VARIABILITY OF THE EMISSION LINE SPECTRUM OF THE NUCLEUS OF SEYFERT GALAXY NGC 1275

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Abstract. Recent spectroscopic observations of the nucleus of NGC 1275, together with results from earlier workers, confirm the variability of the emission lines and indicate corresponding variations in the electron temperatures and densities of different zones. These changes may be associated with the microwave outbursts from this source.

The nucleus of NGC 1275 is known to be very unstable, exhibiting radio variability (e.g. Kellermann, 1972), UBV variability (Lyutyi, 1972) and infrared variability (Khozov, 1971). We have studied the variability of emission lines from the regions of ionized hydrogen in the nucleus of this galaxy. Such H II regions in Seyfert galaxies were discussed by Dibay and Pronik (1967) who concluded that they can be considered as being divided into several zones having different temperatures and densities. The highest electron temperature T_e and electron density $n_e \sim 10^7$ cm^{-3} correspond to the zone emitting wide hydrogen wings; [O III] and [Ne III] lines are emitted in a region with $T_e \approx 16000$ K and $n_e \approx 3 \times 10^6$ cm^{-3} (called the [O III] zone), while [O II] and [S II] lines originate in the most rarefied region with $T_e \sim 12000$ K and $n_e \approx 4 \times 10^3$ cm^{-3} (called the [O II] zone).

The nucleus of NGC 1275 has been observed at the prime focus of the 2.6-m Shajn telescope with V. Pronik's high-speed spectrograph during the period 1971 October 14 to 1973 April 4. 26 spectrograms with dispersion 380 Å mm^{-1} in the region 3700–

TABLE I

Å	Ion	1930 Dec. (i)	1942 (ii)	1964 Dec.– 1966 Feb. (iii)	1966-1967 (iv)	1968-1971 (v)	1971 Oct.– 1972 Oct.	1972 Dec.– 1973 Apr.
3727 + 29	[O II]	3.1	1.4	3.0	2.5	2.0	3.4	2.1
3869	[Ne III]	0.6	0.4	1.0	0.7		1.1	0.6
4069 + 76	[S II]	3.8	0.5		0.4	0.5	0.7	0.5
4102	Hδ	0.6	0.1	0.2	0.2	0.2	0.1	0.4
4340	Hγ	3.1	0.5	0.4	0.5	0.2	0.2	0.2
4363	[O III]	2.5	0.4		0.3		0.6	0.2
4861	Hβ	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4959 + 5007	[O III]	0.6	3.5	2.7	5.4	5.2	7.3	3.6
6300 + 64	[O I]		1.4		1.6	1.7	3.8	1.3
6563 / 6548 + 83	Hα / [N II]		7.0	6.0	11.9	12.9	16.6	4.6
6716 + 31	[S II]		2.1	1.0	3.4	3.6	3.9	1.2

References for Table I: (i) Humason (1932). (ii) Seyfert (1943). (iii) Dibay and Pronik (1967). (iv) Anderson (1970). (v) Wampler (1971).

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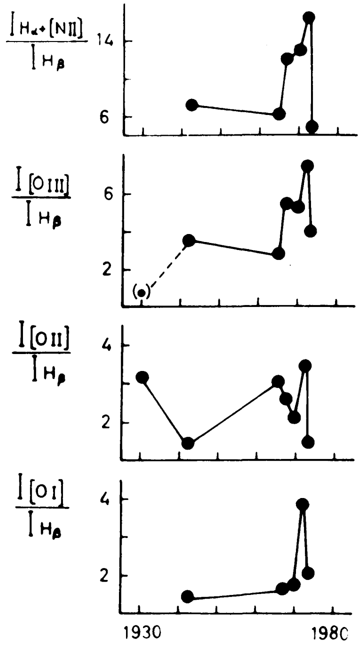

Fig. 1. Variations of the relative line intensities: [O I] 6300 + 64 Å, [O II] 3727 Å, [O III] 4959 + + 5007 Å, Hα + [N II] 6549 + 83 Å and Hβ, in the gaseous nucleus of NGC 1275.

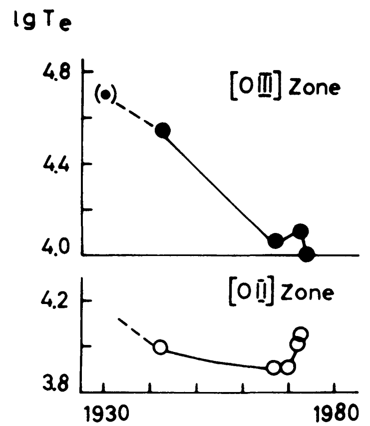

Fig. 2. Variations of electron temperature T_e in the [O III] (●) and [O II] (○) zones.

6800 Å were obtained, which enabled the relative intensities of the emission lines 3727 [O II], 3869 [Ne III], 4069–76 [S II], Hδ, Hγ, 4363 [O III], Hβ, $(N_1 + N_2)$ [O III], 6300+64 [O I], Hα+[N II] and 6716+31 [S II] to be measured. The intensities of some of these emission lines were found to vary, the largest variations being between October and December 1972. We have therefore divided all the observational data into two groups: (1) 1971 October to 1972 October, and (2) 1972 December to 1973 April. Our results, combined with others for the years 1930 to 1971, are presented in

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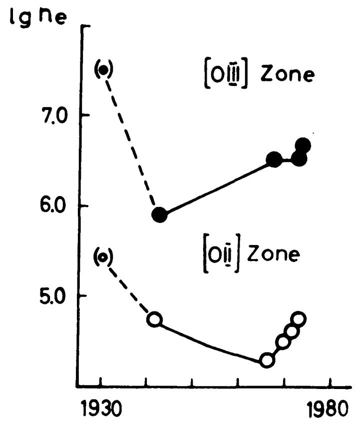

Fig. 3. Variations of electron density n_e in the [O III] (●) and [O II] (○) zones.

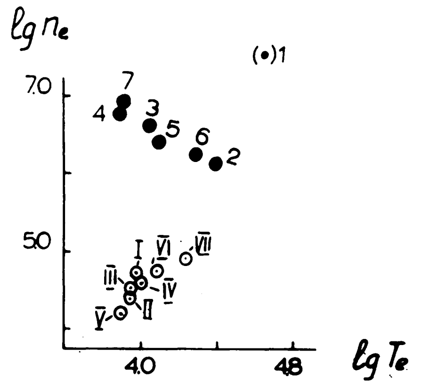

Fig. 4. The relation $\log T_e$–$\log n_e$ for the [O III] (●) and [O II] (○) zones. The Arabic and Roman numerals refer to dates as follows: 1 – 1930 (Humason, 1932); 2 – 1942 (Seyfert, 1943); 3 – 1966–67 (Anderson, 1970) and author: 4 – 1971, October 12; 5 – 1972 October 11; 6 – 1972 February 6; – – I – 1942 (Seyfert, 1943); II – 1966–67 (Anderson, 1970); III–1968–71 (Wampler, 1971) and author: IV – 1972, April 1; V – 1972, October; VI – 1972, December; VII – 1973, April.

Table I and in Figure 1, both of which confirm the variability of the relative intensities of emission lines in the nucleus of NGC 1275. Line intensities given in the Table have been corrected for interstellar absorption in the nuclei of galaxies according to Wampler's (1968) data. They were used to calculate T_e and n_e in the [O III] and [O II] zones by a graphical method (Boyarchuk *et al.*, 1969), and the results of these calculations are presented in Figures 2 and 3. For the [O III] zone they reveal a systematic decrease of T_e and an increase of n_e during the period under consideration, and for the [O II] zone there are also T_e and n_e variations.

This gradual evolution of the gaseous nucleus of NGC 1275 was interrupted in the first half of 1972 at which time there was a 'flash' in the [O III], [O II] and [O I] zones producing values of T_e higher than in the previous period. The relationship between T_e and n_e for the [O III] and [O II] regions is shown in Figure 4. From points 1 to 4, which

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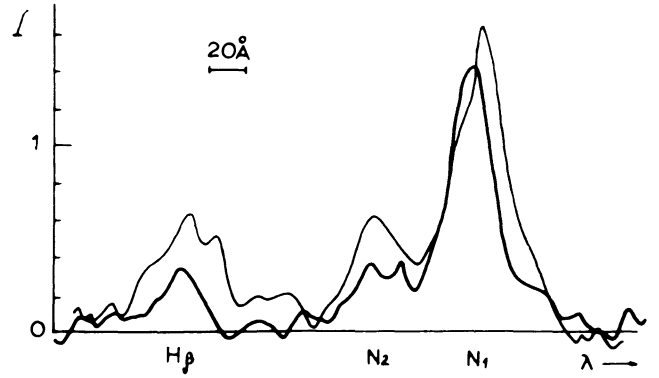

Fig. 5. Mean profile of the emission lines Hβ, N_1 and N_2 of the nucleus of NGC 1275. The thin line corresponds to the quiet state of the [O III] zone, 1972 December 1–3 and 1973 April 4 (10 spectrograms). The thick line corresponds to the period of the [O III] zone flash 1971 October to 1972 October (4 spectrograms).

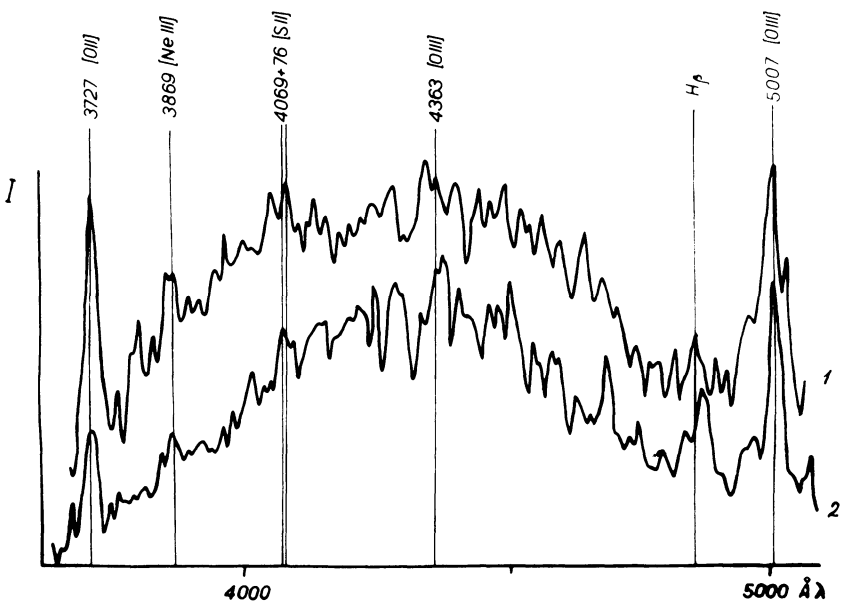

Fig. 6. Intensities of the blue region of NGC 1275 nuclear spectra (O III zone); 1 – 1972, February 6 (time of flash); 2 – 1972, December 2 (quiet state).

refer to the period from 1930 to 1971, there is seen to be cooling and a density increase in the [O III] zone during this time. Points 5 and 6 refer to the time of the 'flash' (1971 October–1972 October) in the [O III], [O II] and [O I] zones, and point 7 to the quiet state after the flash. One can see that during the flash the physical conditions in the [O III] zone approached those observed in 1942.

Careful measurements of our spectrograms show that the profiles of some forbidden lines have also varied from the flash to the quiet state. One can see from Figure 5 that

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during the flash the violet wing of the N_1 line was stronger than the red one, while during the quiet state it was *vice versa*. Moreover, during the flash, the [Ne III] 3869, [S II] 4069 + 76, and perhaps the [O III] 4363, lines in the [O III] zone had violet satellites, which became weaker or disappeared during the quiet state (Figure 6). So our material shows that the [O III] zone is not homogeneous. We suppose that its lower layers are denser and are observed during the quiet state, while its higher layers are more rarefied and are observed during the flash.

According to Kellermann (1972) the radionucleus of NGC 1275 is a double one. It consists of a highly variable source of diameter $\sim$0.3 pc which was born about 30 yr ago, and another more stable source about 5 pc in diameter and 3×10^4 yr old. Bursts of the small source are observed once or twice a year. Our calculations show that about 40 yr ago, when the small radiosource was born, the [O III] and [O II] zones were very hot and dense; according to Humason (1932), the lines $(N_1 + N_2)$ were very weak and the ratio of line intensities I_{4363}/I_{3869} was very high. Then the [O III] region cooled till the present time. Outbursts of the small radiosource may supply relativistic electrons which excite the flashes in the [O III], [O II] and H II zones. It will be very interesting to investigate the connections between the microwave flashes, flashes in the H II zones and flashes in the [O III] zones of the NGC 1275 nucleus.

Andrillat and Souffrin (1968) observed variability of emission line spectra like that of NGC 1275 in the nucleus of the Seyfert galaxy NGC 3516. They supposed that bursts of relativistic electrons were produced in the nucleus of that galaxy. Variability of the ratio $I_{N_1+N_2}/I_{H\beta}$ in the nucleus of the Seyfert type galaxy Markarian 6 also has been observed by Pronik and Chuvaev (1972), so it is very probable that variability of the emission-line spectrum is a characteristic of all Seyfert nuclei.

The detailed results will be published in the *Astronomiceskij Zhurnal*.

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References

Anderson, K.: 1970, *Astrophys. J.* **162**, 743.
Andrillat, Y. and Souffrin, S.: 1968, *Astrophys. Letters* **1**, 111.
Boyarchuk, A., Gershberg, R., Godovnikov, N., and Pronik, V.: 1969, *Izv. Krymsk. Astrofiz. Obs.* **39**, 147.
Dibay, E. and Pronik, V.: 1967, *Astron. Zh.* **44**, 952.
Humason, M.: 1932, *Publ. Astron. Soc. Pacific* **44**, 265.
Kellermann, K. I.: 1972, in D. S. Evans (ed.), 'External Galaxies and Quasi-Stellar Objects', *IAU Symp.* **44**, 190.
Khozov, V.: 1971, *Astron. Tsirk.* No. 607.
Lyutyi, V.: 1972, Ph.D. Dissertation, Moscow.
Pronik, V. and Chuvaev, K.: 1972, *Astrofizika* **8**, 187.
Seyfert, C.: 1943, *Astrophys. J.* **97**, 195.
Wampler, E.: 1968, *Astrophys. J. Letters*, **154**, L53.
Wampler, E.: 1971, *Astrophys. J.* **164**, 1.

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