m8$ and $0.^m7$ in UBVRI bands, respectively. Gradients of brightnesses were: 0.30; 0.23; 0.15; 0.13; 0.11 mag/year for UBVRI bands correspondingly.

There were intranight variations and flares with durations 10–147 days. Amplitudes for flares $A = F_{max}/F_{min}$ decreased from the U to I band. Maximum amplitudes for U and I bands were 3.4 and 1.3 correspondingly.

Gradients of the nuclear brightening during flares in all spectral bands are more than those for total observing time. The largest gradients were observed at the end of the observing period.

UBVRI energy distributions for flux excesses during the flares and during the whole period of observations showed a power-law form $F_\nu \sim \nu^\alpha$. Calculated spectral slopes for flares were $+0.18 \geq \alpha_{pl} \geq -1.83$, $\Delta\alpha_{pl} = 2.01$. Obtained data were discussed in the frame of the model of synchrotron nature of UBVRI variations of the NGC 4151 nucleus. The increasing of spectral indices with time suggests that the optical depth of synchrotron emission clouds increased from the beginning to the end of the nuclear brightening.

Structure Function analysis. Evolution of the process causing the variation of the nucleus in all spectral bands was investigated by the method of the structure function (SF). The slope of SF b=dlog(SF)/dlogΔt characterizes the nature of the process: b = 0 – flicker-noise, b = 1 – shot-noise. SF was calculated separately for four observational time intervals: I.89 – V.90; XI.90 – V.92; XII.92 – I.94 and I.95 – VI.96. The figure shows that:

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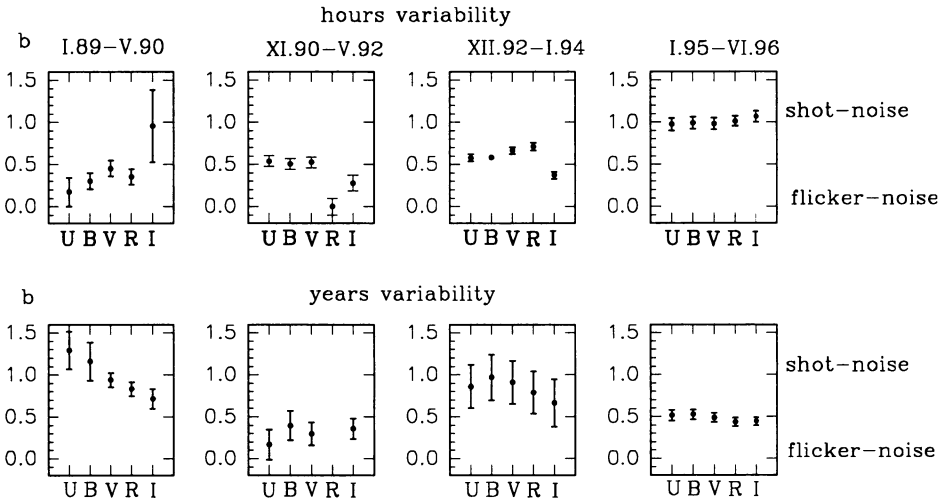

Figure 1. Variation of SF slope "b" with time . Top – for hours variability, bottom – for years variability.

1. Intranight and years UBVRI nucleus variations are caused by a process variable with time. The process varied between flicker-noise (b = 0) and shot-noise (b = 1).

2. The nuclear process evolved with time in different directions, intranight variations evolved from flicker to shot noise, and years variations vice versa.

Discussion. Difference in direction of the evolution of the process acting in the nucleus of NGC 4151 within nights and during 1989 – 1996 years revealed from SF slopes variations suggests that variation of the nucleus is connected with two different sources. One of them acts on a time scale less than one night but another one – on a time scale of years. The source of years time-scale variations at the beginning of the observations was caused by a strong shot–noise process: SF slope "b" for all UBVRI bands were near or more than 1. Emission in U band of this source is characterized by the highest amplitude of variations and highest slope "b". We suppose that increasing of the nuclear brightening on time scale of years was connected with the source of high ultraviolet emission. At the beginning of the nuclear brightening this source was strongly fueled. To the end of the nucleus brightening fueling of the process decreased; it evolved from shot–noise to flicker–noise.

Variations of the source acting on time-scale of hours at the beginning of the nuclear brightening was caused by a flicker–noise process, slope "b" of SF was near 0. But during the nuclear brightening SF slope "b" gradually increased. At the end of the nuclear brightening variations of this source were caused by a strong shot–noise process. This fact suggests that fueling of the source acting on time-scale of hours is increased with increasing nuclear brightening contrary to the source acting on time-scale of years.

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