Arakelian 144: A remarkable high surface brightness galaxy

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Abstract. In 1975 Arakelian selected in the northern hemisphere 591 high surface brightness galaxies (HSBGs). These objects occur normal galaxies with relatively high luminosities and small sizes and they offer a specific field for studying of the galaxies in general. The HSBGs have been registered among Seyfert galaxies, high luminosity galaxies, X-ray sources and IR sources. The object Akn 144 is a remarkable HSBG that shows multi-nuclear structure, emission line variability, etc. Here we present photometric and spectroscopic data taken by the 2-m Rozhen telescope, 6-m SAO telescope, 3.5-m CA telescope and 1.93-m OHP telescope. Identifications and equivalent width determinations of the spectral lines are presented. The work is part of long term cooperative investigation of selected emission line galaxies.

Key words: Galaxies: Arakelian, High surface brightness, spectrophotometry; BG virtual observatory

Introduction

The Arakelian 144 galaxy (MCG 10-12-23) belongs to the non numerous class of objects with a high surface brightness. They were separated as a group by Arakelian (1975) after determination of the surface brightness of all galaxies to the north of Delta ≤ -3 deg with photographic magnitudes given in CGCG (Zwicky et al., 1960-1968) and diameters given in MCG (Vorontsov-Vel'jaminov et al., 1962-1968). With galaxy dimensions of $D = 0.3'$ and $d = 0.25'$ and a photographic stellar magnitude of $m_p = 15.2$ mag, the surface brightness of the galaxy in the Arakelian system is B = 21.5 mag/sq.arcsec. In the MCG the listed galaxy's angular dimensions are $18''$x $15''$, Dibay et al. (1976) established that for the redshift Z = 0.028 the linear dimensions of the galaxy are 9800 x 8100 pc at H=75 km/(s.Mpc).

The first who investigated spectrally Akn 144 were Dibay et al. (1976). They detected strong emission in the Ha line, as well as an emission of medium intensity in the forbidden lines of sulphur and nitrogen, but did not make any estimations. In 1978 the spectra were examined for weak emission lines and we detected a certain inclinations of sulphur and nitrogen lines. For this reason Akn 144 was included in the programme of spectral studies for 1980, to determine the velocity field and physical conditions of the emitting gas.

Spectra of the galaxy with dispersion 50 A/mm were obtained on the 6 m telescope of the Special Astrophysical Observatory of the Soviet Academy of Sciences (see Mineva et al., 1981). Akn 144 was spectroscopically studied by Mineva et al. (1981, 1982) and morphologically — by Golev et al. (1985). Kojoian et al. (1981) determined the precise optical position for all the objects

in the Arkelian's list. Recently a detailed study of the influence of the environment to the surface brightness galaxies have been carried out - Mahtessian & Movsessian (2010).

On the basis of these spectrophotometric and photographic data, Akn 144 can be classified as an object with three nuclei and strong spectral emission lines, as well as a cloud structure of the gas, outflowing off the nucleus at a velocity up to ± 400 km/s.

Table 1 represents a cross–identifications for Arakelian 144.

Table 1. Cross–identification for Arakelian 144

Object Names	Type	Object Names	Type
ARK 144	G	IRAS 07528+6147	IrS
CGCG 286-079	G	IRAS F07528+6147	IrS
CGCG 287-012	G	HS 0752+6147	G
CGCG 0752.9+6147	G	NPM1G +61.0032	G
MCG +10-12-023	G	PGC 022290	G
2MASX J07571093+6139416	IrS	UZC J075711.0+613940	G

1 Observations and reductions

We got spectra of the Arakelian 144 galaxy during February'1980 on the 6-meter telescope BTA-SAO, former USSR, by means of a UAGS spectrograph with a three-stage image tube system 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 $H\beta$ and $H\alpha$. The spectral resolution was about 4 - 5A. The ionized sulphur lines are exceedingly strong — the relation $I\lambda6584/I\lambda(6717+6731) = 0.25$, i. e. it is comparable only with that in some H II regions in the Galaxy. The relation $I\lambda(6717+6731)/I(H\alpha) = 3.50$ is the highest possible known so far.

The relative content of sulphur 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). The electron density of gas is exceedingly high too. Using spectra obtained on the 3.5 m telescope of the Calar Alto Observatory, Spain, by means of a CCD device, we determined the relative intensities of the emission lines. Two (or three) components were established in the nucleus with Vr = ± 240 km/s at the $H\alpha$ line. The data obtained were compared to those from previous observations.

The results of this study are based on two spectra of Akn 144, obtained on the 3.5-m telescope of the Calar Alto Observatory of the Deutch-Spanish Astronomical Centre, Spain. For the purpose a Boller & Chivens spectrograph of dispersion about 20 A/mm was used. For the light signal we used a CCD matrix, a device of Texas Instruments, 356 x 520 pixels, Ti-type, sensitive to red spectral region, together with liquid nitrogen as cooling agent, keeping the temperature ≈ -120 °C. The spectral resolution was 1 pixel = 29 km/s, or about 0.7 A/pixel.

We investigated the region around the $H\alpha$ line. Table 2 represents the dates of observations, telescopes and equipments and types of observations - direct images, spectra, spectral regions.

Table 2. Akn144 – our observations

Month-Year	Telescope	Equipment	Data
Feb. 1981	6-m, SAO	ITS UM-92	Sp - $H\alpha, H\beta$
Sept. 1981	2-m, NAO	Plate ZU-21	Image
Oct. 1985	3.5-m, CA	CCD	Sp - $H\alpha$
Sept. 1986	2-m, NAO	ITS XX-1050	Sp - $H\alpha$
Jan. 1994	3.5-m, CA	CCD	Sp - $\lambda(3600 \div 6500)$
Jan. 2011	1.93-m, OHP	CCD	Sp - $\lambda(3600 \div 7000)$

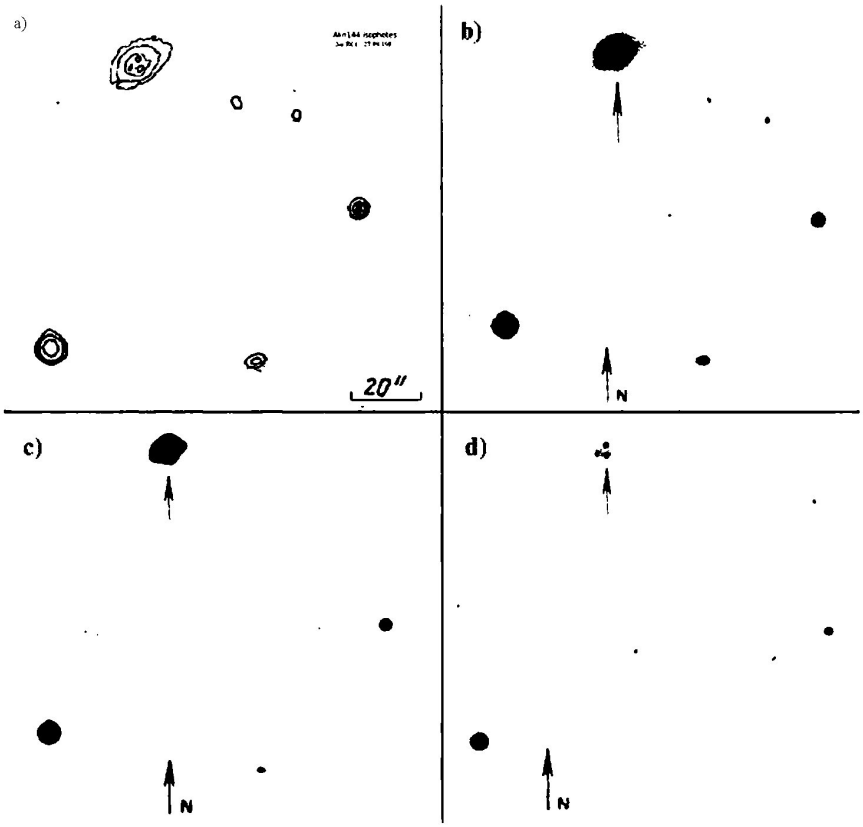

Fig. 1. Arakelian 144 - multi-structure nucleus in 1981 (see the text)

2 Main results and discussion

The galaxy was photographed in the B-color at a seeing of approximately 1″on the 2 m telescope of the Rozhen National Astronomical Observatory. In Figure 1 three nuclei can be discerned for Akn 144. The original scale is 12,9″/mm (linear diameters of the nuclei are about 1 pc).

Figure 1a presents isophotes of the galaxy and Figures 1(b,c,d) represent the different exposures direct images. Faint spiral structure could be seen in Fig.1b. On the original plate an initial spiral structure and a non-symmetrical nucleus can be clearly discerned. These plate-images bring a questions co. classification of Akn 144 to SO-galaxies (Nilson, 1973). Meantime LEDA morphological classification is "S?".

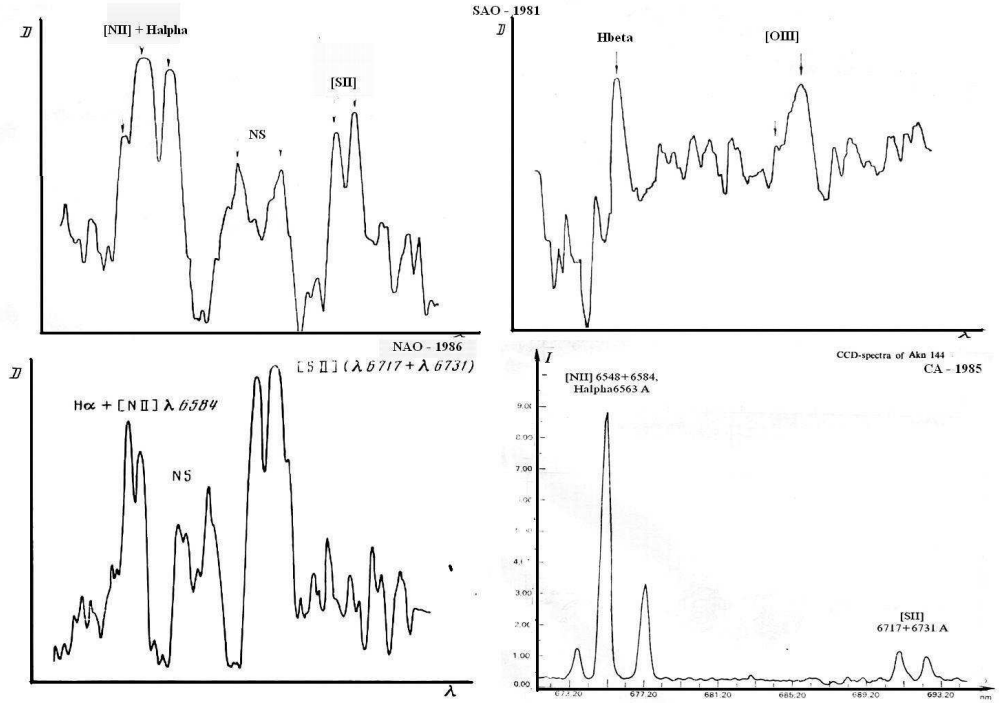

Fig. 2. Arakelian 144 - registrograms of spectra,taken from 1981 to 1985 (see the text)

Figure 2 presents thre old registrograms and one spectrogram of Akn 144, obtained on the 2-m, 6-m and 3.5-m telescopes (see Table2 for details). Figures 2a and 2b present 1981's $H\alpha$ and $H\beta$ spectra from the 6-m telescope, Fig.2c - $H\alpha$ spectrum from the 2-m telescope and Fig.2d - first CCD spectrum from the 3.5-m telescope. For details see Mineva et al. (1981), Mineva et al. (1982) and Petrov (1991).

Figure 3 (upper panel) shows equal intensity lines for $H\alpha$ and ionized nitrogen forbidden lines, and for ionized sulphur forbidden lines, respectively (CCD spectra, CA, 1985) and for $H\beta, [OIII]$ – lower panel (CCD spectra, CA, 1994). This figure supplies information about the spatial structure of the emitting gas. At least two (or even three) components can be discerned, of relative velocity Vr = 165km s^{-1} for sulphur lines, and Vr = 240km s^{-1} for $H\alpha$ in respect to the central maximum. The dimensions of the emitting region are approximately 5″- ca. 2700 pc for H = 75 km s^{-1}/Mpc, and distance to the galaxy 112 Mpc. The third component is best observed at the $\lambda 6584[NII]$ line and is completely absent at $H\alpha$. $H\beta$ spectra taken in 1994 are with lower spectral resolution (Popeskcu et al., 1996), but strong inclinations of all of the lines are clearly visible.

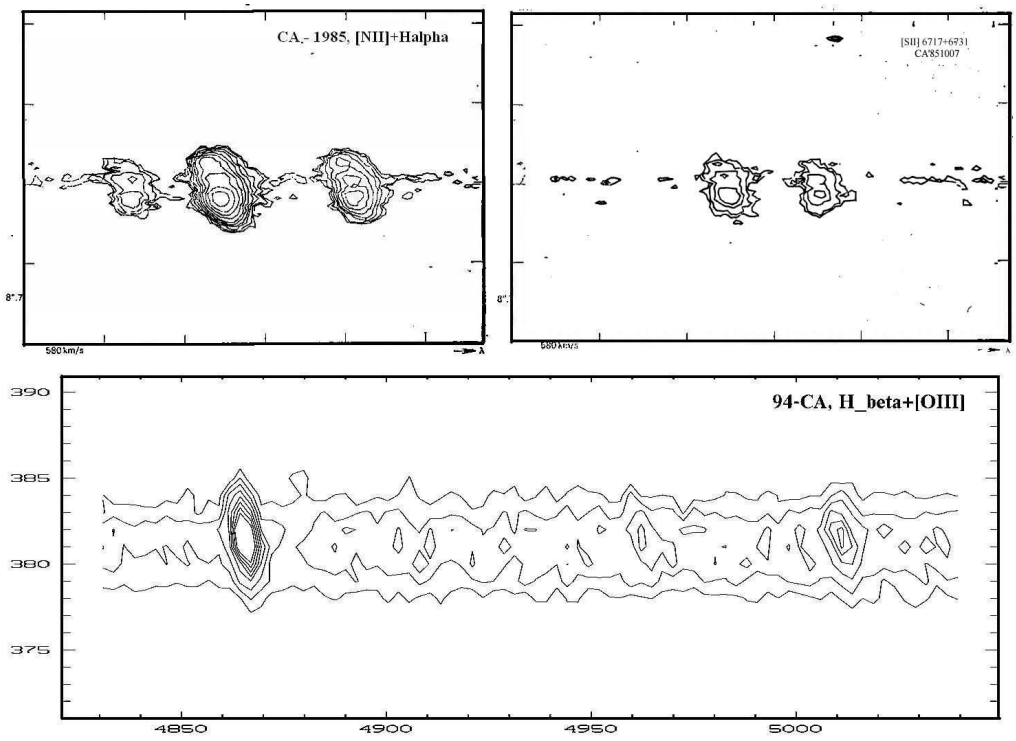

Fig. 3. Arakelian 144 – $H\alpha + [NII]$, $[SII]$ and $[OIII] + H\beta$ isophotes. Inclination of lines and cloud structure are seen.

3 Spectrophotometric data

In the Fig.4 the spectrum of Akn 144 from the 1.93–m OHP telescope is presented. Spectral region covered is $\lambda\lambda(3700 \div 7000)A$. Spectrum is flux calibrated, as shown on the figure.

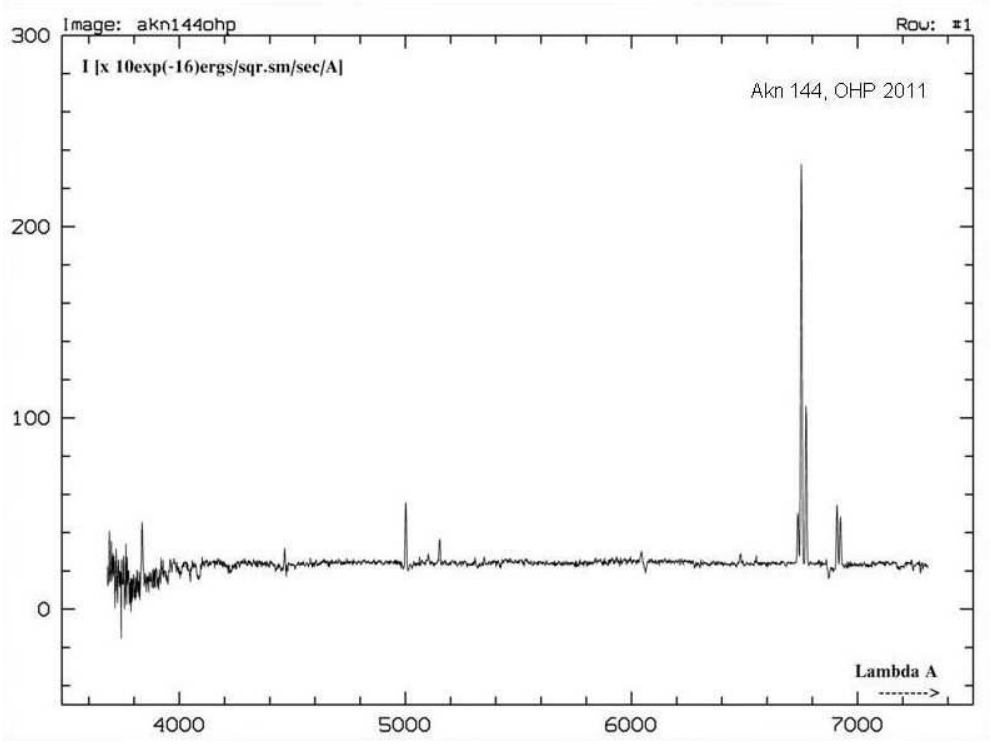

Fig. 4. Arakelian 144 – CCD spectrum taken 2011, January

Table 3 below summarises the spectrophotometric results for Akn 144. Equivalent widths of basic lines are presented and the last two rows present the relative intensities of $[SII]\lambda 6717/6731$ as a measure of the electron density and $I([NII]/I([SII]$ as indirect evidence for the activity of the galaxy.

Following detailed steps from Golev et al. (1985) we have determined several physical parameters for Akn 144 galaxy:

- Electron density $n_e \approx 32000 cm^{-1}$
- Number of ionising O7 V stars – 1680
- Ions abundances: $\log(N+) = 7.52$ and $\log(S+) = 7.68$

In Table 4 the identification of the emission lines in the OHP-spectra is presented. The lines have been selected and identified using MIDAS package. Basement for the identification was Kaller et al. (1976) paper for planetary nebula NGC 7027.

This insignificant change can hardly explain the change of electron density by a factor of 10^3, according to the intensity of the forbidden lines of ionized sulphur. At least one out of the three nuclei is a remnant of a Supernova and its spectrum had influenced the galaxy's integral one obtained in 1980.

Table 3. Akn144 – spectrophotometric results

Spectrophotom. Data	Jan. 2011		Jan. 1994	Oct. 1985	Feb. 1981	
	OHP-1.93m		CA-3.5m		SAO 6-m	
λ	$W\lambda$	$I\lambda/I(H\alpha)$	$W\lambda$	$I\lambda/I(H\alpha)$	$W\lambda$	$I\lambda/I(H\alpha)$
$H\beta - \lambda 4861$	10.2	0.16	16.5		2.2	0.36
$[OIII]\lambda 4959$	1.7	0.03	2.7			
$[OIII]\lambda 5007$	4.2	0.07	6.6		1.9	0.32
$[NII]\lambda 6548$	8.6	0.13			1.6	0.26
$H\alpha - \lambda 6563$	64.1	1.0			6.2	1.0
$[NII]\lambda 6584$	25.9	0.40		0.37	4.0	0.61
$[SII]\lambda 6717$	10.9	0.17		0.11	6.0	1.0
$[SII]\lambda 6731$	9.6	0.15		0.08	16.0	2.56
$I\lambda 6717/I\lambda 6731$		1.12		1.39		0.40
$I\lambda 6584/I\lambda(6717+31)$		3.12		3.2		0.25

The high $[SII]/H\alpha$ ratio is typical for gas, excited by shock waves, which is the case in Supernovae remnants. In order to corroborate or reject this assumption additional observations would be necessary, with high-quality large-size imaging so that the spectra of each individual nucleus should be resolved.

There are at least three possible explanations of the drastic changes observed in the spectrum of Akn 144, and of the possible activity in its nucleus, on which we shall make the following brief comments:

- A possible misidentification of the object during the observations on the 6 m telescope. Differences in the relative intensities are observed in those spectra namely. Though possible, such a contention is hardly probable, since in a radius of 20′around Akn 144 no other bright galaxies have been observed. The nearest bright one is fainter by 1.5-2.0 mag.
- The differences observed really exist and those in the radial velocities reflect the outflow of gas off the nucleus. The linear dimensions of the emitting region are approximately 2700 pc. Thus, for a period of 5 years the gas outflow velocity of $165 \div 240 kms^{-1}$ would eventually cause an increase of dimensions by 1 - 2 pc. So this insignificant change can hardly explain the change of electron density by a factor of 10^3, which is the case, judging by the relative intensity of the forbidden lines of ionized sulphur
- At least one out of the three nuclei is a remnant of a Supernova, whose spectrum had influenced the galaxy's integral one, obtained in 1980. Such an eccentric conclusion is not devoid of sense, since the width of the slot in this case was 3", and the spectral resolution — 2-3 times lower. Besides, this high $[SII]/H\alpha$ ratio is typical for gas, excited by shock waves, which is the case with Supernovae remnants. In order to corroborate or reject this assumption more observations would be necessary, with high-quality large-size imaging so that the spectra of each individual nucleus should be obtained.

Table 4. Emission–lines identification for Arakelian 144

Seq	Lambda	Intensity	Lambda_0	Ident	line
1	3835.11	45.58	3728.31	$[OII]$	3727
2	3883.06	21.09	3774.93	OIII	3774
3	3890.60	20.79	3782.26	HeII	3782
4	4032.68	24.65	3920.38	CII	3920
5	4219.76	23.31	4102.25	$H\delta$	4102
6	4306.66	25.53	4186.73	CIII	4186
7	4465.63	31.93	4341.27	$H\gamma$	4340
8	5001.36	55.63	4862.09	$H\beta$	4861
9	5072.84	25.77	4931.57	$[OIII]$	4931
10	5101.45	29.08	4959.39	$[OIII]$	4959
11	5151.13	36.51	5007.69	$[OIII]$	5007
12	5348.69	27.32	5199.74	$[NI]$	5199
13	5752.10	25.03	5591.92	OIII	5592
14	5840.89	26.80	5678.24	$[FeVI]$	5677 ?
15	6043.76	30.40	5875.46	HeI	5876
16	6148.23	26.48	5977.02	HeII	5977
17	6481.87	29.00	6301.37	$[OI]$	6300
18	6492.31	25.48	6311.51	$[SIII]$	6312
19	6552.18	28.00	6369.72	$[OI]$	6363+?
20	6736.12	50.33	6548.54	$[NII]$	6548
21	6751.32	232.70	6563.31	$H\alpha$	6563
22	6772.51	106.30	6583.92	$[NII]$	6584
23	6909.37	54.29	6716.97	$[SII]$	6717
24	6924.04	48.41	6731.23	$[SII]$	6731
25	7065.90	25.00	6869.13	HeI	6868

$[SII]6717/[SII]6731 = 1.12$
$[NII]6584/[SII]6717 + 6731 = 1.035$

Conclusion

The width of the lines at half-intensity, as well as the relative intensity of the emission lines, are reliable criteria to classify a galaxy as an active object of a certain type (Veron, 1981). In the case of Akn 144 the full width at half-intensity (FWHI) is 140 $\mathrm{km\,s^{-1}}$for $H\alpha$, 130 $\mathrm{km\,s^{-1}}$for the nitrogen lines, and 165 $\mathrm{km\,s^{-1}}$for the sulphur lines, respectively. Because of the smaller intensity of the latter, the relative measurement error for the lines' width is larger. The estimation value for the width are quite smaller than 500 $\mathrm{km\,s^{-1}}$, the width indicating the belonging of a galaxy to the Seyfert type. On the basis of spectrophotometric and photographic data, Akn 144 can be classified as an object with three nuclei and strong spectral emission lines, as well as a cloud structure of the gas, outflowing off the nucleus at a velocity up to $\pm$ 240 $\mathrm{km\,s^{-1}}$.

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