OPTICAL VARIABILITY OF THE NUCLEI OF SEYFERT GALAXIES

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Abstract. The continuum variability (*UBV* observations), the variations in the emission lines, and the properties of the central source in the nuclei of Seyfert galaxies are discussed. There is the quasi-periodicity in the light variations of the nuclei. The emission lines show the variations both in the intensity and the profiles. All data lead to the conclusion, that both continuum and emission-lines intensity variations are due to the variability of the central nonthermal source.

1. Introduction

There are now many reasons to assume that all compact star-like extragalactic objects, such as quasars, *N*-type galaxies, Seyfert nuclei and BL Lac objects are variable.

This description concerns only the nuclei of Seyfert galaxies. We have summarized the most important evidences for the existence of variable central sources in Seyfert nuclei.

2. Continuum Variability

The photometric study, especially UBV measurements, of Seyfert nuclei variability is of great importance in giving some idea of their spectral energy distribution and its temporal variations. More or less systematic studies have been made by Penston *et al.* (1971, 1974), by de Vaucouleurs (1972) and by Lyuty (1972), the latter surveying 8 Seyfert galaxies from 1968 to the present. We now have enough observational data to make some conclusions on the nature of the variability of Seyfert nuclei, and also of quasars, the Seyfert nuclei being brighter and easier to study.

NGC 4151, the most studied, is one of the brightest and most variable Seyfert galaxies. Figure 1 shows brightness variations of its nucleus measured with a 27″ diaphragm. All light curves are given for *U*, where the variations are largest. In Figure 1, photoelectric measurements by other observers reduced to the most used 27″ diaphragm are also plotted. We can see in Figure 1 at least two components: one of a long period on a scale of several years with an amplitude of $\sim 1^m$ and the second comprised of short flares of $0\overset{m}{.}5$–$0\overset{m}{.}8$ amplitude and 20–100 days duration.

Pacholczyk (1971), using photographic observations of the NGC 4151 nucleus from 1932, found a period of 5.1 yr for its light variations. Eight years of continuous photoelectric measurements show a period, if real, changing from 3 to 5 yr. The short period activity cannot be excluded from being periodic.

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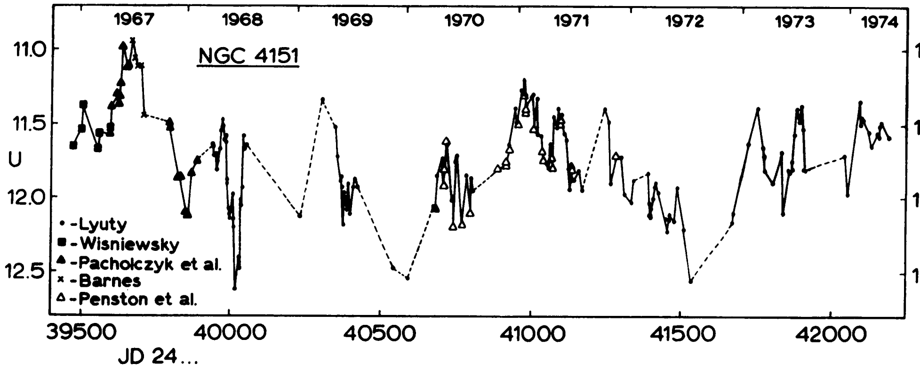

Fig. 1. Variations in U magnitude of the nucleus of NGC 4151.

In 1971 Jurkevich *et al.* (1971) found periodic components of 350 days and 22.5 yr in the light curve of 3C 120, an N-galaxy mentioned by some authors as a Seyfert galaxy.

Babadzanianz and Belokon (1974), using Jurkevich's method, found a 163-day period for the flare component of the variation of the N-galaxy 3C 371. Using the same method with photoelectric observations of NGC 4151, Babadzanianz *et al.* (1975) found a 130-day period for the flare component during 1967–73.

During 8 yr, the minimum brightness of the nucleus of NGC 4151 was $U = 12\overset{m}{.}6$ ($B = 12\overset{m}{.}7$ and $V = 11\overset{m}{.}9$) in 1968, 1970 and 1972. It seems that this is the brightness of the stellar component of the galaxy in the 27″ diaphragm. The correlation between the UBV magnitudes for the 27″ and 13″.5 diaphragms measured simultaneously is linear. During minima, there is a nonlinear relation for B and V; a change of brightness of $0\overset{m}{.}2$–$0\overset{m}{.}3$ in the 13″.5 diaphragm gives no change in the 27″ diaphragm. In U, this effect does not exist, i.e. the intensity of the variable source is sufficiently strong.

NGC 3516. The U magnitudes in a 13″.5 diaphragm are shown in Figure 2. As for NGC 4151, we see two components in the brightness variations – a slow with an am-

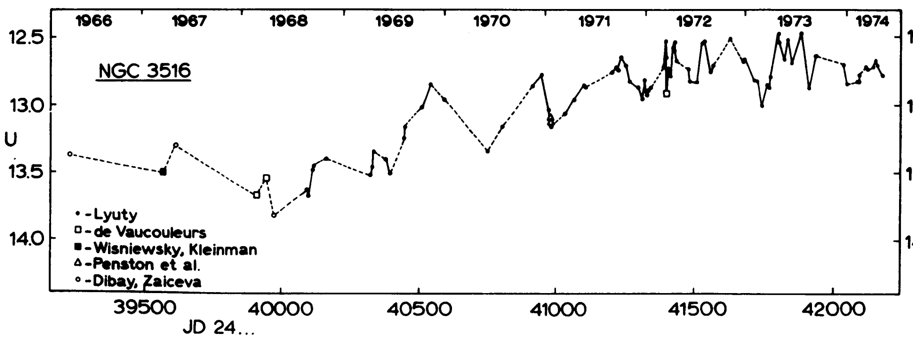

Fig. 2. The same as on Figure 1 for NGC 3516.

plitude of about 1^m and a fast, flare one. The flares are of from 15–20 to 150–200 days duration and nothing can be said on existence of periods, although a long period appears to exist.

Like NGC 4151, the amplitude of the brightness variations increases for smaller diaphragms and shorter wavelengths, but for NGC 3516 both effects are stronger, the variable source contributing a greater part of the radiation in the small diaphragm.

NGC 1275 (= Per A = 3C 84) is a strong variable radio source. At optical wavelengths, it is also very active. Figure 3 shows its light-curve for 27″-diaphragm observations. Here we also see two components; however, in the case of NGC 1275, the slow component has a time scale of about 1.5 yr and a somewhat smaller amplitude of $0\overset{m}{.}5$.

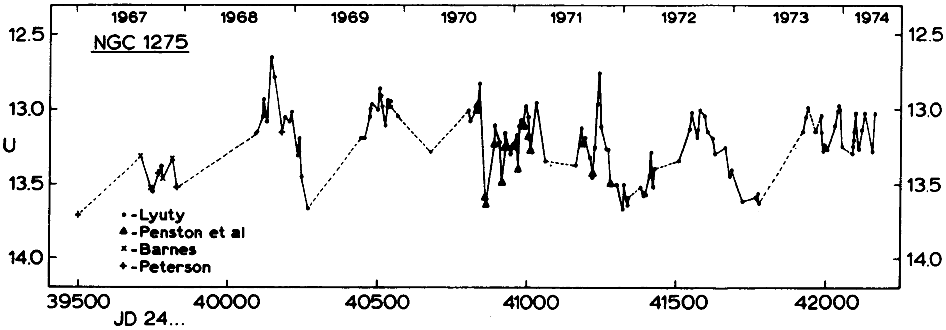

Fig. 3. The same as on Figure 1 for NGC 1275.

The brightness of the nucleus has gone through several minima ($U = 13\overset{m}{.}7$, $B = 13\overset{m}{.}5$, $V = 12\overset{m}{.}8$), the color indices resembling more closely those of stellar radiation than in the case of NGC 4151. The short period component of NGC 1275 nucleus emission is very active; the amplitude reaches $0\overset{m}{.}7$–$0\overset{m}{.}8$. The changes occur very quickly, e.g. in September 1970, the nucleus brightness decreased by $0\overset{m}{.}8$ in 20 days.

A search for periodicity in the short component variations in the nucleus of NGC 1275 was not made, but a 30-day period cannot be excluded. Flares, predicted using a period of 29.5 days, were observed in 1973–74 (Lyuty) with great accuracy.

Thus, the existence of two components in the variable emission of Seyfert- and *N*-galaxy nuclei appears to be their common property. The first, slow component has a time scale of several years and an amplitude $0\overset{m}{.}5$–1^m. The second, flare component has an amplitude of $0\overset{m}{.}2$–$0\overset{m}{.}8$ and a time scale of tens or hundreds of days. Some galaxies show a periodicity in the flare component; the periodicity of the slow component also cannot be excluded. The time scale of the latter is 10–20 times that of the flare component.

NGC 1068, 5548, 7469, 4051 and Markarian 10 are Seyfert galaxies with variable nuclei. They have been studied less than NGC 4151, 3516 and 1275. The nucleus of

NGC 1068 has a constant brightness in B and V, buthas a variability of $0^m_.2$–$0^m_.3$ in U (Lyuty, 1972). NGC 4051 also seems to belong to these less active nuclei, its variability being of $0^m_.3$ (Penston *et al.*, 1974).

The nucleus of NGC 5548 seems to be active like NGC 4151 or NGC 3516 and only the lack of data hinders a better analysis. The amplitude of the light variations of the NGC 5548 nucleus reaches $1^m_.4$ in U if a $13''_.5$ diaphragm is used (Lyuty, 1973).

The nucleus of Markaran 10 is also variable (Lyuty, 1972); its brightness changed from 14^m to 15^m in 1970–72. In 1968, the brightness of the Markarian 10 nucleus was $14^m_.5$ (Arp *et al.*, 1968). Thus, a strong flare seems to have occurred in 1969–70, implying a time scale for the slow component of 10–12 yr. Data concerning the flare component are scarce, but the most rapid change was $0^m_.4$ in 20 days.

3. Properties of the Central Source Based on Photometric Data

Having sufficient three-color observations, we can make an analysis of the properties of the variable emission from Seyfert nuclei. A most detailed study was made by Babadzanianz *et al.* (1972) and Penston *et al.* (1971, 1974).

The former have shown that the variable source is located in the center of the galactic nucleus and has a dimension of $<10^{16}$ cm ($<3'' \times 10^{-4}$). Direct measurements of the central source diameter in NGC 4151 (Schwarzschild, 1973) gave an upper limit of $0''_.08$.

The variable emission from Seyfert nuclei has a very flat spectrum in the optical region ($\alpha = 0.2$ for NGC 4141), well represented by a power law. During maximum, the energy distribution in the spectra of nuclei is also close to a power spectrum; at minimum it changes to a stellar one. Figure 4 shows the NGC 4151, 3516 and 1275 nuclei at minimum and maximum brightness.

We know that the light from Seyfert galaxy nuclei is polarized. The polarization is variable. Babadzanianz *et al.* (1972) have shown the relationship between the degree of polarization and the brightness of the nucleus, the polarization being absent at minimum. The degree of polarization of the nonstellar component is constant.

Therefore, the additional emission from Seyfert nuclei is polarized, shows rapid variability and has a flat spectrum. Such properties indicate a synchrotron origin. The variability of galactic nuclei emission in the optical region can be due to changes of energy emitted from central source electrons.

The photoelectric *UBV* measurements give us information on the continuum variability where the influence of emission lines is small. Observations with narrower band filters give us data on the linė variability. Cherepashchuk and Lyuty (1973) observed the variations of the Hα line intensity in NGC 4151, NGC 3516 and NGC 1068 nuclei. Figure 5 shows the U light curve of NGC 4151 during 1970–74 and its Hα + + [N II] variations, also given on a magnitude scale. The Hα intensity shows a correlation with the *UV*-emission from the nucleus with a time delay of 15–30 days. Rapid variations (10 days or less) of the Hα line intensity were also observed. Assuming this

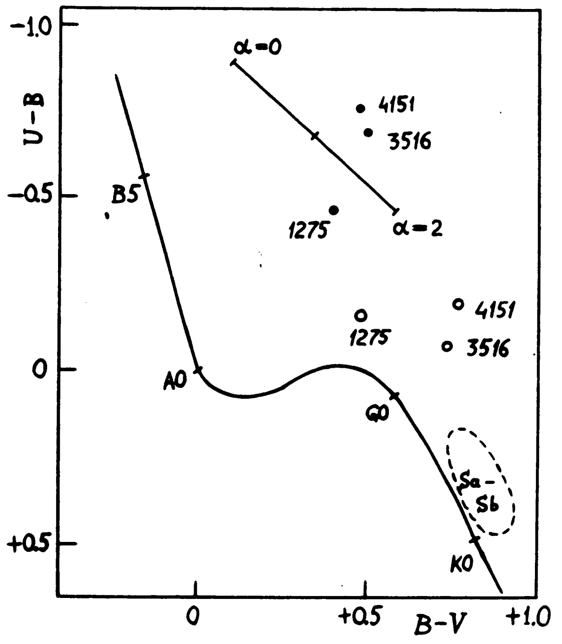

Fig. 4. Position of Seyfert nuclei in the two-color diagram depending on their brightness: the black dots are for maximum brightness, the open circles for minimum brightness.

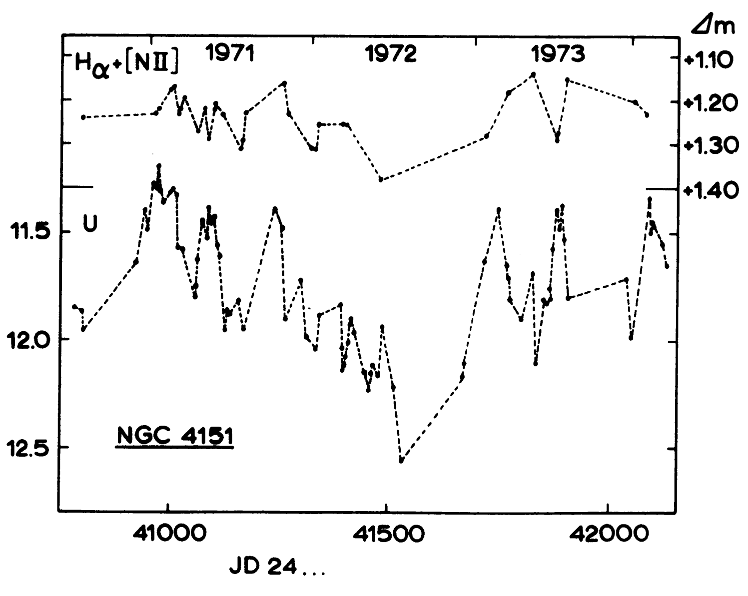

Fig. 5. Variations of Hα + [N II] line intensity and U magnitude for NGC 4151.

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time to be the time of recombination, we obtain $n_e > 10^7$ cm^{-3}; the delay gives a size of the emitting region of $\sim 10^{17}$ cm. In all the observed galaxies, the Hα intensity seems to be limited from both sides; in NGC 4151, maximum values and in NGC 3516 and NGC 1068, minimum values have not yet been observed. Figure 6 shows the relation between U magnitudes and Hα intensity. We see that Hα variations are less than 10–12% for NGC 1068 and 25–30% for NGC 4151. NGC 3516 has shown a 35% Hα variability in 1971–72. A comparison with the 1973–74 data gives an amplitude exceeding 70%. The amplitude of the Hα variations in the nucleus of NGC 3516 seems to be even larger.

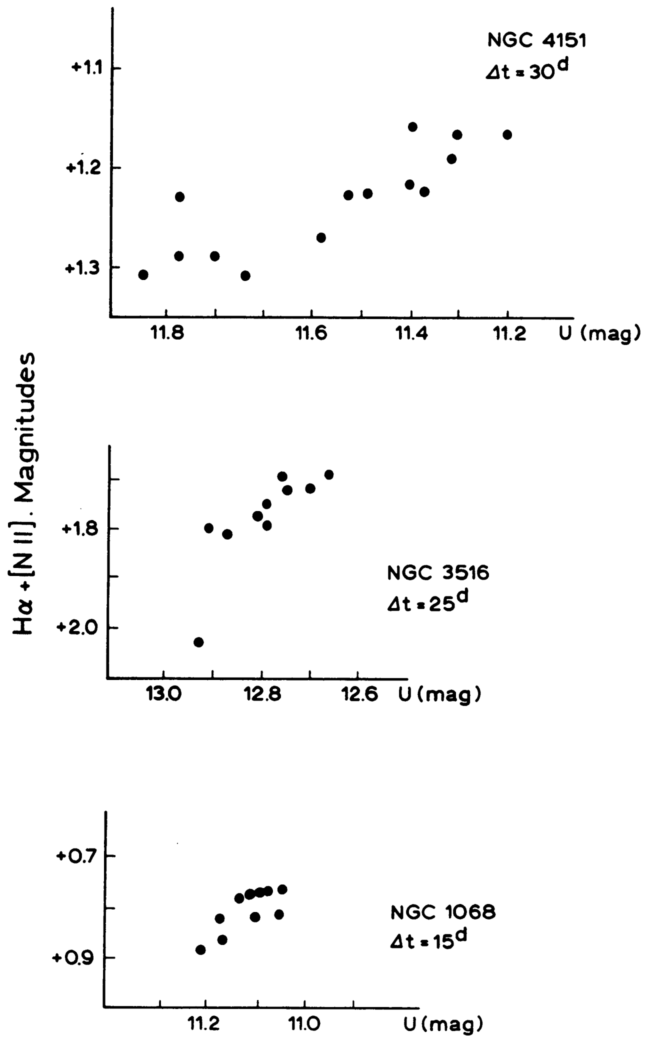

Fig. 6. Correlation between Hα + [N II] intensity and U magnitude for various galaxies.

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4. Variations of Emission Lines in Seyfert Nuclei Spectra. Interpretation

As already mentioned, variations of Hα flux were observed by Cherepashchuk and Lyuty (1973) for three Seyfert galaxies, NGC 1068, NGC 4151, and NGC 3516.

For NGC 1068, the amplitude of the variations is about 10%; such changes are difficult to detect photographically. Nevertheless Eilek *et al.* (1973) recently reported that the profile of Hα+[N II] varied during the three months of observations. The change was apparently due to a change in line width and relative strenghts. The variations were in the [N I] line and the narrow core of Hα.

This variability of narrow lines in Seyfert nuclei is not unique. Pronik (1971) found a change in the central core of Hα relative to the λ 6584 Å [N II] line in NGC 3227. There is a suspicion that the [N II]/Hα ratio varies in NGC 3516 also (compare the tracing of the Hα+[N II] profile in Andrillat's (1968) paper and those obtained by Ulrich (1972).

If the variability of narrow lines is confirmed by subsequent observations, our view of the dimensions and density of gas around the nuclei could change radically.

The amplitudes of the total Hα+[N II] flux changes for NGC 4151 and NGC 3516 during the photoelectric observations by Cherepashchuk and Lyuty (1973) are about 30%. Such changes cannot occur only in the central core of the line because of its small contribution to the total flux of Hα+[N II]. It is well known that the spectrum of NGC 3516 obtained by Andrillat and Souffrin in 1967 shows practically no broad Hβ line which was very bright on Seyfert's spectrogram. The new observations of NGC 3516 made in 1970–1971 by Collin-Souffrin *et al.* (1973) showed the Hβ intensity increasing again, the total amplitude of Hβ line changes being about a factor of four. The equivalent widths of some lines obtained at different times are listed in Table I.

Unfortunately, it is unknown whether or not the profiles of broad hydrogen lines in NGC 3516 change with changes in its intensity; it seems they do not change. In every case, the Hβ profile remains entirely symmetric.

TABLE I

The equivalent widths of emission lines of NGC 3516

	1965 Jan.	1966 Jan. Feb.	1966 1967	1967 May June	1968 1969	1970 1971
λ	1	2	3	4	5	6
5007 [O III]	26	19		20.8	20	17
4959 [O III]	9	6.8	24	7.1	6.5	7
Hβ	32	29	13.6	–	10	47
4363 [O III]			3	5.1		0.4
3869 [Ne III]		3.8	6.4	1.5	3	
3727 [O II]		3	3.5	5.1	8	5

(1, 2) Dibay and Pronik (1967); (3) Anderson (1970) in paper by Collin-Souffrin *et al.* (1973); (4) Andrillat and Souffrin (1968); (5) Pronik; (6) Collin-Souffrin *et al.* (1973).

As already mentioned, the central peak of Hα may vary relative to the narrow [N II] line. Collin-Souffrin *et al.* (1973) deduced a time-scale of the variation in the intensity of the λ 4363 Å [O III] line shorter than three years, perhaps only one month. This is quite possible because, of all forbidden lines, the variation of λ 4363 Å [O III] is the most probable owing to its high value of spontaneous transition probability.

As for [Ne III] and [O II] lines, the changes in their equivalent widths may be due to changes in the ultraviolet continuum. From Table I and Figure 2, it is seen that the equivalent width of the [O II] line was maximum in 1967–1969 when the U magnitude of the nucleus was at a deep minimum. However one cannot completely exclude the variability of even these lines.

Analysing variations of emission line intensity, Collin-Souffrin *et al.* (1973) came to the conclusion that the most probable reason for such changes is a change of electron density due to photoionization by a variable central source.

The variation of NGC 1566, almost identical with that of NGC 3516, was reported by Pastoriza and Gerola (1970). In 1969, they found a marked weakening of the broad Hβ line with respect to narrow N_1 and N_2 lines in the bright quasistellar nucleus of NGC 1566. Earlier observations showed that in 1962, Hβ was much stronger then N_1, N_2 and the λ 3727 Å [O II] and λ 3869 Å [Ne III] lines were absent or very weak; on the spectra of 1969, the $N_1 N_2$ lines as well as λ 3727 Å [O II] and λ 3869 Å [Ne III] lines were clearly seen, while Hβ was very weak. Unfortunately the behaviour of the continuum at that time was unknown. Nevertheless it can be suggested with confidence that the reason for spectral changes in NGC 1566 was the same as in NGC 3516.

The variability of emission line intensities in NGC 1275 was discussed by Pronik (1974). She observed NGC 1275 during 1971–1973 and noticed that the relative intensities of emission lines obtained before October 1972 differed from those obtained

TABLE II

Relative intensities of emission lines in NGC 1275

	1930	1942	1964 1966	1966 1967	1968 1971	1971 1972 Oct.	1972 Dec. 1973 Apr.
λ	1	2	3	4	5	6	7
6716 + 31 [S II]		2.1	1.0	3.4	3.6	3.9	1.2
Hα + [N II]		7.0	6.0	11.8	12.9	16.6	4.6
6300 + 64 [O I]		1.4		1.6	1.7	3.8	1.3
$N_1 + N_2$ [O III]	0.6	3.5	2.7	5.0	5.2	7.3	3.6
Hβ	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4363 [O III]	2.5	0.4		0.3		0.6	0.2
3869 [Ne III]	0.6	0.4	1.0	0.7		1.1	0.6
3727 [O II]	3.1	1.4	3.0	2.5	2.0	3.4	2.1

(1) Humason (1932); (2) Seyfert (1943); (3) Dibay and Pronik (1967); (4) Anderson (1970); (5) Wampler (1971); (6, 7) Pronik (1974).

later. In Table II are presented available data of relative emission line intensities obtained by various authors which leaves no doubt about the variability of the lines. Analysis of forbidden line ratios carried out by Pronik (1974) shows a change of ionization degree, electron density, and electron temperature of the gas.

Remarkable changes in emission lines took place in NGC 5548. There are no publications on the variability of hydrogen lines in this galaxy in spite of considerable differences between the contours of lines published by various authors. Dibay *et al.* (1968), Anderson (1970), Khachikian and Weedman (1971a) at different times over the interval from 1967 to 1970 have observed quite symmetrical profiles of hydrogen lines with very strong wings. In this respect, the Hβ profile obtained by the latter authors is especially so (Figure 7). In 1971, Anderson (1971) published an extremely asymmetrical profile of the Hα line. Such a profile is still observed. Therefore, during one or two years, the profiles of the broad hydrogen lines in NGC 5548 have markedly changed.

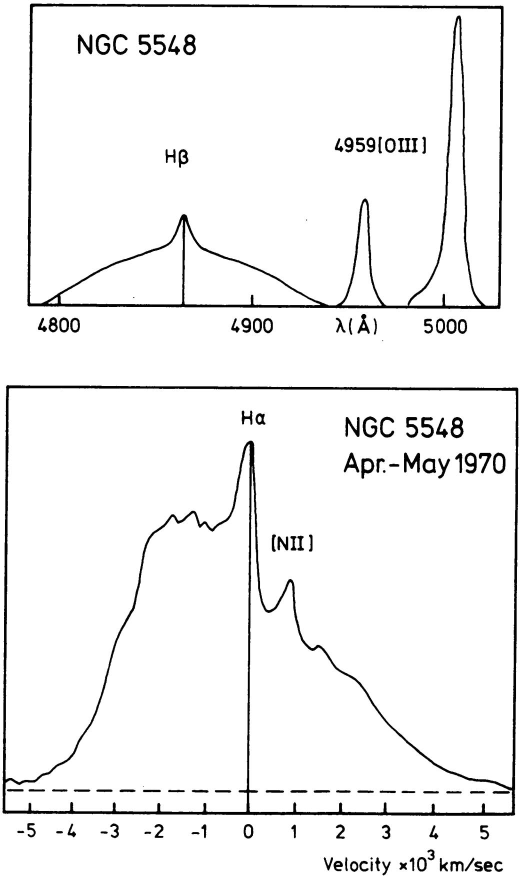

Fig. 7. The profile of the Hβ line in NGC 5548 according to Khachikian and Weedman (1971a) and of Hα obtained by Anderson (1971). The date of the observation of the Hβ profile is unknown. In the lower figure, abscissae are velocities in units of 10^3 km s^{-1}. A change in the profile is very noticeable.

In early 1973, Chuvaev (1974) observed a large flare-up of the Hβ line relative to N_1 and N_2 and Lyuty (1973) observed an increase in the continuum intensity by UBV photometry. It is rather curious that during the flare-up when the intensity of the Hβ line increased by more than a factor of 3, the profile of Hβ remained the same with a high precision. Such constancy of profile during the flare-up suggests that the gas is

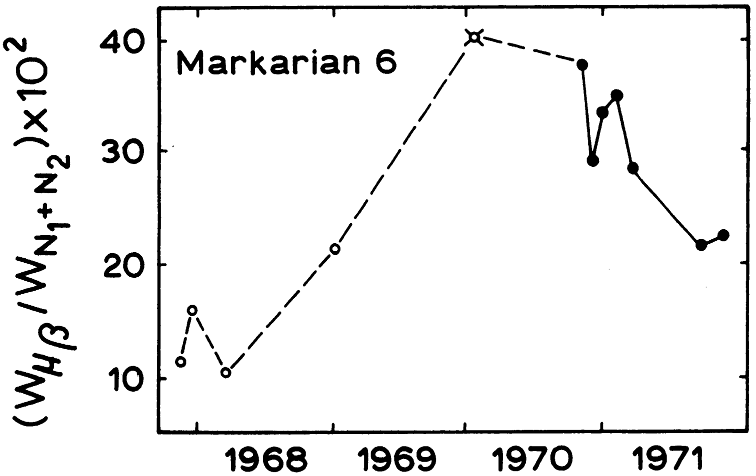

Fig. 8. The change of equivalent width ratio $W(H\beta)/W(N_1 + N_2)$ in the galaxy Markarian 6. The open circles and cross are the observations of Khachikian and Weedman (1971b) the black dots are those of Pronik and Chuvaev (1972).

optically thin in the Balmer lines. But if this is correct, then why is the asymmetry of the Hα and Hβ lines not quite identical and to what is the asymmetry itself due?

The phenomenon of the appearance and disappearance of separate components in the broad wings of the hydrogen lines is of great interest. We mean here the blue-shifted emission component of the Hβ line in Markarian 6 and the blue-shifted absorption component of Hβ in NGC 4151.

The former was found by Khachikian and Weedman (1971b) in early 1969. The spectra obtained by them one year earlier did not show the additional component; therefore it was suggested that this component was formed during one year or less. The observations of Pronik and Chuvaev (1972) showed the existence of wide wings for the hydrogen lines. They also found that the intensity of these wings varied as well as the continuum.

The correlation between the Hβ line intensity and the strength of the continuum (Figure 9) is the same as for NGC 1068 and NGC 3516 with the saturation effect of $I_{H\beta}$ for large values of the continuum.

The blue-shifted component in the hydrogen lines of Markarian 6 was found 6 yr ago and since then, it is observed to be sometimes more sometimes less pronounced. Pronik and Chuvaev (1972) suggested that the appearance of the line component is not connected with the displacement of a mass of gas (formation of new gas cloud or ejection of gas from the nucleus as it was interpreted by Khachikian and Weedman (1971b) but is due to an increase of ultraviolet radiation and the ionization of existing clouds.

The absorption features in NGC 4151 (the hydrogen absorption to the near blue side of the sharp cores of the Balmer lines together with the blue-displaced λ 3889 Å He I absorption) were discovered by Anderson and Kraft (1969) at the beginning of

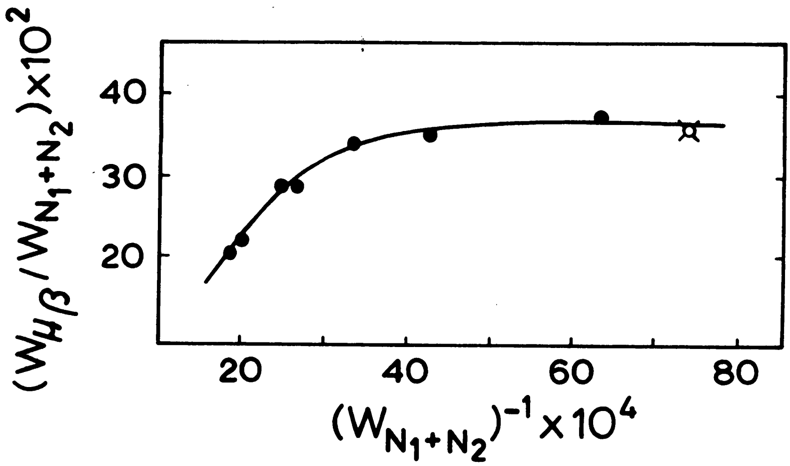

Fig. 9. Correlation between Hβ line intensity and continuum strength for Markarian 6 obtained on the assumption that the $N_1 + N_2$ flux is constant.

1969 and were interpreted as evidence of gas outflow from the nucleus. One year later, in December 1969–January 1970, Cromwell and Weymann (1970) found this absorption much more clearly visible and claimed it to be a transient feature with a time scale of one year (ejection of a gas cloud from the nucleus). At the same time they explained the appearance of a great number of stellar absorption lines and many other faint emission lines on their spectra by the relative decrease in brightness of the nucleus continuum. In Figure 1, it is seen very clearly that the deep minimum in the brightness of the nucleus at the end of 1969 and beginning of 1970 occurs at the same time as the spectra of Cromwell and Weymann (1971). But there is no necessity to resort to two different explanations for the appearance of Hβ absorption and stellar absorption.

According to our view, the absorption feature in NGC 4151 may be interpreted in the same manner as the blue emission component in Markarian 6. Appearance and disappearance of absorption may be caused by a variable central source of ionizating radiation. The main reason for the increase of Hβ absorption in 1969–1970 is a rise in contrast caused by a decrease of the continuum, and the second one may be the rise in the number of neutral hydrogen atoms associated with the drop in the degree of ionization. A piece of indirect evidence for the presence of neutral hydrogen in the nucleus of NGC 4151 is that the correlation between Hα intensity and continuum brightness does not show the saturation effect of the Hα line even for cases of the highest ultraviolet continuum (see Figure 6). Therefore the absorption features must be observed over a period much longer than one year. He I absorption in NGC 4151 was observed as far back as 1934 (Mayall, 1934). The best test of our hypothesis will be the appearance of Hβ absorption during the next *U* (photometric) minimum of the NGC 4151 nucleus.

5. Conclusions

(a) In all Seyfert galaxy nuclei, there is a source of variable (nonthermal?) continuum radiation. The largest part of this radiation is in the ultraviolet region where the background due to stars is rather weak. For this reason, the nuclei of all Seyfert galaxies are variable at least in the ultraviolet region.

(b) Two types of variability are superposed on the light-curves of nuclei: a slow component with a characteristic time from one to ten years and an amplitude of $0\overset{m}{.}5$–1^m and a short-term variability (like flares) with somewhat smaller amplitude and a characteristic time from several days to several months.

(c) The quasi-periodicity in both components (long- and short-term variability) is good evidence for the existence of a central body in the nucleus causing all changes in the vicinity of the nucleus. The size of this central body (or its active region) estimated from the time scale of the variability is no more than 10^{15}–10^{16} cm.

(d) The profiles and intensities of the broad hydrogen lines from Seyfert nuclei are variable. There is also some evidence for the variability of the narrow central cores of the hydrogen lines, λ 6584 Å [N II] and λ 4363 Å [O III] lines. Changes in the λ 3727 Å [O II] line must be found for confirmation.

(e) The variations in the Hα intensity copy those in the continuum with a time shift of 20–30 days. This means that the gas effectively emitting the Hα line is located at a distance of 10^{16}–10^{17} cm from the nucleus.

(f) No processes connected with gas displacement can provide the observed short-term variability of the spectral lines. The most probable reason for these variations is the changes of the degree of ionization of the gas.

The constancy of the shape of the broad hydrogen line profiles during the flare-up while the intensity of the lines varies by several times its minimum value, agrees with this suggestion. The changes in ionization of the gas envelope with density and velocity gradient along the radius can lead to apparent changes of electron density and velocity of the gas.

(g) There is a correlation between the intensity of the broad hydrogen lines and the ultraviolet continuum. The most important feature of this correlation is the saturation of emission lines for high continuum intensity. It may be interpreted as a limitation of line emissivity in completely ionized gas.

(h) The lag of the short-term line variations behind the continuum variations as well as the multiple structure of the profiles indicate the existence of one or several small dense clouds of gas, the radiation from which is comparable with the total radiation of the gaseous envelope of the nucleus.

References

Anderson, K. S.: 1970, *Astrophys. J.* **162**, 743.
Anderson, K. S.: 1971, *Astrophys. J.* **169**, 449.
Anderson, K. S. and Kraft, R. P.: 1969, *Astrophys. J.* **158**, 859.
Andrillat, Y. and Souffrin, S.: 1968, *Astrophys. Letters* **1**, 111.
Andrillat, Y.: 1969, *Astron. J.* **73**, 862.
Babadzanianz, M. K., Belokon', E. T., and Lyuty, V. M.: 1975 (in press).
Babadzanianz, M. K. and Belokon', E. T.: 1974, *Astron. Tsirk.*, No. 819.
Babadzanianz, M. K., Gagen-Torn, V. A., and Lyuty, V. M.: 1972, *Astrofizika* **8**, 509.
Barnes, T. G.: 1969, *Astrophys. Letters* **1**, 171.
Becklin, E. E., Penston, M. V., Penston, M. J., Selmes, R. A., and Neugebauer, G.: 1974, *Monthly Notices Roy. Astron. Soc.* **169**, 357.
Cherepashchuk, A. M. and Lyuty, V. M.: 1973, *Astrophys. Letters* **13**, 165.
Chuvaev, K. K.: 1974, in press.
Collin-Souffrin, S., Alloin, D., and Andrillat, Y.; 1973, *Astron. Astrophys.* **22**, 343.
Cromwell, R., and Weymann, R. J.: 1970, *Astrophys. J.* **159**, L147.
Dibay, E. A. and Pronik, V. I.: 1967, *Astron. Zh.* **44**, 952.
Dibay, E. A., Esipov, V. F., and Pronik, V. I.: 1967, *Astron. Zh.* **44**, 689.
Eilek J. A., Auman, J. R., Ulrich, M. J., Walker, G. A. H., and Kuchi, L. V.: 1973, *Astrophys. J.* **182**, 363.
Fitch, W. S., Pacholczyk, A. G., and Weymann, R. J.: 1971, *Astrophys. J.* **150**, L67.
Humason, M.: 1932, *Publ. Astron. Soc. Pacific* **44**, 265.
Jurkevich, J., Usher, P. D., and Shen, B. S. P.: 1971, *Astrophys. Space Sci.* **10**, 402.
Khachikian, E. Ye., and Weedman, D. W.: 1971a, *Astrofizika* **7**, 389.
Khachikian, E. Ye. and Weedman, D. W.: 1971b, *Astrophys. J.* **164**, L109.
Lyuty, V. M.: 1972, *Astron. Zh.* **49**, 930.
Lyuty, V. M.: 1973, *Astron. Tsirk.* No. 777.
Mayall, N. U.: 1934, *Publ. Astron. Soc. Pacific*, **46**, 134.
Pacholczyk, A. G.: 1971, *Astrophys. J.* **163**, 449.
Pacholczyk, A. G. and Weymann, R. J.: 1968, *Astron. J.* **73**, 850.
Pastoriza, M. and Gerola, H.: 1970, *Astrophys. Letters* **6**, 155.
Penston, M. V., Penston, M. J., Neugebauer, G., Tritton, K. P., Becklin, E. E., and Visvanathan, N.: 1971, *Monthly Notices Roy. Astron. Soc.* **153**, 29.
Pronik, I. I.: 1971, *Astron. Tsirk.* No. 663.
Pronik, I. I.: 1974, in J. R. Shakeshaft (ed.), 'The Formation and Dynamics of Galaxies', *IAU Symp.* **58**, 336.
Pronik, V. I., and Chuvaev, K. K.: 1972, *Astrofizika* **8**, 187.
Schwarzschild, M.: 1973, *Astrophys. J.* **182**, 357.
Seyfert, C. K.: 1943, *Astrophys. J.* **97**, 28.
Ulrich, M.-H.: 1972, *Astrophys. J.* **174**, 483.
Vaucouleurs, G. de and Vaucouleurs, A. de: 1972, *Astrophys. Letters* **12**, 1.
Wampler, E.: 1971, *Astrophys. J.* **164**, 1.

DISCUSSION

T. D. Kinman: What is the error of a single measurement of Hα in these galaxies?

V. M. Lyuty: The errors of the measurements are about 2% for NGC 4151 and about 5% for NGC 3516.

M. Friedjung: Is the time lag the same for different small clouds which contribute to the profile of Hα?

V. I. Pronik: The measurements are not very accurate, but they are approximately the same.

B. V. Komberg: A correlation seems to have been noted between the flare amplitude and its duration in Seyfert galaxies and quasars.

V. M. Lyuty: We did not find such a correlation.

W. Popov: Is the period of the brightness variation in NGC 4151 strictly constant?

V. M. Lyuty: Yes, it is.

L. A. Pustil'nik: Did you look for a correlation between optical and radio radiation?

V. I. Pronik: No.

L. A. Pustil'nik: Can something be said about conditions in absorbing and emitting regions?

V. I. Pronik: For details on the conditions of absorption and emission, see a paper by Osterbrock at the Vatican Symposium 1971 (Nuclei of Galaxies). There are large uncertainties in the values of n_e and T_e.