EMISSION LINES VARIATIONS IN THE SPECTRA OF SEYFERT GALAXIES NUCLEI.OBSERVATIONAL DATA.

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Introduction

The emission lines variability in the spectra of Seyfert galaxies nuclei has been known for more than 20 years. The first report on the problem under consideration was made by Bardin et al.(1967). They published the data on the variation of relative intensities of forbidden 4959+5007 A and 4363 A [OIII] lines in the spectrum of NGC 5548 galaxy nucleus that exceed the errors of observations. It was noticed also that NGC 5548 was the second galaxy where the considered lines show variability. At least four review papers have been published: Lyutyi and V.Pronik(1975),Collin-Souffrin(1980), I.Pronik(1980),Penston(1982).

We have compiled the indications of variability of emission lines in the spectra of 37 Seyfert galaxies nuclei published in literature. Only 5 of them belong to Sy2 type, the other 32- to SyI type.Does it indicate that the emission lines of Sy2 type spectrae are less variable those of SyI ? Rather not,because the programms for emission lines variability observations now are filled mainly by SyI type galaxies. Probably further investigations would show greater percent of Sy2 type galaxies having variable emission spectrae.

The latest several years have been characterized by the advanced investigations of emission lines variability of Syefert galaxies nuclei. Some of them should be pointed out.

I. The majority of earlier paper indicated only the phenomenon of variability. Now a number of specially elaborated programms markedly increased. The first of them were: Lyutyi and Cherepashchuk(1972),I.Pronik(1974,a;1976,a) and more later ones: Chuvaev(1980;1985),I.Pronik(1980,1983),Doroshenko, Terebizh(1983,a,b),Ulrich et al.(1984,1985).

2. The data has been enriched by the space telescopes observations.The important UV lines: L_α ,CIV 1550 A ,CIII] 1909 A, MgII 2800 A and a number of lines with moderate and weak intensities are available now for analysis.

3. Recent current observations often give emission lines fluxes whereas earlier ones only relative intensities.

According to compiled data the emission lines show variation as in optical,so in UV spectral regions.The variation being revealed as in permitted,so in forbidden and semiforbidden lines. All 37 galaxies considered show the variation of permitted lines. The investigation of permitted lines variability advanced both in theory and observations. But

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that is not so for the forbidden lines variations. Twenty years ago it was mentioned that the spectrae of Seyfert type nuclei look like ones of planetary nebulae.And the theory of planetary nebulae emission was transported to the gaseous formations of Seyferts. This theory does not predict forbidden lines variability.So there are very few observations investigating the forbidden lines variability.

Hereinafter we consider the characteristics of variability of permitted and forbidden lines separately.

The characteristics of permitted lines variations

In the spectra of Seyfert galaxies nuclei one can observe the variations both of emission and absorption permitted lines.Anderson,Kraft(I969), Cromwell,Weyman(I970), Ulrich et al.(I984) and others observed absorption lines variation in spectrae of Seyfert galaxies nuclei.Still the data of such kind variability are poor and we wouldn't consider it here.

There is advance now in FeII lines variability investigations.The first data were obtained by Boksenberg and Netzer (I977) for NGC 35I6 nucleus. Later the observations showed that the character of FeII lines variability resembles that of other permitted broad lines,though the widths of FeII lines wings are narrower than that of hydrogen ones.

The main characteristics of permitted lines variability in Seyferts can be summarized in the following points:

I. Time scale of permitted lines variability show wide interval. The least times of Balmer lines variations are found for NGC 4I5I nucleus - about I hour (Collin-Souffrin et al.,I979) and for NGC I275 nucleus - about half an hour(Merkulova,I.Pronik,I985). More observations are available for time scale of several days: Barr et al.(I983)- for NGC 3783, Doroshenko and Terebizh(I983,a)- for Arakelian I20, Bochkarev(I984) and Ulrich et al.(I985)- for NGC 4I5I. The majority of observations reveal the variations of permitted lilines within one or more months: Atwood et al.(I982)-for NGC 3783, Penston et al.(I98I)-for NGC 4I5I, Clavel(I983) and Clavel et al.(I983)-for NGC 4593, Gregory et al.(I982)-for NGC 5548, Doroshenko,Terebizh(I983,a)-for NGC 7469.

2. The variations of lines fluxes correlate with the variations of continuum fluxes. The first observation was made by Lyutyi and Cherepashchuk(I972) for NGC I068,NGC 35I6 and NGC 4I5I: lines variations delay continuum ones by I5-30 days. This important discovery was confirmed by many later observations: V.Pronik,Chuvaev(I972)-for Markarian 6, de Bruyn(I980) -for I5 Seyferts. Fig.I shows the data obtained by de Bruyn: the nuclei luminosity in H_α line correlates with their luminosity in continuum at 3500 A. The ratio $\mathcal{L}_{H\alpha} \sim \sqrt[3]{\mathcal{L}_{3500}}$ is fulfilled. Many observations of variable lines and continuum correlations were made by Doroshenko and Terebizh.

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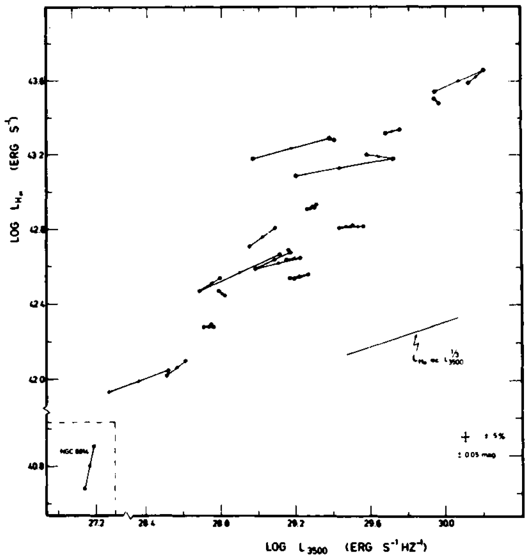

Fig.I.Dependence of H_α emission line flux versus continuum flux near 3500 A according to de Bruyn (I980).

They confirm the results of Lyutyi and Cherepashchuk (1972) for NGC 35I6 , I.Pronik (1975,a,b) and de Bruyn (1980) - for NGC 7469 , Chuvaev (I980) - for 3C I20 and de Bruyn (I980) for NGC 5548. They presented also new data for other galaxies nuclei - Markarian IO and Arakelian I20. For all these galaxies nuclei the fluxes in hydrogen lines are increasing with the increas of continuum luminosity.

The fact of correlation between permitted lines fluxes variations and continuum ones was pointed out in a number of other observations: Lyutyi et al. (I984), Ulrich et al. (I984) - for NGC 4I5I galaxy nucleus,Clavel et al. (I983) - for NGC 4593 galaxy nucleus and so on.

Thus the phenomenon of correlation of hydrogen and other permitted lines variations with the brightness of continuum variations now is known for a large number of Seyfert galaxies nuclei. Unfortunatelly the data on time delay of lines variations from the continuum is still scarce,because in most cases time intervals between separate observations for each galaxy were very long - from several months to even years. At the same time according to the data of Lyutyi and Cherepashchuk (I972) one must expect that time delay equals to I5-30 days. Some of the observations confirm this result : Peterson et al. (I983) - for Arakelian I20, Ulrich et al. (I985) - for NGC 4I5I.

3. The variations of profiles of permitted lines in the spectra of Seyfert galaxies nuclei is observed. The richest material in this respect is available for Balmer lines. The shapes of Balmer lines in spectra of Seyfert galaxies nuclei are very different and complicated. The manifestations of the lines profiles variations are various too: one observes as both wings variation and only one wing of the profile,

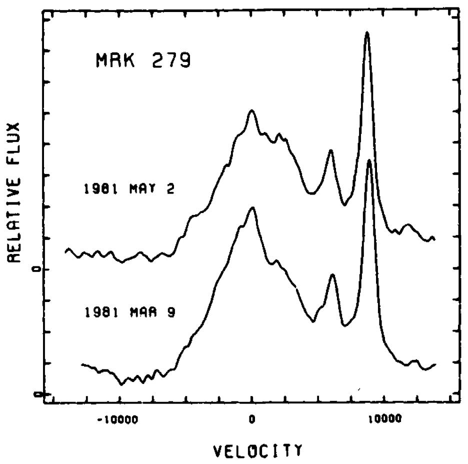

Fig.2. Lines profiles of H_β ,4959 and 5007 A [OIII] in the spectrum of Markarian 279 galaxy nucleus for different dates of observations according to Peterson et al. (1982).

so the cores of the profiles too. Fig.2 shows the red wing of H_β line variation during 2 months in the spectrum of Markarian 279 gakaxy nucleus. The same variation were found by Foltz et al. (1980) for Arakelian 120 galaxy nucleus, Variations of blue wings of hydrogen lines were observed by Lyutyi et al. (1984) for the nucleus of NGC 4151, Merkulova and I.Pronik (1985) for the nucleus of NGC 1275. Both wings of CIV 1550 A line have been drastically changed during 3 months of observations of NGC 5548 galaxy nucleus (Gregory et al., 1982 - see Fig.3). Broad wings of hydrogen lines have been decreased in the spectrum of NGC 7469 galaxy nucleus from 1975 till 1980 . It is shown in Fig.16.

In a number of papers the appearance and disappearens of some detailes in the profiles of permitted lines are considered. The first observation was made by Khachikian and Weedman

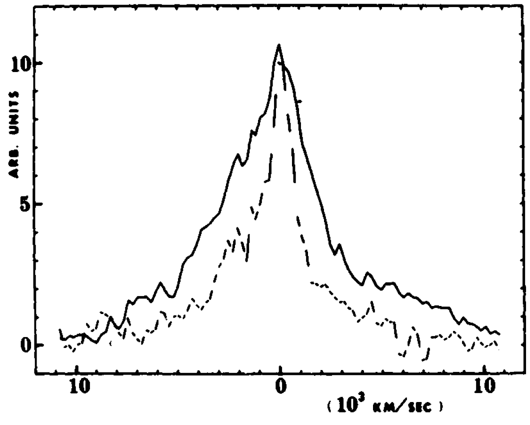

Fig.3. CIV 1550 A line profiles in the spectrum of NGC 5548 galaxy nucleus. The intensities are normalized by the central peak in the line. The uncertainty in continuum level is about 2% from the intensity in the peak.Solid line - 27.XI.1980,dotted line - 23.II.1981 (Gregory et al.,1982).

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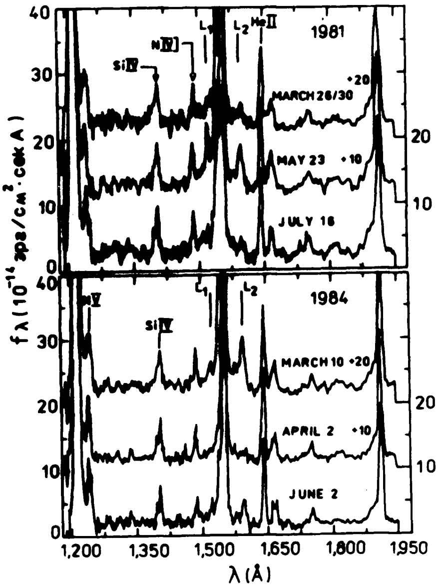

Fig.4. NGC 4151 nucleus spectrum for 6 epochs obtained in the region of CIV 1550 A line. The fluxes are expressed in the units 10^{-14} erg/cm^2 A (Ulrich et al.,1985).

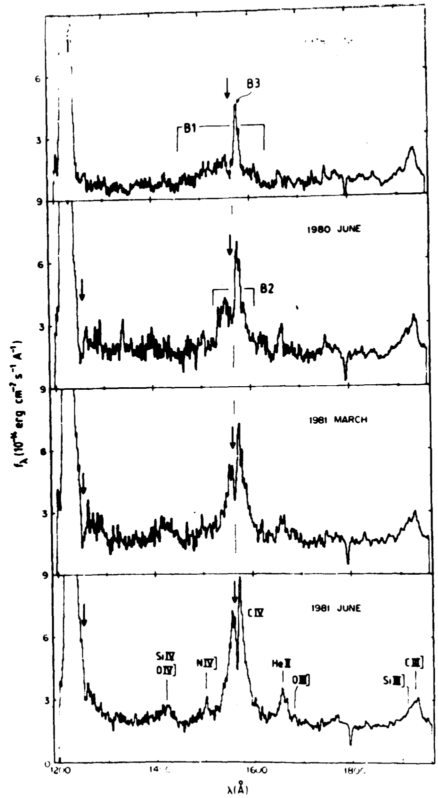

Fig.5. Spectrum of NGC 3516 nucleus in the region of 1200-1980 AA for 4 epochs.Vertical line- 1550 A in the galaxy system. B_1, B_2 and B_3 are the components of CIV line(Ulrich et al.,1984).

(1971) for Markarian 6 galaxy nucleus. Quite recently Ulrich et al.(1985) published very interesting results on the variation of profile components in CIV 1550 A line in the spectrum of NGC 4151 nucleus: L_1 and L_2 on Fig.4.They are situated at -30 A and +40 A from the center of CIV line.During 3 years the brightness of the components changed fourfold.

The core of CIV 1550 A line variations were observed in the spectrum of NGC 3516(Ulrich,Boisson,1983-see Fig.5) and in NGC 4151 one (Ulrich et al.,1984).

4. The degree of variation of lines profiles was found dependent on its number in Balmer series.The first observations of this phenomenon were made by I.Pronik for NGC 7469 (1975,a,b). Fig.6 shows this effect for Arakelian 120.

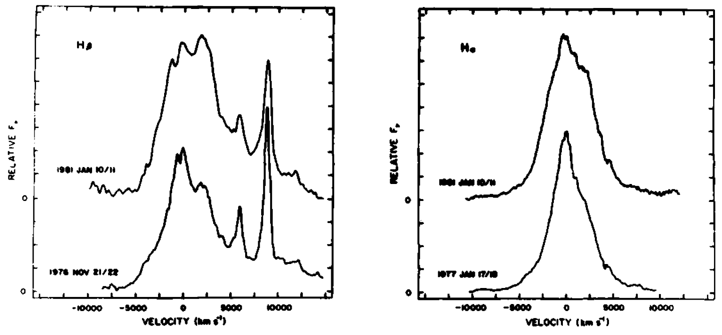

Fig.6. H_β and H_α lines in the spectrum of Arakelian I20 galaxy nucleus for different epochs (Schulz et al.,I98I).

5. Balmer decrement is varing with the time.According to the observations of I.Pronik(I975,a,b) carried out in I97I -1972 Balmer decrement $I_{H\alpha} : I_{H\beta} : I_{H\gamma} : I_{H\delta} : I_{H\epsilon}$ of NGC 7469 nucleus spectrum varied for 8 months from 6,34 : I,00 : 0,89 : 0,76 : 0,47 to 2,37 : I,00 : 0,54 : 0,33 : 0,2I De Bruyn refers for this nucleus decrement obtained in June I975 and December I977 similar to the second case given above. In June I977 the decrement was altogether different -4,20: I,00 : 0,43 : 0,I8(de Bruyn,I980).

The variation of Balmer decrement was observed for the NGC 35I6, NGC 5548,Markarian 54I galaxies nuclei(de Bruyn, I980; Phillips,I978) and others.

6. The series of systematic observations show the character of permitted lines variations depending on time: I.Pronik(I980,b;I983) for NGC I275 and NGC 3227 galaxies nuclei; Doroshenko and Terebizh(I983,a) for NGC 35I6 one and others.

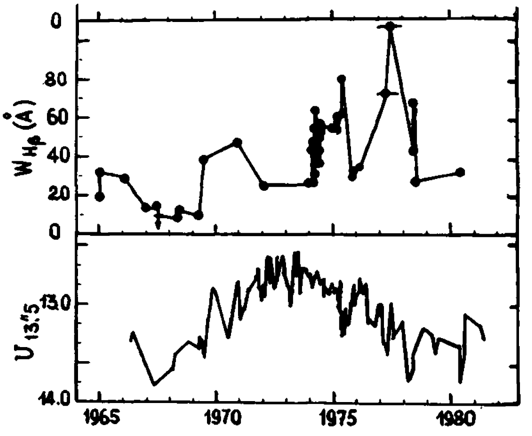

Fig.7. Time variation of equivalent width of H_β line and continuum of NGC 35I6 nucleus spectrum in diafragm I3"5(Doroshenko,Terebizh,I983,b).

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The comparison of continuum variations and the equivalent width of H_β line on the Fig.7 permit us to conclude that there is time scale variation of this line in the spectrum of NGC 3516 about 2-3 years.The same results arise from the observations of NGC 1275 and NGC 3227 nuclei.

Systematic observations of the emission spectra of Seyfert galaxies nuclei in time intervals longer than 10 years are absent and in shorter than a week are very scarce. According to the preliminary results of I.Pronik and N.Merkulova (1985) hydrogen lines in the spectrum of NGC 1275 galaxy nucleus have time scale variation of about 1-2 days and half an hour too.

The characteristics of semiforbidden and forbidden lines variations

As it was mentioned above the first report on emission lines variation concerns just the forbidden lines in the spectrum of Seyfert galaxy NGC 5548 nucleus(Bardin et al., 1967).Then this phenomenon was described in more detailes by Andrillat and Souffrin(1968) for NGC 3516 galaxy nucleus. But later they resisted their conclusions on forbidden lines variability.At present the majority of authors suspect the constancy of forbidden lines referring to the absence of theory explaining this effect. But it is well known that the lifetimes of atoms and ions on the metastable levels giving brightest forbidden lines in violet and optical region of spectrum are less than 7 hours (Kaplan and Pikel'er,1963).So they do not contradict to a plausible variability of forbidden lines in time scale of months or even days.

The data on possible variability of semiforbidden and forbidden lines are more scarce than that for permitted lines. They concern 12 Syefert galaxies belonging as to Sy1 and to Sy2 types.Characteristics of semiforbidden and forbidden lines variability are similar to that of permitted ones.

1. What is time scale and amplitude of the variations? There is scanty data on several days scale variations for galaxies nuclei F 427 (Fairall,1983) and NGC 1275(Merkulova

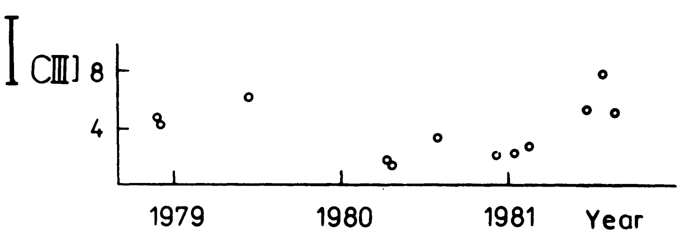

Fig.8. Flux variations in CIII] 1909 A line in the spectrum of NGC 3783 nucleus with time(Barr et al.,1983).The flux is expressed in the units10^{-13} e/cm^{2}s.

and I.Pronik(1985). Sygnificantly more observations showed the time scales variations of semiforbidden and forbidden lines for weeks and years. Fivefold variations of CIII] 1909 A line flux in spectrum of NGC 3783 galaxy nucleus during several weeks are in Fig.8. Penston et al.(1981) obtained the flux variation in 2470 A [OII] line of NGC 4151 nucleus spectrum by more than fourfold for two months. Semiforbidden lines variations were observed in NGC 4593 nucleus spectrum (Clavel,1983; Clavel et al.,1983) and in NGC 7469 one(Westin,1984). Twofold variations of CIII] 1909 A, [OIII] 2321 A and 4959A,5007 A lines fluxes were marked by Kollatchnij et al(1981) during one year in Arakelian 120 nucleus spectrum. Fig.9 shows the variations [FeX] 6374 A line in the spectrum of NGC 4151 nucleus during several months.

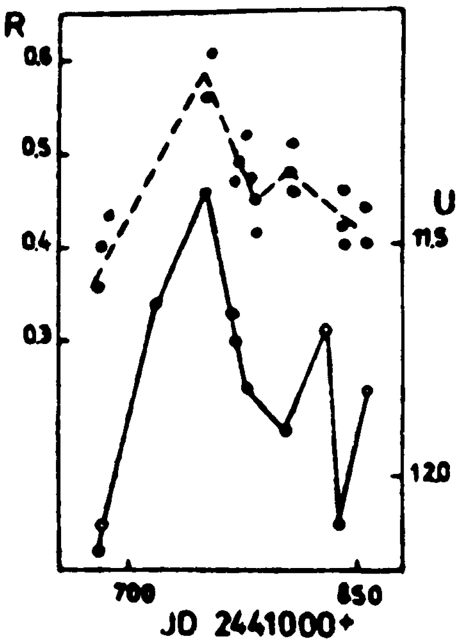

Fig.9. The variations of $\mathcal{R} = I(6364+6374)/I(6300)$ (open circles) and nucleus brightness in U-system for NGC 4151 galaxy (Oknyanskij, Chuvaev,1982).

2. The fluxes of semiforbidden and forbidden lines variations correlate with the continuum ones: Kollatchny et al.(1981), Oknyanskij and Chuvaev(1982-see Fig.9).

The data on time delay in forbidden lines variation from continuum one are more scanty than that for permitted lines. Barr et al.(1983) give time delay of CIII] 1909 A line variation in the NGC 3783 nucleus spectrum by several weeks.

3. The variations in forbidden lines profiles 4959 A and 5007 A [OIII] were observed by Glaspy et al.(1976) in the spectra of NGC 1068 and NGC 4151 galaxies nuclei during half a year, and by Kingham and O'Connel - in the spectrum of NGC 1275 nucleus in 10 years (1979). Fig.10 shows the variations of 5007 A [OIII] line profile in the spectrum of NGC 1068 nucleus for several years (V.Pronik,1985), and

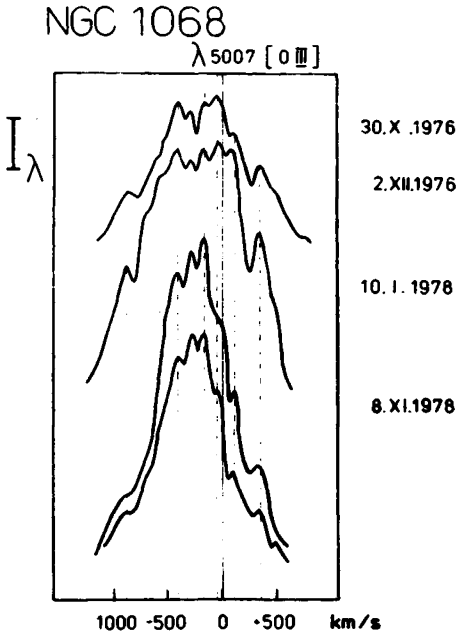

Fig.IO. Time variations of 5007 A [OIII] line profile according to V.Pronik(I985).

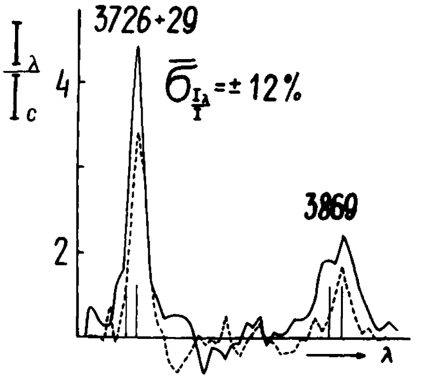

Fig.II. Time variation of 3869 A [NeIII] line profile in spectrum of NGC I275 galaxy nucleus according to Merculova and I.Pronik(I985).

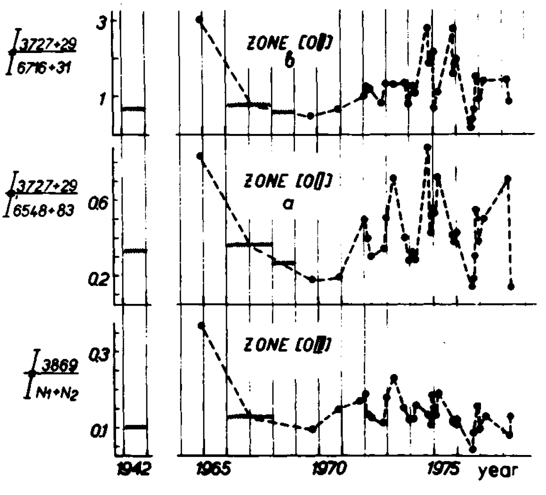

Fig.I2. Time variations of forbidden lines relative intensities in the spectrum of NGC I275 nucleus (I.Pronik,I980).

Fig.II - the variations of profile 3869 A[NeIII] line in the spectrum of NGC I275 nucleus within 2 days.

4. Long series of observations shown in Fig.I2 permit to reveal the one year scale variations of forbidden lines variations in the spectrum of NGC I275 nucleus.At the same time observations made with the same telescope and spectrograph do not show sach variations for NGC 3227 nucleus(I.Pronik,I983).

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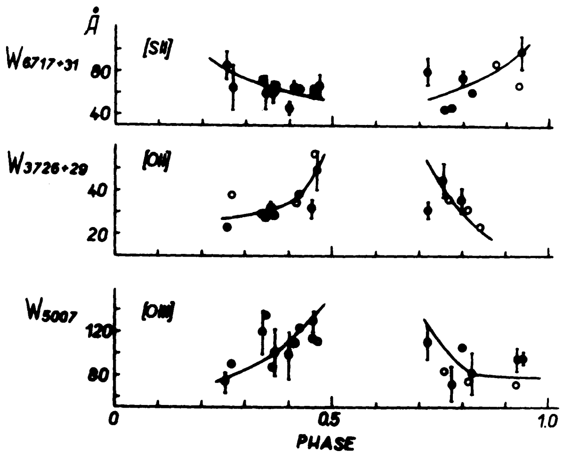

Fig.I3. Variations in the equivalent widths of forbidden lines of NGC I275 nucleus spectrum with the quasiperiod 2,3 days (Merkulova, I.Pronik, I985).

According to the prelimenary results of Merkulova and I.Pronik(I985) there is more short scale of forbidden lines variation in the spectrum of NGC I275 nucleus. It is illustrated in Fig.I3 -scale is about 2,3 days.

5. For the NGC I275 galaxy nucleus the correlation between relative intensities of forbidden lines and forbidden and hydrogen lines has been found. One can see them in Fig. I4 and I5,a,b according to observations of I.Pronik(I980, a,b) and Merkulova and I.Pronik(I987). Data of Fig.I5,a were obtained with the spectrograph and the time gap of years and months whereas of Fig.I5,b ones - with the scanning spectrophotometer with time gap of days and hours. Both figures show the same character of emission lines variations. The correlations presented in Fig.I4 and I5 evidence for the recurrence of the identical physical conditions in the variable part of gaseous envelope of NGC I275 nucleus.

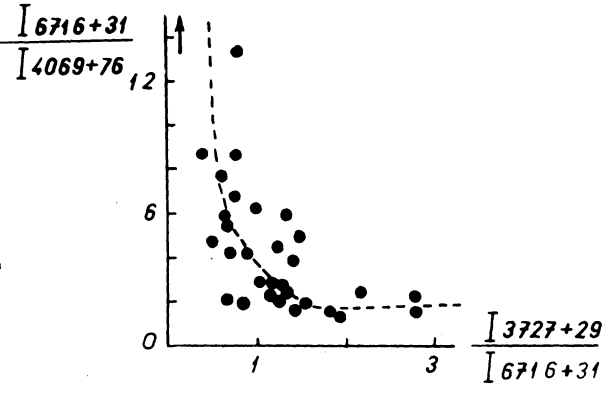

Fig.I4. The correlation of forbidden lines relative intensities in the spectrum of NGC I275 nucleus obtained during 8 years(I.Pronik,I980).

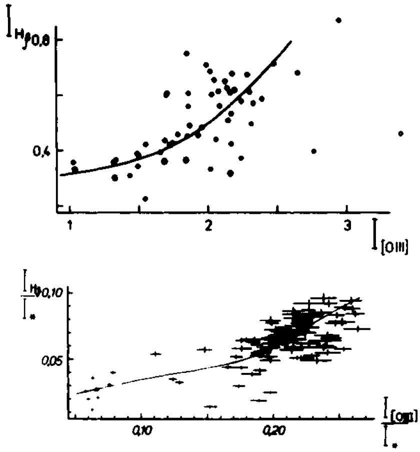

Fig.I5. Correlation of flux variations in H_β and 4959+5007 A [OIII] lines in the spectrum of NGC I275 nucleus according to :
a. I97I-I982 spectral observations,
b. I982-I984 photoelectrical observations. The crosses show mean square errors of the observations.

Seyfert nucleus type variations with time

Variation of emission lines in the spectra of Seyfert galaxies nuclei sometimes was very significant and lead to the variation of Seyfert nucleus type. This variation could have been registered when the spectra of these nuclei were observad regularly.Really,Seyfert(I943) included NGC 68I4 in his list of peculiar galaxies. Then Burbidge et al.(I963) exclude this galaxy from Seyferts since the spectrum of its nucleus obtained by them showed very narrow H_α + [NII] blend. In I970 Ulrich(I97I) reported that total width of H_β line was equal to 95 A or 6000 km/s. Probably it was the first case when the Seyfert type time variation was registered.

Now the results are published evidencing variation of Seyfert nucleus type for several galaxies: Markarian 6(Khachikian,Weedman,I97I;V.Pronik,Chuvaev,I972), NGC 3227(I. Pronik,I983), NGC 4I5I(Lyutyi,Oknyanskij,Chuvaev,I984;Penston and Peres,I984), NGC I566(Alloin et al.,I985). Long series of observations showed that the variation of Seyfert nucleus type is accompanied by the nucleus brightness variations: for NGC 4I5I- by I^min U-system in aperture 27", for NGC I566-fivefold at spectral region 3700 A.

The evolution of H_β line profile in the spectrum of NGC 7469 nucleus from I972 to I980 one can see in Fig.I6 : wings of the profile line weakened and ratio of intensities of 5007 A [OIII] and H_β lines increase almost twice.According to Barbiery et al.(I977) the core of H_β line consists of two components separated by 25 A or I500 km/s. Both components were equal in brightness till I975. After that time red component weakened compared to the blue one.Unfortunatelly the brightness of the nucleus is known only to I975.According to Lyutyi(I977) the brightness of the central region of NGC 7469 in aperture I3".5 in U-system decreases from I97I to I975 on $0^m.3$.Observad variations of the spectrum and bright-

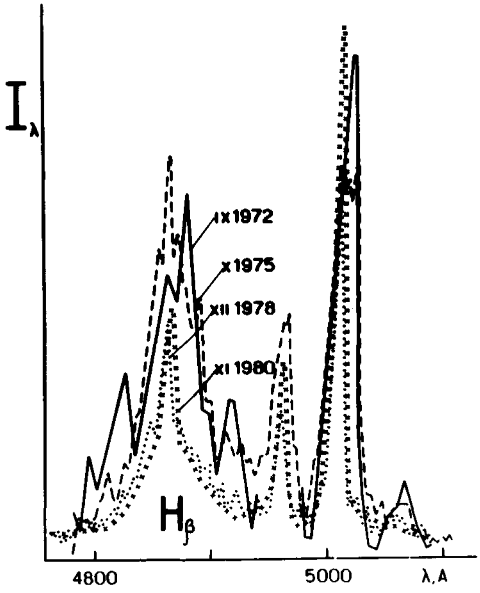

Fig.16.Profiles of H_β and 4959,5007 A [OIII] lines in the spectrum of NGC 7469 galaxy nucleus for several dates: 1972 (I.Pronik,1975), 1975(Barbiery et al.,1977), 1978 (Capriotti et al., 1980), 1980 (Peterson et al.,1982).

ness of the nucleus not so strong and Seyfert type of the nucleus is still SyI. But it is possible to expect its changing.

The classification of Seyfert nuclei in two types was proposed by Khachikian and Weedman (1974). It turned out later that this classification has a deep sence:two types of galaxies being classified showed different characteristics: relative intensities of emission lines 5007 A [OIII] , H_α and H_β ,colour indexes of the nuclei and central regions of galaxies(Adams,Weedman,1975), nuclei luminosities in H_β and [OIII] lines (Dibaj,Tsvetanov,1980),relative luminosities of nuclei and galaxies (Dibaj,1983).There are some indications to tiny morphological differences between two types of galaxies (Pavlova,1981). All these facts permit to believe that two types of Seyfert nuclei belong to the galaxies of different evolutionary development. Hence,the question arises, how one can explain the dependence of variable Seyfert nucleus type on fundamental characteristics of the galaxies? So we suppose that the variation of Seyfert nucleus type is developing in such a manner that each of the nuclei preserves its particular spectrum longer than other one.

Conclusions

The data on emission lines variations in the spectra of Seyfert galaxies nuclei with time permit us to estimate the size of the emitting zones: 10^{15} -10^{17}cm and electron concentration $N_e \sim 10^8$-10^{11}cm^{-3}.We are inclined to conclude,that none of the known theories explains the forbidden lines variations in Seyferts.According to them gas emitting has large

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shapes. For example in the theory proposed by Carrol and Kwan (I983) the shape of gaseous region equals to 60-I000 pc. At such dimension one can hardly observe the variations of forbidden lines not only within several days,but even months. Probably the most advantageous would be the models accounting on the X-ray emission from the central sources that can intensify the Auger effects and charge transfer in the emission zones of Seyfert galaxies nuclei.

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DISCUSSION

DULTZIN-HACYAN: What is the shortest time scale for variation of type (I or II) of nucleus?

ALLOIN and PRONIK: Alloin et al. (Astrophys. J. 288, 205, 1985) observed variation of NGC 1566 nucleus type during several months.

BOCHKAREV: Variations of spectrum lines may be good proof for structure in the innermost parts of AGNs. For interpretations of the variations it is necessary to know the spectrum of variations: amplitude as a function of timescale for shortest times. What are the shortest time-scales and amplitudes of real (physical, not to be misunderstood as a result of binary nuclei as Dr. Fairall talked yesterday etc.) variations of allowed and forbidden lines.

PRONIK: I have preliminary results only.

ALLOIN: I would not say that NGC 1566 went from a Seyfert 1 to Seyfert 2 type during its variations. The broad Hα component never goes away completely. It's rather that, when the AGN weakens, the underlying stellar component becomes more prominent and this affects much the very faint wing at Hβ (less at Hα).

PRONIK: We are now at the beginning of the problem. Some of the people suggest that they investigate Seyfert nuclei type variations and other ones - only details of the spectrum variations. It does not matter. All investigate the same event.

ALLOIN: For which object do you observe [FeX] line variations?

PRONIK: NGC 4151: Oknyanskij, Chuvaev, Russian Astron. Tsirk. No. 1228, 1982).

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