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SPECTROPHOTOMETRIC STUDY OF GALAXIES WITH HIGH SURFACE BRIGHTNESS. I. ARAKELIAN 144

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The Arakelian 144 galaxy (MCG 10-12-23) belongs to the non-numerous class of objects with a high surface brightness, separated as a group by Arakelian in 1975 [1]. It has coordinates of the epoch 1950, 0α: $07^h\,52^m$, 9 and δ: $61^b47'$. With galaxy dimensions of $D=0,'3$ and $d=0.'25$ and a photographic stellar magnitude of $m_p=15.2$, the surface brightness of the galaxy in the Arakelian system is $B=21.5m/\square''$.

Arakelian described the object as very compact, bluish, with a weak asymmetric envelope. Its radial velocity was determined by Dibai, Doroshenko a. Terebizh [2]: $z=0.028$; they also noted the presence of emission lines — a strong line H_α and forbidden lines of mean intensity of single ionized nitrogen and sulfur.

The study of the Arakelian galaxy is justified, because it comprises unique objects. About 1 % are Seyfert galaxies. The percentage of galaxies with emission lines is high (up to 90 % — Arakelian, private communication). Some of them are among the brightest objects in the whole Universe. Sources of X-ray radiation were also discovered; for instance, Akn 120. According to Arakelian [3], these galaxies show a heightened radio emission at a frequency of 408 MHz.

Spectrophotometrically the Arakelian galaxies have been studied but little. Osterbrock a. Philips [4] investigated those referred to the Seyfert type, while Petrov [5] adduced the equivalent widths of the emission lines and their relative intensities for 12 Arakelian galaxies of the nonseyfert type.

Spectra of the Arakelian 144 galaxy were obtained last February on the 6-metre telescope BTA-SAO USSR by means of a UAGS spectrograph with a three-cascade image tube UM-92. At a dispersion of 100 A/mm, exposure was 10 min on emulsion A — 600. Two spectrograms were obtained, respectively in the blue and the red region of the spectrum, centered on the lines H_α and H_β. The spectral resolution of the apparatus was about 4—5 Å.

A unified method for exploring the emission objects was proposed by Dibai a. Pronik [6], as well as by Osmer, Smith a. Weedman [7]. The results by [7] differ about twice from those obtained by [6], chiefly because of rougher approximations.

The method used by us was that of Dibai a. Pronik. The results of the processing of our spectrograms — equivalent widths and relative intensities of the emission lines — are shown in Table 1.

Table 1

Ion	[N II] 6548	H_α 6563	[N II] 6584	[S II] 6717	[S II] 6731	$\frac{6717}{6731}$	$\frac{6584}{6724}$
W_λ	1.6	6.2	3.8	6.0	16.0		
$I_\lambda/I_{H\alpha}$	0.26	1.0	0.61	0.95	2.56	0.37	0.25

Note; 6724 denotes the sum of the lines 6717 and 6731.

In order to determine the flux in the line H_α, besides its width, the stellar magnitude of the galaxy nucleus must be known. The integral stellar magnitude, determined by Zwicky in the system m_p, is 15.2. There is no morphological classification of the galaxy in a standard system, but the descriptions by Arakelian in [1] and by Vorontsov-Veljaminov a. Krasnogorskaya [8] suggest that the galaxy is probably of the SO type.

Gorbachev adduced in [9] the stellar magnitudes of the nuclei of galaxies of a different morphological type and their integral stellar magnitudes. Similar data were also adduced in [10]. The following connections were obtained between the integral stellar magnitude and the stellar magnitude of the nucleus of a galaxy for the following types by means of LSM:

$$\text{E/SO:}\quad m_{\text{nuc}}=0.82\,m_{\text{gal}}+4.97\quad r=0.68\quad n=64$$

$$\text{Sa/Sab:}\quad m_{\text{nuc}}=0.64\,m_{\text{gal}}+6.38\quad r=0.68\quad n=41$$

$$\text{Sb/Sbc:}\quad m_{\text{nuc}}=0.53\,m_{\text{gal}}+8.40\quad r=0.64\quad n=79$$

$$\text{Sc/Scd:}\quad m_{\text{nuc}}\simeq0.28\,m_{\text{gal}}+12.11\quad r=0.46\quad n=54$$

where "r" is the correlation coefficient and "n" is the number of galaxies with known stellar magnitudes of the nucleus. It should be noted that by the data in [10] the following dependence is obtained for SO type galaxies: $m_{\text{nuc}}=1.26\,m_{\text{gal}}-1.50$ $r=0.86$.

Obtaining by the above dependences on the average for Akn 144 $m_{\text{nuc}}=17.5$, the flux in H_α is $F_{H_\alpha}=2.60\times10^{-15}$ erg. cm^{-2} sec^{-1} and consequently $F_{H_\beta}=8.67\times10^{-16}$ erg. cm^{-2} sec^{-1}. The relative intensities of the forbidden lines of ionized sulfur $I\lambda$ 6717/$I\lambda$ 6731 are a measure of the electron density of the emitting gas. The relation $r=I\lambda$ 6717/$I\lambda$ 6731 $=0.37$ corresponds to a fairly high electronic density $\sim320{,}000$ cm^{-3} ($\lg N_e=5.50$). Assuming, as usual, an electron temperature of $T_e=10{,}000$°K, all the parameters characterizing the released gas can be calculated. The results are adduced in Table 2.

In some respects the Arakelian 144 galaxy has proved most interesting. To begin with, the ionized sulfur lines are exceedingly strong — the relation $I\lambda$ 6584/$I\lambda$ 6724 $=0.25$, i. e. it is comparable only with that in some H II regions in the Galaxy. The relation $I\lambda$ 6724/$IH_\alpha=3.50$ is the highest possible known so far. The mean relation for all emission objects is below 0.5 (Petrov, dissertation, 1980) and frequently less than 0.1.

The relative content of sulfur ions is of one order higher than the average for the emission objects (planetary and diffusion nebulas, Arakelian galaxies, Markarian galaxies, Seyfert and radio galaxies), while that of nitrogen ions is like that of all galaxy types with the exception of the Seyfert type 1. The electron density of gas is exceedingly high, (the average for these zones in all emission objects being $\lg N_e=3.0$), and is equal to that for the zones

[O III] in the Seyfert type-2 galaxies. The luminosity of the H_β line, however, is by 1—2 orders lower than the average for Seyfert galaxies, and the kinetic energy of gas is comparable to that of the Seyfert type-2 galaxies and by one order lower than that of type 1.

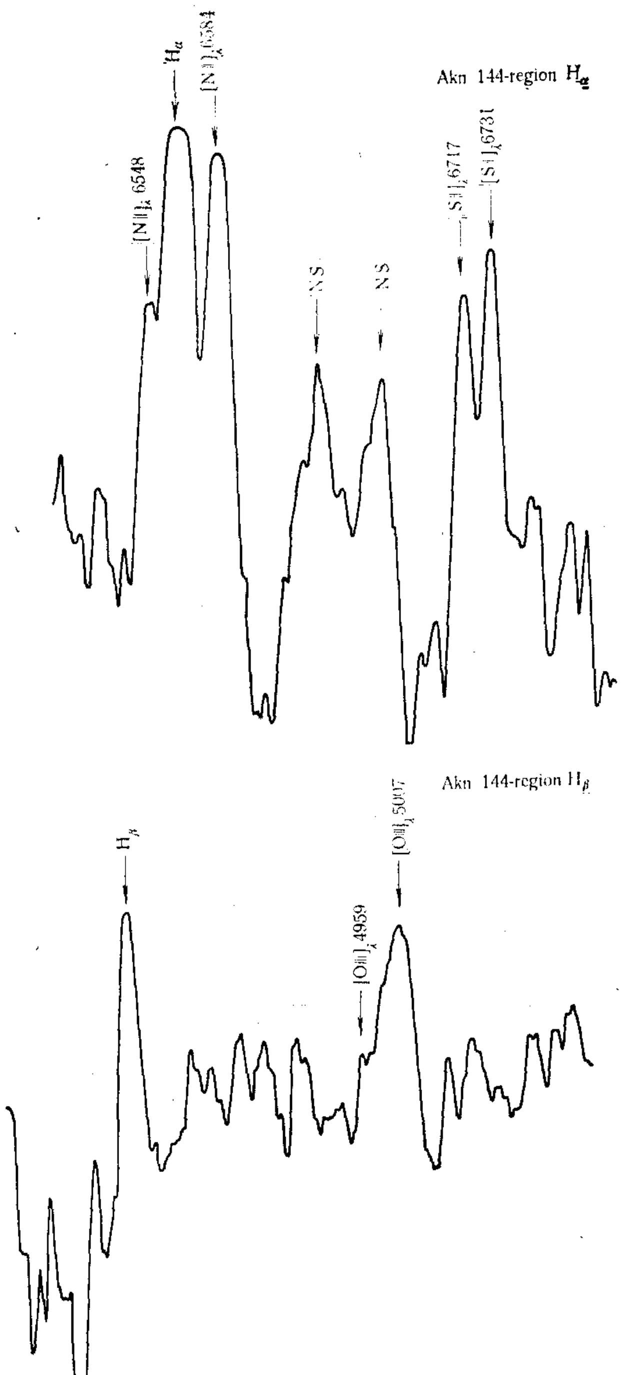

Fig.

The number of stars of the O7 V type, whose UV emission is sufficient to maintain the gas in a ionization-recombination equilibrium, is about 450, i. e. the young stars are a probable source of gas heating.

Table 2

Stellar magnitude of nucleus	$m_{nuc}=17.5$
Flux in the H_β line	$F_{H_\beta}=8.67\times10^{-16}$ erg/cm^2 . sec
Luminosity in the H_β line	$I_{H_\beta}=1.30\times10^{39}$ erg/sec
Bulk coeffcient of emission	$\varepsilon_{H_\beta}=1.27\times10^{-14}$ erg/cm^3 . sec
Effective radius	$R_{eff}=4.67\times10^{17}$ cm
Effective gas volume	$V_{eff}=1.02\times10^{53}$ cm^3
Gas mass	$M_{gas}=5.44\times10^{34}$ g
Kinetic energy	$E_{kin}=2.45\times10^{49}$ erg
Number of Balmer quanta	$N_{Bal}=3.56\times10^{51}$
Total gas energy	$E_{tot}=7.80\times10^{40}$ erg/sec
Number of O7 V stars sufficient to ionize gas	$N_*=440$
Relative number of ions	$N^+=7.52$
H=1200)	$S^+=7.68$

The submitted data testify to the unusualness of the processes in the nuclei of galaxies with a high surface brightness and call for an in-depth study.

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