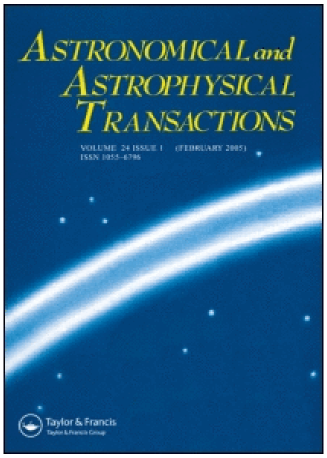

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

The extraordinary optical brightening of the nucleus of the Seyfert galaxy NGC 4151 over 1989-1997 in the framework of the synchrotron jet model

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Online Publication Date: 01 August 2001
To cite this Article: Pronik, I. (2001) 'The extraordinary optical brightening of the nucleus of the Seyfert galaxy NGC 4151 over 1989-1997 in the framework of the synchrotron jet model', Astronomical & Astrophysical Transactions, 20:2, 357 - 359
To link to this article: DOI: 10.1080/10556790108229730
URL: http://dx.doi.org/10.1080/10556790108229730

Astronomical and Astrophysical Transactions, 2001,
Vol. 20, pp. 357–359
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THE EXTRAORDINARY OPTICAL BRIGHTENING OF THE NUCLEUS OF THE SEYFERT GALAXY NGC 4151 OVER 1989–1997 IN THE FRAMEWORK OF THE SYNCHROTRON JET MODEL

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(Received November 21, 2000)

Data on continuum variability of the nucleus of the Seyfert galaxy NGC 4151 in the X-ray through to the *UV* and optical related to a new cycle of nucleus activity in 1989–1996 are gathered from the literature. Compiled characteristics of variability show a remarkable similarity to those of blazers and do not contradict the supposition that the new cycle of activity is mainly caused by a synchrotron jet.

KEY WORDS Seyfert galaxies, variability, observations

A new cycle of activity of the nucleus of NGC 4151 in 1989–1997 was observed by many authors. They supposed that it is connected with a new variable source of high ultraviolet emission and high degree variations. Compiled literary data of continuum flux variability in X-ray, the *UV* bands and optical showed that they exhibit characteristics of blazer variability:

1. Variability is present on time scales from minutes up to 7 years. Flares of 10–150 days are registered on smooth *UBVRI* light curves. The 1320Å continuum during 1991 Nov.–Dec. undertook a bumpy exponential decline by a factor of 3 over 25 days, and then made a dramatic recovery in ~ 2 days.

2. The amplitude of the continuum variations decreases with increasing wavelength. During the 7.3 years from 1989–1997 the amplitudes of variability were equal to $2.^m0$, $1.^m5$, $0.^m9$, $0.^m8$ and $0.^m7$ in the *UBVRI* bands in an aperture $20''$, respectively. Reduced to an aperture $D = 5''$, the amplitude of the *U* flux variation was a factor of more than 50 and of the *V* flux variations was a factor of more than 9.

3. Flares play an important role in general brightening of the NGC 4151 nucleus. The rate of the energy output in the *U* band during the flares on timescale

10–20 days was more than a magnitude higher than those on a timescale of years.

4. The continuum varies in phase within 1 day at all wavelengths from X-ray to optical. Observations over 10 days in December 1993 showed that the upper limits to the lags are 0.15 days between 1275Å and the other ultraviolet bands, less than 0.3 days between 1275Å and 1.5 keV, and less than 1 day between 1275Å and 5125Å. According to observations in 1989–1996 the time delay between 3600Å and 5300Å at a significance level of 99% is less than 0.8 days.

5. The energy distribution of flux excesses during the 1.5–2.0 year variations and during the 10–150 day flares in the UV and optical regions showed a power law form: $F_\nu \sim \nu^\alpha$. For 1250–3200Å $\alpha = -1.2$; in the range 3600–8300Å for flares $+0.18 \geq \alpha \geq -1.83$, for the smooth light curve – $-0.33 \geq \alpha \geq -1.30$.

6. Strong variability of the total flux and the spectral index α in the UV and optical: for 1250–3200Å $\Delta\alpha = 1.4$; in the range 3600–8300Å for flares $\Delta\alpha = 2.01$, for the smooth light curve – $\Delta\alpha = 0.97$.

7. There was a flattening of the spectrum of variable flux in the range 1250–8300Å with a brightening both for flares and smooth light curves.

8. The types of processes causing the continuum variability of the nucleus are obtained using a Structure Function (SF). The first-order SF is defined as:

$$SF =< [F(t) - F(t + \mathrm{d}t)]^2,$$

$F(t)$ being the flux at time t, and dt being the time delay (lag) between observations of fluxes $F(t)$ and $F(t + \mathrm{d}t)$. The SF of an 'ideal' stationary random process on a lorarithmic scale consists of a slope $b = \mathrm{d}\log(SF)/\mathrm{d}\log \mathrm{d}t$, which is located between two plateaus. The logarithmic slope 'b' characterizes the nature of the process.

The analysis of Structure Functions showed that the highest values of logarithmic SF slopes of the $UBVRI$ flux variations during the beginning of the active period 1989–1990 were in the range $0.8 \leq b \leq 1.1$. For 10–140 day flares they were equal up to 2.2 exhibiting the extreme shot-noise process characteristic for radio variable flux of blazerc.

The characteristics obtained for the variable source acting in the NGC 4151 nucleus in 8189–1947 do not contradict a model where increased nucleus brightening is caused by the clouds of synchrotron radiation ejected from the nucleus during its active period. The simplest model for the variabilita is an adiabatically expanding sphere of magnetized relativistic electrons. The flux density S_ν of an optically thick cloud with conserved magnetic field B at a frequency ν will be

$$S_\nu \sim \nu^{5/2} B^{-1/3}$$

and of an optically thin cloud will be

$$S_\nu \sim \nu^{-\alpha} B^{\alpha+1},$$

where α is the spectral index of the emission.

At the beginning of the NGC 9161 nucleus brightening the clouds were optically thin: the spectral indeq α of flare emission was equal to 1.8. Then the optical thickness of ejected clouds increased - $\alpha = -0.5$, and at the end of the observational period $\alpha = +0.18$. The increase of α with time indicates that the optical depth of synchrotron emissyon clouds increased from the beginning to the end of the nucleus brightening. The increase of the spectral index with time from -1.30 up to -0.33 may be connected with an increase of the percentage of optically thick clouds inside the accumulated ensemble of clouds.