Доклады Болгарской академии наук
Comptes rendus de l'Académie bulgare des Sciences
Tome 37, N° 1, 1984

ASTRONOMIE
Astrophysique

ON THE SPACE DENSITY OF ARAKELIAN GALAXIES

V. K. Golev, Z. I. Tsvetanov, G. T. Petrov

(Submitted by Corresponding Member K. Serafimov on August 30, 1983)

Applying a criterion proposed by him, Arakelian [1] recently separated 621 galaxies with a high surface brightness (AKG). The red shifts z of 284 objects in the list [1], or $\sim 45\%$ of all AKG, are obtained; on their basis it should be possible to obtain some general properties of these galaxies.

As a first step we may examine the distribution of the visual and absolute magnitudes of this sample AKG and to determine their space density. We made use of the absolute magnitudes $M_z = m_z - 25 - 5\ \lg\ (cz/H) - 0.24$ cosec (b^{II}), where m_z are the visual photographic magnitudes of Zwicky's CGCG. With an accuracy of ~ 0.1 mag [2] $M_z \approx M(B) + 0.17$ and the data can be connected with the standard B-system. The Hubble constant $H = 75$ km. s^{-1}. Mpc^{-1} was adopted.

The completeness of the sample is of major importance when determining the space density. The examined objects are spatially close, so that the difference of the slope of the dependence $\lg N(m) - m_z$ from 0.6 [3], where $N(m)$ is the number of galaxies in the sample with $m_z \leq m$, can be taken as indicator of observational selection. The condition for a 0.6 slope follows from the Schmidt method [4,5], frequently used in the determination of the space density of extragalactic objects of a different type. In this method we investigated the distribution of the ratio $\langle V_z/V_m \rangle$, where V_z is the spatial volume corresponding to the object with a redshift z, and V_m is the volume corresponding to the maximal z, at which the object with a magnitude M is still included in the sample with a limit magnitude m_l. In the Euclidean space with a uniform distribution of objects in it and with no observational selection, the mean ratio for the sample $V_z/V_m = 1/2$ and $\lg\ (V_z/V_m) = -0.6\ (m_l - m)$, so that the distributions of V_z/V_m and of the visible magnitudes are strictly equivalent [3].

Let us now examine the dependence $\lg N - m_z$ for the sample AKG, shown in Fig. 1. The selection at $m_z > 14.25$ is substantial and has to be considered when determining the space density, as well as when distributing the absolute AKG magnitudes in the sample shown in Fig. 2. In the latter case the underestimation of the number of galaxies with faint luminosity has led to a certain enhancement of the mean observable absolute luminosity $\langle M_z \rangle = -20.00 \pm 1.60$ of the sample, as compared to the real one. All the same, from Fig. 2 it follows that the distribution of $n(M_z) - M_z$ is characterized by a sharp maximum, which is shifted toward the high luminosities, as compared to an analogous distribution for galaxies in the vicinity of the Local Group obtained by Holmberg [6]. The distribution shows great similarity with an analogous distribution of the Seyfert galaxies (SyG) [7].

The space density $\Phi(M_z)\Delta M$ in the interval $\Delta M = M_z \pm 1/2$ is at first determined by a method proposed by A r a k e l i a n in [8]. For each ΔM interval the objects are displaced by the growth of their redshift and for each object in the interval the magnitude

$$\varphi_k(M_z) = 3(k-1)/\omega r_k^3 \text{ mag.Mpc}^{-3}$$

was determined, where r_k is the distance to the k-th object, and $\omega = 4.5$ sterad is the solid angle of the Arakelian survey. The selection was made by rejecting in each ΔM interval all galaxies for which $\varphi_k(M_z)$ decreases systematically with an increase of k, i. e. only galaxies lying closer to a certain distance $r_{\max}$ were considered. The differential luminosity function of the galaxies in the ΔM interval is then:

$$\Phi(M_z)\Delta M = (n-1)^{-1}\sum_{k=3}^{n} \varphi_k(M_z) \text{ mag. Mpc}^{-3}$$

with a dispersion

$$\sigma^2 = (n-2)^{-1}\sum_{k=3}^{n} [\varphi_k(M_z) - \langle\varphi(M_z)\rangle]^2$$

where n is the number of the galaxies remaining in the interval.

The results are shown in Table 1. The total number n_t of galaxies in the sample per interval and, bracketed, the number of galaxies remaining after recording the selection are adduced in column (2), and the values of the differential luminosity function with their dispersions in column (3).

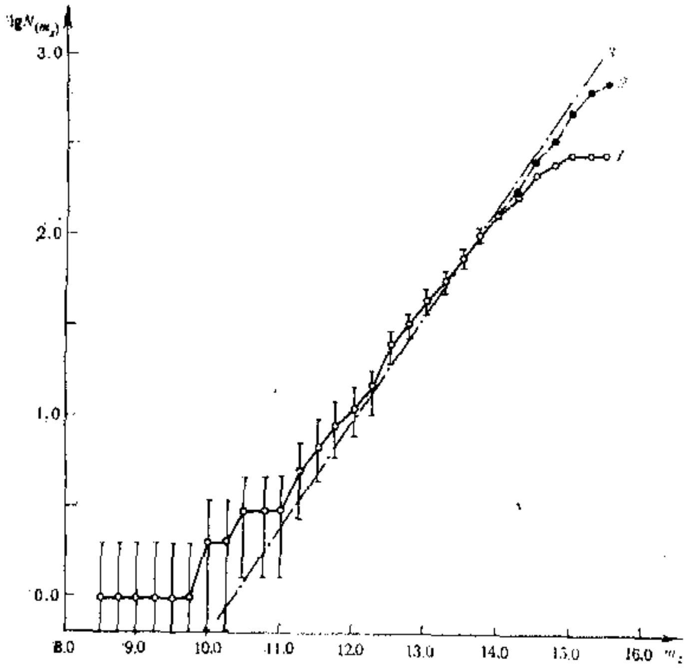

Fig. 1

1 — before correction; *2* — after correction; *3* — lg $N(m) = 0.6$ m+const

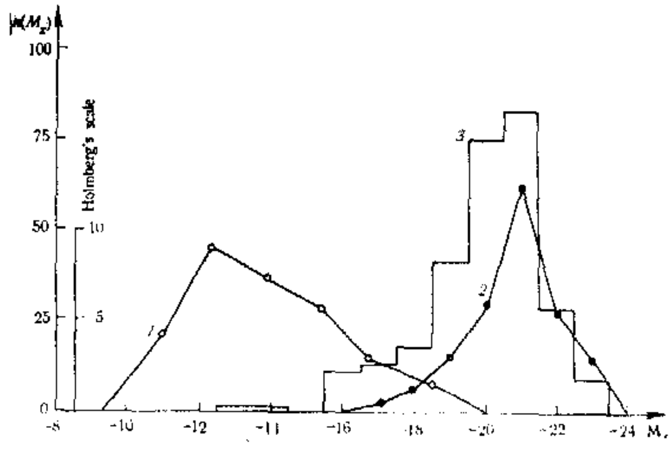

Fig. 2

1 — nearby normal galaxies [6]; *2* — Seyfert galaxies [7]; *3* — $\langle M_z \rangle_{AKG} = -20.0 \pm 1.60$ mag

Owing to a rather intuitive recording of the selection effects, we also determined the luminosity function of AKG by the already mentioned V_z/V_m method. The volumes

$$V_z = (4/3)\,\pi\,(cz/H)^3$$

and

$$V_m = (4/3)\,\pi \text{ dex } [0.6\,(m_l - 25 - M_z)]$$

are calculated for each AKG in the $M_z \pm 0.5$ intervals, adopting $15^m, 5$ for m_l. The uncorrected values for the selection were obtained by

$$(1) \qquad \Phi_s(M_z)\Delta M = (4\pi/\omega)\sum_k (1/V_m)_k \quad \text{mag. Mpc}^{-3},$$

Table 1

Differential function of luminosity for Arakelian galaxies and their percentage content as compared to field galaxies

M_z (1)	n_t (2)	$\Phi(M_z) \pm\sigma$ (3)	$\Phi_S(M_z)$ (4)	% AKG (5)	% MKG (6)	% SyG (7)
—16	11(10)	$(1.41\pm0.35)\times10^{-3}$	2.56×10^{-3}(11)	1.9	6.5	. . .
—17	13(8)	$(1.03\pm0.16)\times10^{-3}$	5.73×10^{-4}(13)	3.9	10.7	. . .
—18	18(16)	$(2.84\pm0.61)\times10^{-4}$	2.16×10^{-4}(18)	2.0	7.4	. . .
—19	42(30)	$(1.20\pm0.33)\times10^{-4}$	1.22×10^{-4}(42)	1.2	4.4	0.3
—20	76(70)	$(5.96\pm0.41)\times10^{-5}$	6.66×10^{-5}(76)	1.1	5.4	0.4
—21	84(73)	$(2.93\pm0.30)\times10^{-5}$	2.04×10^{-5}(84)	4.4	9.6	1.5
—22	29(22)	$(2.38\pm0.41)\times10^{-6}$	2.13×10^{-6}(29)	6.8	12.6	5.2
—23	9(9)	$(1.20\pm0.24)\times10^{-7}$	1.39×10^{-7}(9)	~54:	~100:	~48:

Table 2

Determination of correction for observed selection of the Arakelian galaxies excerpt

m_l (1)	N (2)	$\langle V_z/V_m\rangle$ (3)	n (4)	k (5)	f (6)	$\langle V_z/V_m\rangle_{add}$ (7)
14.0	124	0.516	. . .	. . .	. . .	. . .
14.1	136	.501	. . .	. . .	. . .	. . .
14.2	149	.511	. . .	. . .	. . .	. . .
14.3	172	.510	. . .	. . .	. . .	. . .
14.4	183	.485	5	1	1.000	0.22
14.5	197	.467	9	2	.871	.25
14.6	213	.454	10	3	.759	.29
14.7	224	.429	18	4	.661	.33
14.8	240	.417	18	5	.575	.38
14.9	252	.397	25	6	.501	.44
15.0	264	.379	30	7	.437	.50
15.1	274	.356	37	8	.380	.58
15.2	279	.324	50	9	.331	.66
15.3	282	.290	58	10	.288	.76
15.4	282	.253	70	11	.251	.87
15.5	282	.221	69	12	.219	1.00

In order to determine the incompleteness of the sample, let us compose the V_z/V_m relations for all AKG forming part of it, and let us examine their distribution (Fig. 2*a*). The distribution differs from uniform and the incompleteness is obvious. The idea of a correction [5] is based on data adduced in Table 2, where $\langle V_z/V_m\rangle$ is tabulated as a function of m_l in the interval $0^m,1$. The number N of galaxies remaining in the sample with a corresponding m_l is shown in column (2), the corresponding value of $\langle V_z/V_m\rangle$ in column (3), the number n of galaxies which is to be added to the sample so that $\langle V_z/V_m\rangle=0.5$ at a certain m_l in column (4), the index k of the intervals requiring a correction in column (5), the factor f indicating the change of $\langle V_z/V_m\rangle$ with a consecutive increase of m_e by $0^m,1$ in column (6), and the mean $\langle V_z/V_m\rangle_{add}$, whereby the added galaxies enter into the final sample with the $m_l=15^m,5$ adopted by us, in column (7).

The number n_k of 'fictitive' galaxies added in the k-th interval requiring a correction is determined by

$$n_k=N_k+\sum_{i=1}^{k-1} n_i-2(N_k\langle V_z/V_m\rangle_k+\sum_{i=1}^{k-1} n_i f_{k-i+1}).$$

Any value obtained by eq. (1) is multiplied by the general correcting factor $(N_k+\Sigma_{i=1}^{k} n_i)/N_k=2.38$ for the investigated sample. The effect of the correction on the distribution of V_z/V_m is satisfactory (Fig. 3*b*), as after the correction the dependence $\lg N - m_z$ (Fig. 1) improves above the critical $m_z=14^m,25$.

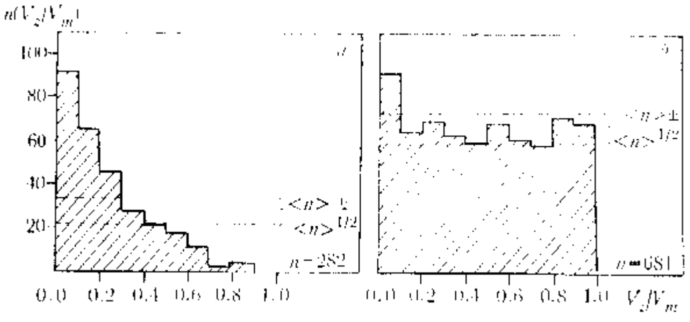

Fig. 3

a — before correction ; *b* — after correction

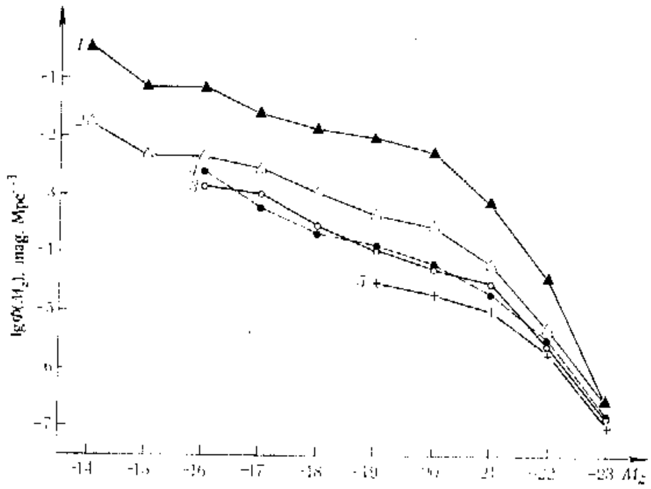

Fig. 4

1 — field galaxies [5] ; *2* — Markarian galaxies [5] ; *3*—Arakelian galaxies—lgΦ ; *4* — Arakelian galaxies—lg Φ_s ; *5* — Seyfert galaxies [3].

The corrected values of $\Phi_s(M_z)$ are shown in column (4) of Table 1 (the number of galaxies in the corresponding interval, whereby the space density is determined, is given in brackets). The dependences lg Φ $(M_z)-M_z$ and lg Φ_s $(M_z)-M_z$ are shown in Fig.4. The data are in good agreement (for the sake of comparison, analogous dependences are shown there for the field galaxies and for MKG, taken from [5] and for SyG [3]). The luminosity function of the field galaxies has been the subject of many studies [2,5,9], etc. We made use of data in [5], where the same system of absolute magnitudes was applied. Table 1 shows the AKG percentage in relation to the field galaxies (column (5)) and analogous contents of MKG and SyG, respectively taken from [5] and [3] (columns (6) and (7)). AKG represents an approximately constant part of the field galaxies (~2 %) in the range $-16^m > M_z > -20^m$, while at greater luminosities their percentages increase sharply, attaining 50 % at $M_z=-23^m$. Thereby AKG resemble the behaviour of MKG [5].

Let us note in conclusion that all data, obtained here suggest that there are good reasons for considering AKG as a separate group of objects, without of course this implying that they are identical in physical nature.

Department of Astronomy
Sofia University
Bulgaria

Department of Astronomy
Bulgarian Academy of Sciences
Sofia, Bulgaria

REFERENCES

1. М. А. Аракелян, Сообщ. Бюраканской обс., **47**, 1975, 3. 2. J. E. Felten. Astron. J. **82**, 1977, 861. 3. В. Ю. Теребиж. Астрофизика **16**, 1980, 45. 4. M. Schmidt. Astrophys. J. **151**, 1968 393. 5. J. Huchra, W. L. W. Sargent. Ibid. **186**, 1973, 433. 6. E. Holmberg. Stars and Stellar Systems. Galaxies and the Universe. A. Sandage, M. Sandage, J. Kristian (Eds), 123, Univ. Chicago Press **IX**, 1975, 123. 7. Э. А. Дибай, А. М. Романов. Астрон. ж. **57**, 1980, 438. 8. М. А. Аракелян, Астрофизика **6**, 1970, 531. 9. P. L. Schechter. Astrophys. J. **203**, 1976, 297.