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Characteristics of the variability of the nucleus of NGC 1275 in the optical in 1982–1994

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Abstract. We study the variability of the nucleus of NGC 1275 in the optical region using two samples of the photoelectric observations obtained with the 1.25-m telescope of the Crimean Astrophysical Observatory. The first sample contains one series of 379 measurements of the nucleus brightness obtained with the scanning spectrophotometer during 35 nights from 12.XI.1982 to 23.X.1987. The slit $\Delta\lambda$ = 80 Å was centered at the wavelength λ 5200 Å. The second sample contains 5 series of 820 measurements obtained simultaneously in each of the UBVRI bands during 37 nights from 22.XII.1989 to 29.XII.1994. The observations during one night lasted from 0.5 up to 8.7 hours. Each of the 6 independent observational series was analyzed separately.

An analysis has been made of the variations both on a time scale of years and of single nights (intra–night). Ratios of Standard Deviations (SD) of the variable flux to the error of the observations (σ) were calculated for each night, and the parameters of Structure Functions (SF) were used as indications of the intranight variability. We assume that the intranight variations of the flux are real, when SD $\geq 3\sigma$. There were 8% of such nights in 1982–1987, and about 40% of nights showed intranight variability in 1989–1994.

SFs of the intranight variations for all series of observations are characterized by the two slopes log(SF) $\sim$ b log dt: for time scales less than 4 hours the slope is in the range 0.25$\leq$b$\leq$0.66, for the time scales less than 9 hours it is in the range 0.66$\leq$b$\leq$1.19. These data allow us to conclude that during 1982–1994 two processes operated in the nucleus of the NGC 1275 galaxy, causing variations of its flux in the optical on a time scale of several hours. One of the processes was a mixture of shot–noise and flicker–noise, and the second one was nearer to pure shot–noise.

The SF slopes for the time scale of years were in the range of 0.06–0.14. They evidenced that on the time scale years the process was absent, or a pure flicker–noise is operated. The evolution of the processes acting in the nucleus from 1968–1980 to 1982–1994 is mentioned. A years process is evolved in accordance with the general flux variations, but an activity of the intranight variations is increased with the decreasing of the general brightness of the nucleus. All obtained data are discussed from the point of view of the current models of a powering mechanism.

Key words: galaxies: individual: NGC 1275 – galaxies: Seyfert – instabilities

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1. Introduction

The peculiar galaxy NGC 1275 contains a peculiar nucleus. According to the emission–line characteristics of its optical spectrum, the nucleus is of Sy2 (Marziani et al., 1996), or Sy 1.5 (Veron–Cetty & Veron, 1998) type. But, considering the strong and rapid variability of the total and polarized flux in the optical and radio region the nucleus is suggested to be a blazar (Angel & Stockman, 1980; Kinney et al., 1991; P. Veron, 1978; Courvoisier et al., 1992 and others). Readhead et al. (1990) argued that the discrepancies between the emission lines and the continuum spectrum characteristics of the nucleus are a result of observational selection. The distance to the galaxy NGC 1275 is less by an order of magnitude than those to other galaxies of the same high–level luminosity $\sim 10^{44}$ ergs/s. This gives rise to observational increase of the equivalent widths of the emission lines, compare to those of other blazars.

The nature of the processes causing the high blazar luminosity is not exactly clear. The mechanisms of the continuum emission are open to discussion, too. The spectrum of the nucleus of NGC 1275 was fitted by many authors, e.g. for the infrared by Hildebrand et al. (1977), Impey & Neugebauer (1988), Knapp et al. (1990), Knapp & Patten (1991); from the optical to the infrared by Rieke (1978), from optical to radio by Babadzhanjants et al. (1972), Longmore et al. (1984) and others. Unfortunately there is no common opinion for these fittings. Martin (1978) investigated the spectrum of the nucleus of NGC 1275 from the X – ray to radio and concluded that “NGC 1275 is a fascinating and important object. Understanding it would surely signify progress towards understanding active nuclei and quasars. All observational efforts to this end should be encouraged”.

Variability measurements are a tool for exploring the physics of blazars, quasars and other Active Galactic Nuclei (AGNs). The high variability of the NGC 1275 nucleus was pointed out in the far ultraviolet (Treves & Girardi, 1991). It is in the list of the three most variable blazars among 8 observed with IUE from 1978 to 1984. The characteristics of the optical variability of the NGC 1275 nucleus were investigated over 30 years after the first study by Barnes (1968). The longest runs of observations were made by Lyuty (references in Lyuty, 1977, 1987; Nesterov et al., 1995), and Babadjaniants, Hagen–Thorn (see Babadjaniants et al., 1972; Babadjaniants & Hagen–Thorn, 1975; Hagen–Thorn, 1987). The extreme active flaring period was mentioned during the sixties and seventies, but from the end of the seventies the nucleus was at a minimum of activity (Nesterov et al., 1995). Lyuty & V. Pronik (1975) revealed two components in the U light curve in 1967–1974: a slow component with a time scale of 1.5 years and an amplitude $0.^m4$, and a rapid one – with a time scale of 20 days and an amplitude $0.^m8$. When the sampling became dense enough, the time scale of a rapid component decreased (Dibaj & Lyuty, 1976; Lyuty, 1977, 1987; Hagen–Torn, 1987; Basko & Lyuty, 1977 and others). The highest number of components in the light curve of the nucleus of NGC 1275 was revealed by Lyuty (1987) – 5 components with time scales of from 1 day to 16 years.

The variability in the optical on a time scale of about one day was investigated by Martin et al. (1976). The intranight variability of the nucleus was studied by Merkulova & Pronik (1985), Merkulova et al. (1987, 1988, 1992, 1993), Pronik et al. (1990, 1998), and Merkulova & Metik (1995, 1996). It was shown that in 1989–1994 the nucleus's intranight UBVRI variations at a level SD$\geq 3\sigma$ (SD – the standard deviation of the variable flux averaged by night, and σ – the error of a single flux measurement) have a duty cycle of 0.4.

The optical variability of the nucleus of NGC 1275, with its diverse morphological characteristics and seemingly stochastic nature, is still a problem, with which no current model can adequately deal. In this paper, we examine the character of the optical variability of the nucleus of NGC 1275 using two samples of photoelectric observations obtained in 1982–1994. The examination led to the supposition that the variation of the nucleus is caused by two or more sources. Time evolution of the observed characteristics of the nucleus was suspected.

2. Observations

Two samples of photoelectric observations of the NGC 1275 nucleus, obtained with the 1.25-m telescope of the Crimean Astrophysical Observatory were considered. The first sample consists of photoelectric narrow–slit observations of the galaxy continuum; these have been made during the period 12.11.1982–23.10.1987 using the scanned photocounting spectrometer ASP-38.

The diaphragm was 10″, an entrance slit of the spectrometer $\Delta\lambda$ = 80 Å was centered at the wavelength λ 5200 Å. During 35 nights of observations 379 flux measurements with a time resolution of 4–5 min were made. The accuracy σ of a single flux measurement was in the range $\pm$4%.

The second sample consists of five observational series obtained simultaneously in five bands of the UBVRI (λ 3700–8300 Å) photometric system from 22.12.1989 to 29.12.1994 with the use of the Double Image Chopping Photometer–Polarimeter (Piirola V., 1973). Observations were carried out with the round diaphragm 20″. During 37 nights 820 estimates of the flux in each filter were made. The error σ of a single flux measurement was in the range $\pm$1%, the time resolution was about 4 min.

The observations are carried out using a conventional technique. Two comparison stars are used, the second one for check purposes. Stars were taken from the list by Lyuty (1972). The telescope is fully automated, during observation the location of the object inside the diaphragm is controlled by the autoguide. The duration of one night's observations varied from 0.5 to 8.7 hours. The monitoring of the NGC 1275 nucleus was made in good atmospheric conditions; as a rule, the estimated seeing was 1–3 arcsec. The sky background has been subtracted. Details of the observational techniques, part of the observational data of nucleus of the NGC 1275 and the analysis of the errors of the measured fluxes were published in papers by Merkulova (1986), Merkulova & Pronik (1987), Merkulova et al. (1988, 1992, 1993), Merkulova & Metik (1995, 1996). Averaged values of the flux F of the nucleus of NGC 1275 for each night of observations in 1982–1987 are listed in Table 1.

There were 6 independent series of observations: one series was obtained in 1982–1987, and 5 sets in the U, B, V, R and I bands were obtained in 1989 –1994. During some nights 40–60 measurements of the nucleus brightness were made. To keep the observational material homogeneous and to examine differences in the characteristics of the variability at different times and different wavelength regions, we examine below the variable flux of the NGC 1275 nucleus separately for each of the 6 series.

3. Light curves

Fig. 1 presents the light curve of the nucleus of NGC 1275, obtained by Lyuty (Nesterov et al., 1995) in 1968–1994. It shows week averaged fluxes (F, mJy). One can see that a period of high activity was observed in 1968–1980, and from the end of the seventies the nucleus is in the long minimum of brightness. Our two observing runs shown by brackets were made in the period of a gradual decrease of the nucleus brightness. Fig. 2 presents the light curves of the NGC 1275 nucleus, obtained at the first run (1982–1987) from observations in the spectral region λ 5200 Å and at the second run (1989–1994) – from the UBVRI system. The data in Fig. 2 do not show a systematic trend of the flux variations with time. But variations of the nucleus brightness during the separate nights are clearly seen. The character of the variability is dominated by rapid outbursts, exceeding the luminosity of the quiescent state by more than 20%.

It is evident from Table 1, that the intranight activity of the nucleus of NGC 1275, when SD$\geq 3\,\sigma$, was observed in 8% of the nights of observations during 1982–1987. One can conclude that the duty cycle of the intranight variations was 0.08.

We study the character of the flux variations of the NGC 1275 nucleus by means of SF analysis. It is a powerful

Table 1. Observational data of the NGC 1275 continuum at λ5200 Å obtained in 1982–1987

Date 1	jd 2	n 3	F_{5200} 4	SD/σ, 5
12/13 Nov. 82	5286	12	0.94	1.25
18/19 Dec. 82	5322	1	0.81	–
06/07 Jan. 83	5341	12	1.02	1.44
03/04 Sep. 83	5581	5	0.94	1.32
04/05 Sep. 83	5582	10	0.97	1.30
06/07 Sep. 83	5584	12	0.79	3.93
02/03 Oct. 83	5611	2	1.04	–
06/07 Dec. 83	5675	2	1.08	–
03/04 Jan. 84	5703	22	1.01	1.08
03/04 Feb. 84	5734	11	1.03	1.19
04/05 Feb. 84	5735	7	1.04	1.62
05/06 Mar. 84	5765	5	1.06	1.46
15/16 Jan. 85	6081	6	1.14	2.25
16/17 Sep. 85	6325	10	0.76	4.53
13/14 Nov. 85	6383	1	0.73	–
14/15 Nov. 85	6384	4	0.91	1.98
06/07 Dec. 85	6406	43	1.25	1.07
07/08 Dec. 85	6407	18	1.27	0.91
08/09 Dec. 85	6408	30	1.25	0.99
09/10 Dec. 85	6409	2	1.05	–
07/08 Feb. 86	6469	14	1.03	1.05
08/09 Oct. 86	6712	3	1.16	1.12
10/11 Oct. 86	6714	5	1.14	2.92
11/12 Oct. 86	6715	22	1.03	1.71
13/14 Oct. 86	6717	12	1.00	1.17
11/12 Nov. 86	6746	8	0.94	1.95
04/05 Dec. 86	6769	2	0.68	–
05/06 Dec. 86	6770	4	0.98	1.19
06/07 Dec. 86	6771	29	1.08	2.12
07/08 Dec. 86	6772	22	1.09	1.64
08/09 Dec. 86	6773	12	1.15	1.06
04/05 Feb. 87	6831	14	1.07	1.54
16/17 Sep. 87	7055	2	0.64	–
17/18 Sep. 87	7056	12	1.03	1.77
23/24 Oct. 87	7092	2	1.03	–

Columns contain:
1. Date
2. Julian date JD= jd+4240000
3. n – number of measurements
4. Flux at λ 5200 Å in units 10^{-14} erg/s cm^2 Å
5. SD/σ – measure of detected variability,
SD – standard deviation
σ – error of one flux estimation

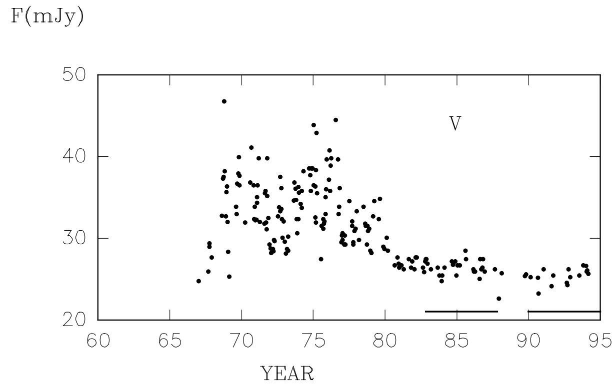

Fig. 1. Light curve of the NGC 1275 nucleus, representing week averaged fluxes in filter V according to Nesterov et al. (1995). Two periods of Crimean observations are shown by two brackets.

tool to measure time variations of sources on different scales especially if the data are spaced rather inhomogeneous by time.

4. The structure function of the variable optical fluxes of the NGC 1275 nucleus

4.1. The structure function properties

Press (1978) suggested that the variability in quasars is caused by a process aliased as "noise". The power spectrum of the simplest of them has a form g(ν) $\sim \nu^{-\gamma}$. The compact variable AGNs exhibit three types of noise: white–noise (γ = 0), flicker–noise (γ = 1), and shot–noise (γ = 2) (see Terebizh, 1993). Such processes are easily revealed by the technique of SF analysis. In application to AGNs it was discussed by Hufnagel & Bregman (1992); Hughes et al. (1992); Lainela & Valtaoja (1993) and others. The first–order SF is defined as:

$$\mathrm{SF} = \left\langle [F(t) - F(t+dt)]^2 \right\rangle ,$$

F(t) being the flux at time t, and dt being the time delay (lag) between observations of fluxes F(t) and F(t+dt), the angular brackets denote an ensemble average. The SF of an "ideal" stationary random process on a logarithmic scale consists of three components: a slope b = d log(SF)/ d logdt, which is located between two plateaus. For short time scales, the plateau is just twice the variance of the measurement noise, because it has a zero correlation time scale. The longest correlation time scale – T$_{max}$ gives the time lag when SF reaches the upper plateau with an amplitude equal to twice the variance of the fluctuation. The logarithmic slope "b" characterizes the nature of the process: b = 0 corresponds to flicker–noise, b = 1 to shot–noise. T$_{max}$ characterizes the duration of the flares.

There is a simple correspondence between the power spectrum of the Fourier analysis and the SF analysis: if SF(dt)$\sim$ dt^b, then g(ν) $\sim \nu^{-(b+1)}$. SF has advantages compare to traditional power spectrum analysis, because there are no problems of windowing and aliasing. It provides more readily comprehensible information on the time scales, and is more successful in determining the noise process. It excludes the influence of stellar contamination on the observed flux. If we have several processes, or if the process is periodic, the interpretation of SF becomes more complicated.

4.2. Structure function analysis realization

The Structure Function analysis was done using a special program package by S.G.Sergeev.

The program package used was tested using the optical observations of the quasar 3C 273 during 1887–1967, reduced in

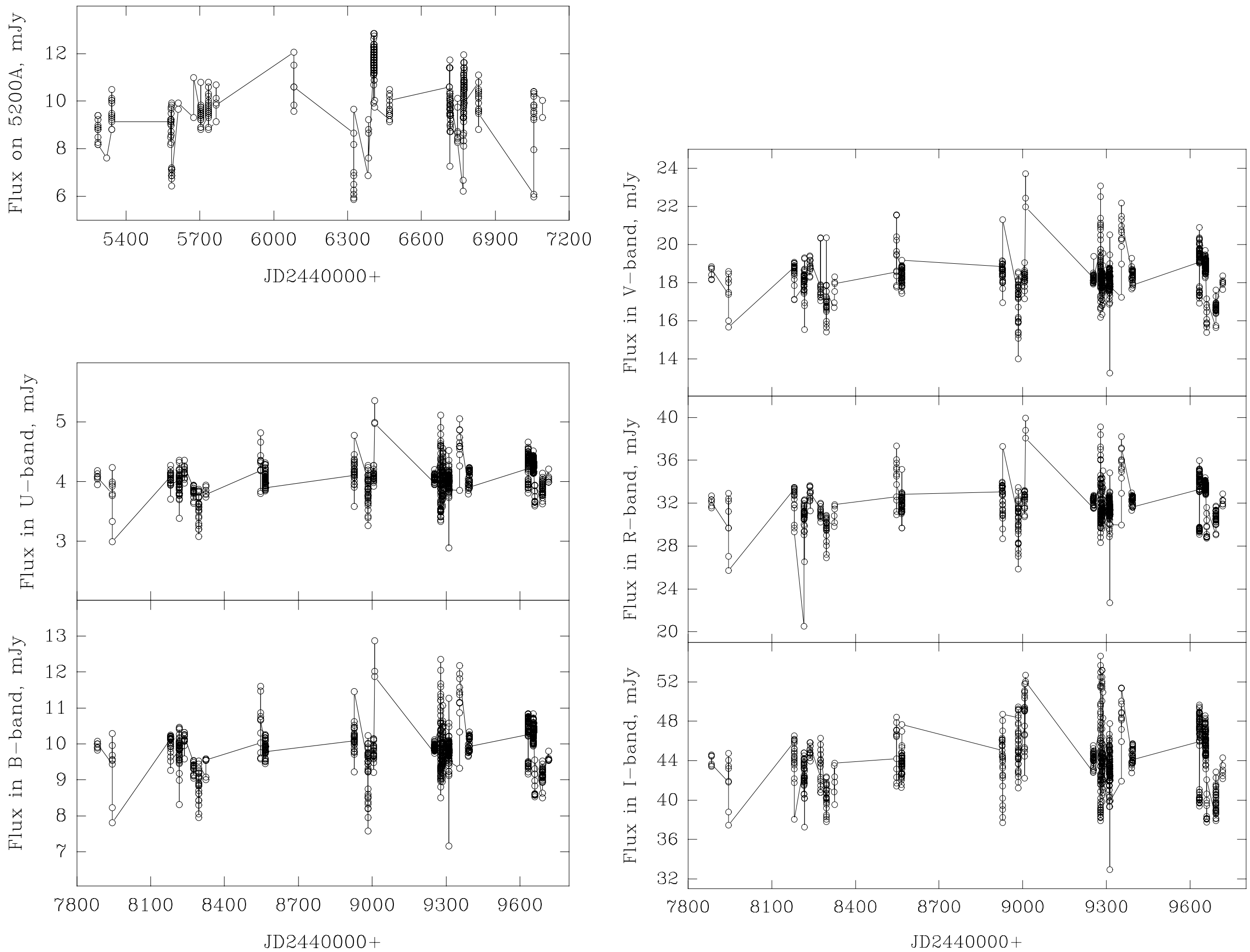

Fig. 2. Light curves of the NGC 1275 nucleus. Continuum flux near λ 5200 Å was obtained in 1982–1987 by Merkulova et al. (1987, 1988, 1992), dimension of one circle equals to about σ. UBVRI fluxes for 1989–1994 were obtained by Merkulova & Metik (1995, 1996), Pronik et al. (1998), dimension of one circle equals to about 3σ.

a common system by Kunkel (1967). The light curve of 3C 273 in arbitrary units was given by Fahlmann & Ulrich (1975). Data are averaged over 100 days intervals.

This light curve was investigated with a correlation method and power spectra analysis by Kunkel (1967), Terrell & Olsen (1970), Terebizh (1993) and others. According to these investigations, the power spectrum of the variable flux of the quasar is g(ν) $\sim \nu^{-2}$. The average duration of one flare equals 3.2 years according to Terrell & Olsen (1970), and 2.7 years according to Terebizh (1993). Using our program package we have calculated the SF at time lags from 100 to 1200 days. It is shown in Fig. 3. A regression line for this figure gives a logarithmic slope b = 0.98 with a coefficient of correlation k = 0.99±0.01, T_{max} = 3.23 years. From this result follows that g(ν) $\sim \nu^{1.98}$. The maximum time of a correlated variability T_{max} is 3.2 years. The evaluated characteristics of variability of the 3C 273 quasar are in good agreement with the data calculated by other authors using different methods. Results of this test allow us to conclude that our program package works rather well.

Fig. 4 shows SFs for the variable flux of NGC 1275 in 1982–1987 and 1987–1994. One can see that there is no SF of a simple "ideal" one – process form with one slope for all time lags. The slopes "b" of SFs for the intranight and years variations are essentially different. We examine these SFs on the intranight time–scale and on the months – years timescale separately.

4.3. The structure function of the intranight variability of the nucleus of NGC 1275. Microvariability

Fig. 4 shows that the intranight part of all SFs does not contain a well–defined first plateau, caused by the observational errors. All logarithmic slopes are restricted only by T_{max} and are not restricted by a plateau of the measurement errors. SF slopes are restricted only by the time of a single flux measurement (equal to 5 min). We cannot exclude that T_{min} is less than 5 min. Shapes of SF for the intranight variations (microvariations) of the NGC 1275 nucleus show two parts with different slopes. These are shown by the two regression lines on each SF in Fig. 4 in the interval $-2.8 \leq \log dt \leq -0.45$ (2.5m$\leq$dt$\leq$8.6h). The

Table 2. Structure function parameters of low level microvariability of the NGC 1275 nucleus

Data	Spectral region	time interval	b	T_{max}, hours	k	conf.level
1	2	3	4	5	6	7
1982–1989	5200 Å	4 m–3.7 h	0.25±0.04	3.7	0.73±0.09	1.000
1989–1994	U	4 m–56 m	0.42±0.11	1.0	0.71±0.12	0.999
-”-	B	-”-	0.42±0.12	-”-	0.66±0.11	0.998
-”-	V	-”-	0.35±0.12	-”-	0.62±0.15	0.996
-”-	R	-”-	0.48±0.11	-”-	0.74±0.11	1.000
-”-	I	-”-	0.66±0.07	-”-	0.92±0.04	1.000

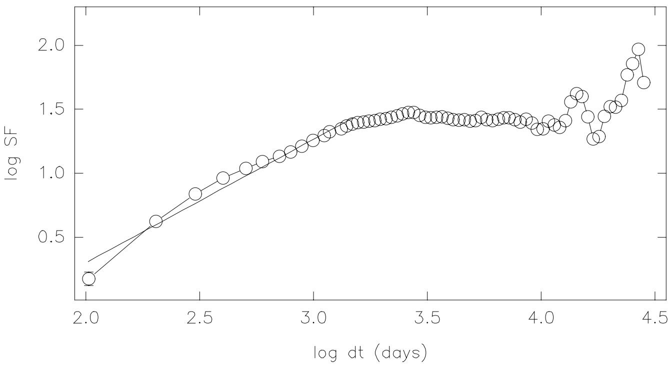

Fig. 3. Structure function of variable flux of quasar 3C 273, obtained using data by Kunkel (1967). Straight line is a line of regression.

corresponding T_{max} of variations for the less steep part of SF in 1982–1987 and in 1989–1994 are about 4 hours and one hour respectively. The T_{max} for the more steep part of SF is about 8.5 hours. We labelled these two types of variations as low and high level ones. Parameters of these two types of the microvariability of the NGC 1275 nucleus are represented in the columns of Tables 2 and 3: 4 – logarithmic slope – b; 3 – time interval (T_{max} – T_{min}); 5 – T_{max}; 6 – coefficient of correlation – “k” between the values log dt and log SF, obtained for the regression lines of Fig. 4. The confidence levels of the correlations are given in Column 7.

The data in Table 2 show that the slopes of SFs of the low–level microvariations of the nucleus of NGC 1275 were in the range $0.25 \leq b \leq 0.66$, and T_{max} was about 4 hours in 1982–1987 and one hour in 1989–1994. The confidence level of the correlation in all cases was almost 1.0.

One can see that the slope “b” for λ 5200 Å in 1982–1987 and for V band in 1989–1994 was 0.25–0.35 – just the same within the limits of errors. Obtained data show that the low–level microvariability of NGC 1275 in 1982–1994 was caused by a mixed process of flicker–noise and shot-noise. The character of the microvariability does not change with time, but T_{max} decreases from 4 hours in 1982–1987 to one hour in 1989–1994.

Table 3 contains the SF parameters of the high–level flux microvariations. The logarithmic slopes of the SFs are in the range 0.66–1.19, and T_{max} is about 9 hours. T_{max} = 4 hours for variations in 1989–1994 is not real, it is restricted by observational time interval, as can be seen in Fig. 4. The confidence level of all correlations is almost 1.0.

Comparison of the slope “b” for λ 5200 Å in 1982–1987 and for the V band in 1989–1994 shows that it decreased from 1.14 to 0.66. The difference is insignificant, because it is equal to about 2.5σ.

The data of Fig. 4, Tables 2 and 3 show that the SF of the microvariability of the optical flux of the NGC 1275 nucleus in the period 1982–1994 shows the presence of two types of intranight process with different time scales. A mixed process of flicker–noise and shot–noise dominates on time scales less than 4 hours, and a shot–noise type process – on time scales more than 4 hours. The maximum time scale of the correlated flux variations is equal to 8.6 hours.

The slopes of the SFs obtained for the observations in the UBVRI system are not equal each to other. The highest slopes of the SF are calculated for the U and I bands: 0.42–0.66 against 0.35 in the V band for low level variations, and 1.19–1.04 against 0.66 in the V band for high level variations. The excess for the I band amounts to 0.66–0.35=0.31 (about 2.5σ) and 1.04–0.66= 0.38 (more than 3σ). The excess in the slopes of the SF in the U and I bands compared to the slope in the V band can be interpreted as an elevated activity of the nucleus in the ultraviolet and near–infrared regions of the galaxy spectrum compare to the visual region, but the differences are at a low confidence level.

4.4. Structure function of the optical flux of the NGC 1275 nucleus for time lags from 1 day to several years

Table 4 contains the SF parameters of the variability of the optical flux of the NGC 1275 on a time scale of years. The columns are the same as for Tables 2 and 3. Both Table 4 and Fig. 4 demonstrate that the SF for the 1982–1994 observations on time scales of more than one day exhibits the slope b $\sim$ 0.06–0.14 with a confidence level of the correlation of up to 0.99. The second plateau of SFs is not clearly present. It is possible that in the NGC 1275 nucleus in 1982–1994 a weak flicker–noise type process was present on time lags more than 4 years, or entirely absent.

Fig. 4 exhibits several minima and maxima in SFs on time lags of days, months and years. Such peculiarities of SFs are usually interpreted as the evidence of cyclic processes or individual flares in active nuclei. Cyclic processes must be shown by SFs for both periods of observations. One can see that there is only one short interval of time lags with a common minimum for all SFs: $-0.3 \leq \log dt \leq +0.4$, or $0.9 \leq dt \leq 2.5$ days. In this

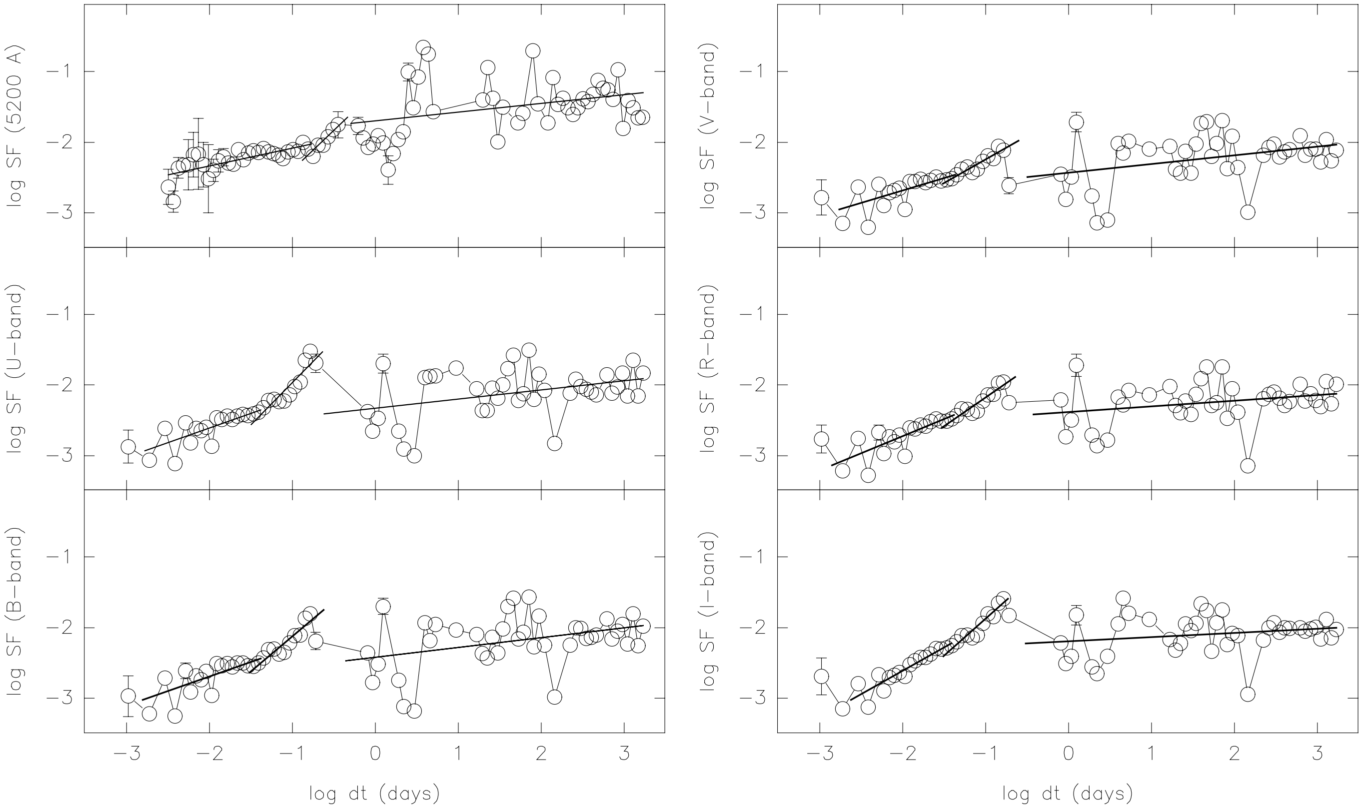

Fig. 4. Structure functions of the variable flux of the NGC 1275 nucleus: in the period 1982–1987 at λ 5200 Å, in 1989–1994 for UBVRI system. Error bars of SF are absent in cases when their dimension are less than the dimension of circles. Each plot contains three straight lines being the regression lines, obtained separately for two types of intranight and one type of years variations of the NGC 1275 nucleus.

Table 3. Structure function parameters of high level microvariability of the NGC 1275 nucleus

Data	Spectral region	time interval	b	T_{max}, hours	k	conf.level
1	2	3	4	5	6	7
1982–1987	5200 Å	4 h–8.6 h	1.14±0.19	8.6	0.94±0.04	0.999
1989–1994	U	1 h – 4 h	1.19±0.18	4.0	0.91±0.05	1.000
-”-	B	-”-	0.99±0.13	-”-	0.93±0.04	1.000
-”-	V	-”-	0.66±0.08	-”-	0.94±0.04	1.000
-”-	R	-”-	0.82±0.10	-”-	0.94±0.04	1.000
-”-	I	-”-	1.04±0.11	-”-	0.95±0.03	1.000

interval of time lags one can look for the cyclic variability of the optical flux of the NGC 1275 nucleus. All other maxima and minima are caused by noncorrelated individual flares.

5. Results and discussion

5.1. Results of structure function analysis

Examination of 6 light curves of the NGC 1275 nucleus in the spectral band near λ 5200 Å in 1982–1987 and in the UBVRI system in 1989–1994 allows us to draw the following conclusions:

1. SFs for 2 different periods of the observations and different spectral regions do not show an ideal one–process form: no SFs have a lower plateau, the upper plateau is broken, and different slopes are presented for time lags of less and more than one day.
2. The lowest limit of variability is not observed because a first plateau of SFs has not been revealed. Therefore we suggest that the minimum time–scale of the optical variability of the NGC 1275 nucleus could be less than 5 min (i.e., the time resolution of our observations). It would be obtained using a shorter time resolution and a higher level of the threshold of detection.
3. Shapes of SFs obtained show that during 1982–1994 there were at least three processes in the NGC 1275 nucleus causing the optical variability: two processes with time scales of

Table 4. Structure function parameters of years variability of the NGC 1275 nucleus

Data 1	Spectral region 2	time interval 3	b 4	T_{max}, years 5	k 6	conf. level
1982–1987	5200 Å	1d–4.6 y	0.12±0.05	≥4.6	0.35±0.13	0.991
1989–1994	U	1d–4.7 y	0.13±0.05	≥6.0	0.38±0.14	0.992
-”-	B	-”-	0.14±0.05	–”–	0.37±0.14	0.991
-”-	V	-”-	0.12±0.05	–”–	0.35±0.14	0.987
-”-	R	-”-	0.08±0.05	–”–	0.27±0.15	0.954
-”-	I	-”-	0.06±0.04	–”–	0.21±0.15	0.903

less than one day, and the third one with a time scale of at least 4 years.

4. Two processes causing intranight variability are more pronounced than the process causing variability in a scale of years. They are characterized by a rather steep SF (0.25≤ b ≤ 1.19): a mixed process of flicker–noise and shot–noise, or pure shot–noise is observed. The third process, operating on years time lags is pure flicker–noise, or absent: the slope “b” of SFs is in the range 0.06–0.14.
5. The slopes of SFs obtained in the UBVRI system in 1989–1994 for the intranight variations are not equal to each other. The highest slope is obtained for the U and I bands: b = 1.0–1.2. This value exceeds the slope of the SF in the V band by (2–3)σ. It can be interpreted as the existence of independent activity of the nucleus in the near infrared compared to the ultraviolet and visual regions of spectrum (on a level of (2–3)σ). The same result was obtained by I.Pronik et al. (1998): an examination of the calculated SDs of the variable flux for each night showed that there were about 40% of nights with SD $\geq 3\sigma$ for the UBVR bands and 53% for the I band.
6. Maxima and minima on SFs, corresponding to time lags more than one day exhibit the presence of separate flares on time lags of days, months and years. There is only one common minimum for all 6 SFs, it is located on time lags 0.9 days≤ dt ≤2.5 days. We suppose that there are possible periodical or quasi–periodical signals in the NGC 1275 nucleus within the interval (0.9–2.5) days. It is impossible to ascertain the more exact value of this quasi–period using SF analysis.

5.2. Evolution of a process in the nucleus of NGC 1275 causing its optical variations

According to the V light curve shown in Fig. 1, during 1968–1979 the NGC 1275 nucleus was in an enhanced state, rapid and powerful flares were observed to occur up to twice a year. In 1979 the optical source made a transition to a new and quiescent stage which has lasted up to the present date. After 1980 the decay of the nucleus brightness is continuing, but more slowly. Estimates showed that the average V brightness of the nucleus reduced to the diaphragm 5′′ in 1989–1994 was about 40% lower than it was in 1982–1987.

Table 5. Structure function parameters of years variability of the NGC 1275 nucleus in 1968–1980

Spectral region 1	time interval 2	b 3	T_{max}, years 4	k 5	conf. level 6
U	3 d –0.5 y	0.40±0.06	0.5	0.75±0.07	1.000
B	-”-	0.34±0.05	-”-	0.75±0.07	1.000
V	-”-	0.37±0.04	-”-	0.80±0.05	1.000

Signs in Table 5 are the same, as in Tables 2–4.

In Table 5 we show the parameters of the SFs of the UBV variable fluxes for the time interval 1968 – XII.1979, which we have calculated using data by Lyuty (1980) and Nesterov et al. (1995). One can see that the slopes of the SFs are 0.34≤ b ≤ 0.40, the confidence levels of the correlations in all cases are equal to 1. The slopes show that in 1968–1980 in the NGC 1275 nucleus a mixed process of flicker–noise and shot–noise was operated.

A comparison of the data of Tables 4 and 5 permits us to suppose that the flux decrease of the NGC 1275 nucleus in the UBV bands from 1968–1980 to 1989–1994 is accompanied by a decrease of the slopes of the SFs from (0.3–0.4) to (0.12–0.14). The SF slopes showed that the processes have evolved from mixed flicker–noise and shot–noise in 1968–1980 to classical flicker–noise in 1982–1994. This evolution was in agreement with the decrease of the nucleus brightness.

Pronik et al. (1998) registered the evolution of microvariability of the NGC 1275 nucleus on time scales less than of one day, too. From 1982–1987 to 1989–1994 an increase of the number of nights with SD$\geq 3\sigma$ was observed from 8% to ∼40% , showing the increase of the duty cycle of the nucleus. Intranight activity of the nucleus is increased when its general flux decreases. These results need to be interpreted by theoretical models.

5.3. Comparison with the radio data

The relationship between the optical and radio fluxes of blazars was investigated by Hufnagel & Bregman (1992). The optical and radio data are positively correlated in the sense that the optical flux variations precede those in the radio region, implying a significant processing of the optical–emitting plasma before it becomes a radio–emitting plasma. There is a dissimilarity between the optical and radio variations, which indicates the possibility that the connection may not be linear and there is a difference in the structure of the emitting plasma in the two domains. Based upon the results that the optical flux variations precede those of the radio region, the authors conclude that the two regions are physically related although on substantially different length scales. The variability data indicate that the plasma emitting optical and ultraviolet radiation has a dimension about an order of magnitude smaller, than the size of the plasma emitting in the radio domain. One of the models of the nucleus flux variability is the inhomogeneous jet of blazars in which shocks propagate along the jet which produce individual radio outbursts and may hold promise to explain optical variations as well.

The slopes of the SF for the variable optical flux of the NGC 1275 nucleus in 1982–1994 are different for the intranight and years time scales. The most powerful nuclear process in the time interval 1982–1994 operated on time scales of less than one day. The slopes of the SF for the intranight variability were in the range 0.25≤b≤1.19, but for the larger time scales 0.06≤b≤0.14. Unfortunately we cannot compare the intranight and long–term radio variations. There is poor information on time scales of less than one day in the radio domain. But it is important that intranight and night–to–night variations of the radio emission have been registered. Joint observations at λ 1.35 cm at the Crimean observatory and Metsahovi (Finland) in June 1978 (Efanov et al.,1980, 1981) showed a variability of about 23% over one day. Terasranta et al. (1987) measured in Metsahovi an intranight flux variability of the NGC 1275 nucleus (3C 84) in April, May 1984 at λ 3.9 mm of about 4%, and night–to–night variations of up to 10%. But these data are not enough for the investigation of SF and for drawing a conclusion on the character of the intranight radio variability.

The structure functions of the radio source 3C 84 were calculated only for time scales of years. Hughes et al. (1992) have obtained SFs with time lags from 2 weeks to 10 years using sets of the observations in a time interval of more than 20 years from 1965, at frequencies of 4.8 GHz, 8 GHz and 14.5 GHz. Averaged for 3 frequencies, the value of the slope b is equal to 1.6. The maximum time of the correlated nonperiodical variability equals more than 10 years.

Lainela & Valtaoja(1993) using sets of observations at 22 GHz and 37 GHz, obtained at Metsahovi from 1980 to 1986, have calculated an SF with a slope b = 1.5, the time scale for 37 GHz was 3.75 years, and for 22 GHz it was more than 9.5 years.

The comparison of the characteristics of SF of the NGC 1275 nucleus in the radio and optical domains shows that on time scales of years nonperiodical variations in the radio are near to shot–noise: b $\sim$ (1.5–1.6); in the optical during the maximum activity in 1968–1980 – the process is a mixed shot–noise and flicker–noise (0.3≤b≤0.4), but in a quiescent state in 1982–1994 the slope corresponds to pure flicker–noise (b $\sim$0.14). SFs in the optical are flatter than in the radio domain.

Results obtained for the nucleus of NGC 1275 cannot be distinguished from the results obtained for the other blazars: the flatness of the SF and a decrease of the time scale of variability from the radio to the optical were characteristic (Hufnagel & Bregman, 1992). SF analysis showed that the nature of the variability of optical and radio fluxes is different. It may be described by different power–law forms: shot–noise in the radio, and a mixed process of shot–noise and flicker–noise in the optical.

5.4. *Quasi–periods*

Basko & Lyuty (1977) looked for possible periods in the UBV variability of the NGC 1275 nucleus using 1966–1976 observations. They revealed six probable quasi–periods from 15 to 340 days on a low level of probability. Our data of SFs for the 1982–1994 observations do not support any of these quasi–periods. A quasi–period of 2.3 days was suspected by Merkulova & Pronik (1985) using spectral observations with the 6-m telescope on January 1977. It lies within the range of the common minimum in all SFs, obtained for 1982–1994 observations (Fig. 4), showing the probability that a quasi–period exists equal to $\sim$ 2.2–2.3 days. This quasi–period may be supported by future investigation.

It is not excluded that the several–day quasiperiodic modulation with time scales slightly larger than one day is a common property of the flux variations of blazars. For instance, the V light curve of one of the best observed blazars OJ 287 revealed quasi–periods of 8.5 days and 22 days according to Turner et al. (1994), and of 12.6 days – according to Lehto (1994). Gonzalez–Perez et al.(1996) gave a review of possible interpretations of such events: “spotty disk”, binary singularity, et al. An examination of the nature of quasi–periods is very important for the definition of the nucleus model. It is necessary to continue this analysis for the NGC 1275 nucleus using new observations.

5.5. *Implications of the observational data for various models*

Many studies have suggested that noise–type variations of AGNs are caused by instability either in disk or in jets, connected with a black hole in the sources. From Table 5, the SF slopes of year–scale variability of the nucleus of NGC 1275 during the active phase in 1968–1980 are in the range (0.34–0.40), near to 0.35 evaluated by Kawaguchi & Mineshige (1998) for the optical flux variability of the quasar 0957+561. They concluded that the disk instability model is favored for these quasar variations, because fluctuations on days scales are hard to produce by other models. Below we discuss the data obtained on the characteristics of the NGC 1275 nucleus variations from the point of view of current models.

Accretion onto a black hole (ABH). Some authors concluded that the optical continuum of the NGC 1275 nucleus has a nonthermal nature (Oke, 1968; Anderson, 1970; Wampler, 1971; Babadjaniants et al., 1972; Shields & Oke, 1975; de Bruyn & Sargent, 1978). A power law spectrum of the optical continuum $F_\nu \sim \nu^{-1.5}$ and polarization up to 5% constitute the observational evidence for this conclusion. In particular, Edelson & Malkan (1986) modelled the optical continuum of the NGC 1275 nucleus by summing the nonthermal part with a power coefficient – 1.53 and the thermal part from the black hole having T = 20 000 K. In this model the optical thermal emission equals only 12% of the nonthermal one. They made the supposition that the luminosity of both synchrotron and thermal emission arises from the accretion at the Eddington limit of the luminosity on central black hole. Based on the accreting nature of variability of blazars, Elliot & Shapiro (1974) forecast a time scale of the NGC 1275 nucleus's microvariability of the order of 5 min. Edelson & Malkan (1986) calculated a lower limit of the Schwarzschild radius for this source equal to $2\cdot 10^{12}$ cm. Region $3 \leq R_g \leq 10$ for the NGC 1275 nucleus is equal to $(6–20)\cdot 10^{12}$ cm, corresponding to (3–10) light minutes. One can expect a flux variability on such a time scale. It does not contradict our data on intranight variability of the optical continuum flux of the nucleus.

Instabilities in shock-in-jet (SJ) model is also possible the explanation of the intranight variations of the NGC 1275 nucleus. Heidt & Wagner (1996) obtained parameters of SFs for 34 radio selected BL Lacertae objects in the optical R band; the slopes of the SFs are within the range $0 \leq b \leq 2.5$, with a mean value of 0.8 and a dispersion of 0.6. The typical time–scale lies in the range between 0.5 and 5 days. The duty cycle of these objects is at least 0.8. They concluded that intraday variability is a characteristic property of BL Lac objects. Our data on microvariability of the optical flux of the NGC 1275 nucleus gave $0.25 \leq b \leq 1.19$ and do not contradict these data. In general, the results were explained by the standard model where shocks are propagating down a relativistic jet: the shock–in–jet model. There will be a high degree of microvariability, if jets are bent and turbulent (Marscher,& Travis 1991; Wagner, 1991). The explanation of the variability is based on the scenario of shocks propagating within the jet entering a turbulent region.

But in both models (ABH and SJ) of the NGC 1275 nucleus's microvariability there exist unclear points. It is interesting that the power processes acting on the short–term and long–term variability of the optical continuum of the NGC 1275 nucleus correspond to the general brightness of the nucleus in different ways. Long–term variability operated dependent on the brightness of the nucleus: from 1968–1980 to 1994 the brightness of the nucleus decreased and the power of the long–term variability decreased, too, from mixed shot–noise and flicker–noise to pure flicker noise. On the contrary, the high level microvariability in 1989–1994 increased compared to that 1982–1987, while the general brightness of the nucleus was not enhanced. According to our data (Pronik et al. 1998) when the flux varies by 20–30%, the amplitude of microvariability changes by a factor of 4. Is it possible that the process increases when the brightness of the nucleus declines in terms of accretion onto a black hole and shock-in-jet models? It is a question for future investigations.

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