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THE SPECTRA AND REDSHIFTS OF THIRTY MARKARIAN GALAXIES WITH ULTRAVIOLET CONTINUA*

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ABSTRACT

Redshifts have been determined from 190 Å mm^{-1} image-tube spectrograms for thirty of the seventy galaxies with ultraviolet continua discovered by Markarian. These thirty do not constitute a random sample of the Markarian galaxies. The redshifts, corrected to the galactic center, range from 918 to 22869 km sec^{-1}; the absolute magnitudes lie in the range $-21.5 < M_p < -14.7$ with a mean value of $\langle M_p \rangle = -19.6$. Twenty-six of the thirty galaxies have emission-line spectra, and five of these also have absorption lines. There are two new galaxies (Markarian 50 and Markarian 69), with Seyfert-like spectra composed of broad Balmer emission lines with sharper forbidden lines. The other twenty-four emission-line objects have sharp lines with a half-width less than 300 km sec^{-1}. Their range of excitation is similar to galactic H II regions. It is tentatively concluded that these sharp-emission-line objects are excited by hot stars; however, most of them are probably not Type I irregular galaxies at large distances. The galaxies with ultraviolet continua have at least one-thirtieth the space density of normal galaxies.

I. THE MARKARIAN GALAXIES

Markarian (1967) has published a list of seventy galaxies which were discovered on objective-prism plates to have spectra with abnormally strong ultraviolet continua. During his visit to the United States in 1967–1968, Dr. E. Khachikian of the Byurakan Observatory obtained spectra of forty of these galaxies at several observatories. The results of some of this work have been published (Weedman and Khachikian 1968, 1969; Arp *et al.* 1968). On his departure, Dr. Khachikian left me a list of the galaxies which he had not observed. This paper is an account of the spectra of these remaining thirty galaxies.

Markarian's search covered an area of about 650 square degrees in the constellations Ursa Major and Camelopardalis together with an area near the North Galactic Pole. The seventy galaxies listed are all fainter than an estimated $m_p = 13$; fifty-five of the seventy galaxies fall within the limits 13–16 mag. Within this magnitude range Markarian found an average of one ultraviolet galaxy every 12 square degrees. The total number of galaxies in this magnitude range is about three per square degree, so that the abnormal galaxies constitute about 3 percent of all galaxies brighter than 16 mag.

As will be seen in § II, Markarian published an estimate of the strength of the ultraviolet continuum; in addition, he observed emission lines in fourteen of the galaxies and possible faint emission in seventeen others. This information was used by Khachikian in deciding which objects to observe. Thus the galaxies studied in the present paper do not constitute a random sample of Markarian's seventy objects. On the average they are fainter and have less prominent emission lines than the sample chosen by Khachikian.

The Markarian galaxies exhibit a variety of shapes and angular sizes. Markarian points out that some of them are compact in the sense used by Zwicky (see, e.g., Zwicky

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1964).[1] They are spheroidal in appearance and have small angular dimensions, frequently with a faint halo, a tail, or, in some cases, a faint blue satellite.

II. OBSERVATIONS AND SPECTRA

The thirty galaxies observed are listed in Table 1. Spectra having a dispersion of 190 Å mm^{-1} were obtained on IIaO emulsion with the image-tube spectrograph at the Cassegrain focus of the Hale telescope. The spectrograms covered the wavelength range λλ3500–6000 in reasonable focus. The exposures averaged 5 minutes, and were obtained with the object stationary on an entrance slit 1″ wide and 40″ long. The slit was normally aligned east-west. Column (2) of Table 1 gives the redshift of each galaxy, corrected for the motion of the Sun around the center of the Galaxy at an assumed circular velocity of 250 km sec^{-1}. These redshifts have accuracies of about ±60 km sec^{-1}. Column (3) gives a description of the spectrum. This is largely self-explanatory. "Sharp em." means that at least two of the normal emission lines found in the spectra of H II regions—[O II] λ3727, Hγ, Hβ, [O III] N_1 and N_2—were observed and were not resolved on the spectrograms. This implies a velocity spread of less than 300 km sec^{-1}.

Of the thirty galaxies in Table 1, twenty-six show emission lines, five (Nos. 12, 16, 38, 39, and 60) in conjunction with absorption lines. Four objects (Nos. 18, 29, 47, and

TABLE 1

PROPERTIES OF THE OBSERVED GALAXIES

Markarian No.	V_R (km sec^{-1})	Spectrum	Markarian Class	m_p	M_p	Size (kpc)
7.....	3178	Sharp em.	*d*12	13.9	−19.7	5.2×8.2
12.....	4140	Sharp em.; H and K abs.	*d*2	12.7	−21.5	3.2×6.7
15.....	6497	Sharp em.	*s*12	(17)	(−18.1)	4.2
16.....	2473	Abs. (F)+sharp em.	*ds*1	14.6	−18.3	2.2×3.2
18.....	1479	H and K abs.	*ds*2	13.1	−18.7	4.8×2.4
20.....	3615	Sharp em.	*d*2	14.7	−19.1	3.0×5.4
21.....	8574	Sharp em.	*sd*2	15.1	−20.4	6.6×5.0
24.....	13675	Sharp em.	*ds*12	(17)	(−19.5)	9.9×11.5
27.....	2215	Sharp em.	*d*1	(17)	(−15.5)	1.4
28.....	9121	Sharp em.	*ds*12	(17)	(−18.6)	4.7
29.....	12862	H and K abs.	*d*12	(16.5)	(−19.9)	8.3×10.8
30.....	8166	Sharp em.	*d*2 (e)	(17)	(−18.4)	5.3×7.9
31.....	7819	Sharp em.	*s*12	14.7	−20.6	5.1
32.....	918	Sharp em.	*d*2	(16)	(−14.7)	0.6×0.8
38.....	10730	Hyd. abs. +3727 em.	*sd*2	15.2	−20.0*	17.4
39.....	10959	Hyd. abs. +sharp em.	*ds*1 (e)		−20.0*	17.7
43.....	6129	Sharp em.	*d*12	(16)	(−18.8)	4.0×7.9
44.....	6923	Sharp em.	*s*12	15.3	−19.8	5.4×8.1
45.....	4282	Sharp em.	*ds*2	15.6	−18.5	2.5×4.5
46.....	3753	Sharp em.	*d*2	(17)	(−16.8)	1.9×2.7
47.....	5876	Hyd. abs.	*sd*2	(16)	(−18.7)	3.4
48.....	4760	H and K abs.	*s*2	(16)	(−18.7)	3.1
50.....	6911	Seyfert-like em.	*s*1	(15.5)	(−19.6)	5.4
53.....	4806	Sharp em.	*ds*12	15.5	−18.7	3.1×4.0
55.....	4865	Sharp em.	*sd*2	(16)	(−18.2)	3.8
56.....	7292	Sharp em.	*d*12 (e)	15.4	−19.7	4.7
57.....	7603	Sharp em.	*sd*1	15.4	−19.8	7.4
60.....	5156	Sharp em.; H and K abs.	*ds*2 (e)	(15.5)	(−18.9)	4.0
68.....	5202	Sharp em.	*d*12 (e)	(17)	(−17.2)	2.7×4.0
69.....	22869	Seyfert-like em.	*s*1	(16.5)	(−21.2)	11.8

* A combined magnitude is given in the CGCG. In computing M_p, we have assumed the two galaxies to be equally bright.

[1] In the English version of Markarian's paper (*Astrofizika*, **3**, 24 [1969]) the phrase *Kompactiya Galactika* is translated as "dense galaxy" instead of "compact galaxy."

ADDITIONAL NOTES TO TABLE 1

No. 7. "Seems to be an irregular galaxy of small dimensions." Emission from two knots 3 kpc apart.

No. 12. "Morphological type SBb. The data refer to the central portion. Not far from the center (SW) there is a blue formation." The apparent magnitude quoted is that for the whole galaxy. The emission comes from a region 25″ = 6.7 kpc in extent along the slit.

No. 15. "Very small and faint galaxy with two extensions." The emission comes from a region 10″ = 4.2 kpc in extent along the slit.

No. 16. "Has a slight corona." The emission lines have an extent of 10″ = 1.6 kpc.

No. 18. "Elongated galaxy with an envelope." Identified as NGC 2726 in CGCG, Vol. 4. Spectrum shows continuum very concentrated.

No. 20. "Two merged spheroidal galaxies in a common envelope." Emission from region 3.5 kpc in extent along the slit.

No. 21. "Elongated in α. Two blue knots of 17.5 mag at the ends of the major axis." Emission from region 5″ = 2.8 kpc in extent along the slit. Stellar nucleus seen at the telescope.

No. 24. "Has a faint corona." Emission localized to less than 5″ = 4.4 kpc along slit.

No. 27. "Compact galaxy. Slightly elongated in δ." Emission localized to less than 5″ = 0.7 kpc along the slit.

No. 28. "Compact galaxy. Slightly elongated in α." Emission from less than 5″ = 3 kpc along the slit.

No. 29. The H- and K-lines measured are not very prominent; the quoted redshift is not absolutely certain.

No. 30. "Galaxy with elliptical shape and an extension; forms a double system with No. 31." Emission from region 10″ = 5.3 kpc in extent along the slit. The projected separation between Nos. 30 and 31 is 40″ = 21.7 kpc. This leads to a total mass $\mathfrak{M} \geq 5.9 \times 10^{11}\,\mathfrak{M}_\odot$ and a mass-to-light ratio $\mathfrak{M}/L_p > 20$ for the two galaxies. These values are reasonable in view of the rather large errors in the velocities.

No. 31. "Morphological type SBr, central portion surrounded by a discontinuous ring. The data refer to the central region." Identified as NGC 3188 in CGCG, Vol. 4. The quoted apparent magnitude is that for the whole galaxy. Emission from region less than 5″ = 2.5 kpc in extent along the slit; i.e., only from the nucleus.

No. 32. "Elongated in δ." Emission from region 10″ = 0.6 kpc in extent along the slit. Noted as having stellar nucleus at the telescope.

Nos. 38 and 39. "Pair of galaxies with small extensions." Noted as "double system connected" in CGCG, Vol. 3. The radial velocities are consistent with the system being physical. They lead to a mass for the whole system $\mathfrak{M} \geq 2.7 \times 10^{11}\,\mathfrak{M}_\odot$. The projected separation is 33″ = 23 kpc, and the mass-to-light ratio $\mathfrak{M}/L_p > 9$ solar units. The emission comes from a region 7″ = 4.9 kpc in extent for No. 38, and 15″ = 10.5 kpc in extent for No. 39.

No. 43. "Elongated in α. Has a small extension." Emission from region 10″ = 4 kpc in extent along the slit.

No. 44. "Has two faint satellites at opposite ends of the major axis." Identified as IC2987 in CGCG, Vol. 3. Emission from region 5″ = 2.2 kpc in extent along the slit.

No. 45. "Elongated almost in δ-direction." (Incorrectly given as α-direction in Markarian's paper.) Emission from region 5″ = 1.4 kpc in extent along the slit.

No. 46. "Possibly a compact double galaxy." The object observed is that indicated in the finding chart published by Markarian (1967). It is about 17′ north of the position given by Markarian in the same paper. Emission from region 15″ = 3.6 kpc in extent along slit.

No. 47. "Has a pronounced tail and a blue satellite of 17 mag in W direction." Noted as appearing stellar at the telescope.

No. 48. "Has an envelope."

No. 50. "Mainly red appearance. According to the spectrum should have a very blue center." Emission from region less than 3″ = 1.3 kpc in extent along the slit.

No. 53. "Rather compact galaxy." Noted as "compact" in CGCG, Vol. 3. Emission from region 7″ = 2.2 kpc in extent along the slit.

No. 55. "Rather compact." Emission from region 5″ = 1.6 kpc in extent along the slit.

No. 56. "Has a faint corona." Emission from region 5″ = 2.4 kpc in extent along the slit.

No. 57. "Rather compact." Emission from region 10″ = 4.4 kpc in extent along the slit.

No. 60. "Double system. The data refer to the bright (W) component." Emission from region less than 5″ = 1.7 kpc in extent along the slit. In field of Coma cluster. Redshift is consistent with membership.

No. 68. "Elongated in α-direction, may be a close double system." Emission from region 5″ = 1.9 kpc in extent along the slit.

No. 69. "Very compact." Emission from region less than 5″ = 7.4 kpc in extent along the slit. Appears stellar at telescope.

48) show only absorption lines. Two of the twenty-six emission-line objects, Nos. 50 and 69, have broad hydrogen lines and sharp forbidden lines. These spectra are similar to those of the Seyfert galaxies such as NGC 4151. We have made eye estimates of the relative strengths of the lines in the sharp emission objects; these are given in Table 2. For this purpose the strength of Hβ was defined to be 10. To aid in the estimates it was *assumed* that the intensity ratio of N_1 to N_2 is 3:1 and that the intensity ratio Hβ:Hγ is also 3:1. The implication of the results in Table 2 are discussed in § III.

Column (4) of Table 1 quotes Markarian's estimate of the strength and character of the ultraviolet continuum of each galaxy as judged from his objective-prism plates. The letters *s* and *d* refer to the concentration of the ultraviolet continuum in a direction perpendicular to the dispersion. Highly concentrated continua are denoted by *s* (sharp)

TABLE 2

RELATIVE EMISSION-LINE INTENSITIES*

Markarian No.	[O II] λ3727	Hβ	[O III] λ5006
7.....	50	10	30
12.....	20	10	5
15.....	30	10	30
16.....	40	10	30
20.....	20	10	6
21.....	40	10	...
24.....	30	10	15
27.....	40	10	30
28.....	60	10	30
30.....	50	10	10
31.....	50	10	10
32.....	30	10	10
39.....	50	10	10
43.....	50	10	20
44.....	40	10	...
45.....	30	10	15
46.....	40	10	30
53.....	40	10	12
55.....	40	10	10
56.....	50	10	10
57.....	30	10	10
60.....	15	10	15
68.....	20	10	15

* Eye estimates.

and more diffuse ones by *d*. The numbers 1 and 2 indicate that the ultraviolet continuum is "strong" and "moderately strong," respectively. Intermediate cases are denoted by the appropriate combination of letters and numbers.

Column (5) gives the apparent photographic magnitude of the galaxy. The values in brackets are taken from Markarian's paper; they are estimated to the nearest half-magnitude. However, where available we have given magnitudes taken from the *Catalogue of Galaxies and Clusters of Galaxies* (Zwicky, Herzog, and Wild 1961; Zwicky and Herzog 1963, 1966, 1968; Zwicky, Karpowicz, and Kowal 1965; Zwicky and Kowal 1968). In the Notes to Table 1 and elsewhere, this catalog is denoted by CGCG. In general, the estimates given by Markarian agree reasonably well with the more accurate magnitudes in the CGCG. Eleven of the Markarian galaxies are also listed in the *Morphological Catalogue of Galaxies* (Vorontsov-Velyaminov and Krasnogorskaja 1962; Vorontsov-Velyaminov and Arhipova 1963, 1964, 1968). This catalog is referred to elsewhere as the MCG. The cross-references are given in Markarian's paper.

Column (6) of Table 1 gives the absolute photographic magnitude M_p of each galaxy calculated from the redshift with a value of $H = 75$ km sec^{-1} kpc^{-1}. A correction of 0.24 cosec$|b|$ mag has been included to allow for Galactic absorption. The size of the galaxy in kiloparsecs is given in column (7). The required estimates of angular size were taken from Markarian's paper.

Additional information on each galaxy is given in a series of footnotes to Table 1. For convenience, we have reproduced in quotation marks the English translation of the comments on each galaxy given by Markarian. For the emission-line objects we have also given an estimate of the size of the emitting region, which for some objects is considerably different from the size of the whole galaxy in Table 1.

III. THE NATURE OF THE MARKARIAN GALAXIES

The data of Table 1 show clearly that the Markarian galaxies are far from being a homogeneous group of objects. Their redshifts cover the range $918 < V_R < 22869$ km sec^{-1}, with a mean value of $\langle V_R \rangle = 6762$ km sec^{-1}. Their absolute magnitudes lie in the range $-21.5 < M_p < -14.7$, with a mean value of $\langle M_p \rangle = -19.6$. Accordingly, there is marked observational selection in their discovery. A plot of *absolute* luminosity against log V_R for the data in Table 1 reveals a pronounced tendency for objects with low absolute magnitudes to have low redshifts.

In discussing the nature of these galaxies, we shall divide them into four groups according to their spectral characteristics as summarized in Table 1: (*a*) the Seyfert-like galaxies, (*b*) the objects with sharp emission lines, (*c*) the objects with absorption lines and sharp emission lines, and (*d*) those with absorption lines only. The galaxies have been divided according to their spectra solely to provide a basis for discussion. Other divisions may be equally valid; for example, we could have used size or absolute magnitude. Before we turn to a detailed discussion of the four groups, two general points are of interest. First, there is only one obvious correlation between Markarian's estimate of the character of the ultraviolet continuum and the general character of the spectrum. Both the new Seyfert-type galaxies, Nos. 50 and 69, fall in the category *s*1, denoting a strong ultraviolet continuum which is sharply confined in angular extent. Theses are the only *s*1 objects among the thirty galaxies observed. Two other Seyfert-like galaxies, Nos. 9 and 10 reported by Arp *et al.* (1968), also have *s*1 continua. Second, a plot of mean size against absolute magnitude (Figure 1) shows that, as expected, there is a relation between these quantities. This will be discussed further in § III*b* below.

a) Seyfert-Type Galaxies

On the *Sky Survey* prints both Markarian 50 and Markarian 69 appear as structureless, blue, compact objects. Their spectra are more like that of NGC 4151 than like NGC 1068. Markarian 50 has a luminosity which is typical of the classical Seyfert galaxies. Markarian 69 is much more luminous than average.

b) Galaxies with Sharp Emission Lines

There are nineteen galaxies in Table 1 with sharp emission lines and no detectable absorption spectra. Their mean absolute magnitude is $\langle M_p \rangle = -18.5$, and the range is $-20.6 < M_p < -14.7$. Seven of the nineteen galaxies have been classified in the MCG. Markarian 7 is described as "patchy" in the MCG and as an irregular of small dimensions by Markarian (see the Notes to Table 1). Markarian 21 and 31 are barred spirals; in both cases the emission comes from the nuclear regions of the galaxies. Markarian 15 and 30 are both classified as spirals in the MCG, although in both cases the absolute magnitudes are low for spiral galaxies. In these two galaxies the emission comes from the whole object. In the MCG, Markarian 20 is classified as E? and Markarian 45 as a lenticular galaxy.

Thus, of the nineteen sharp emission-line galaxies, five, Nos. 15, 21, 30, 31, and 45,

may be spiral galaxies, and No. 7 may be a Type I irregular. The remaining thirteen objects are small in size and are often described as "compact" or "rather compact" in the Notes to Table 1. In about half of them the emission lines came from a region which is appreciably smaller than the optical image of the galaxy. These galaxies have absolute magnitudes in the range -14.7 to -19.8. This is roughly the same as the range quoted by Holmberg (1964) for Type I irregular galaxies. Holmberg lists fifteen such objects. Their mean absolute magnitude is $\langle M_p \rangle = -17.0$, and the values range from -13.8 for the Wolf-Lundmark system to -19.6 for NGC 4656. The redshifts of Holmberg's Type I irregulars are small—the mean is only about 300 km sec^{-1}, about one-tenth the mean redshift of the Markarian sample. In the Humason, Mayall, and Sandage (1956) catalog of redshifts, the spectra of the Type I irregulars are invariably described as "emission." However, an examination of the footnotes in that paper reveals that in all cases individual emission knots were used to determine the redshift; as a result, we have no knowledge of the *integrated* spectrum of a Type I irregular galaxy.

The emission-line strengths in Table 2 give some insight into the nature of the galaxies. The ratios $\lambda 3727$:Hβ or $(N_1 + N_2)$:Hβ may be used to read off "excitation classes" (which are in fact indications of the state of *ionization* of the hot gas) from the graphs published by Aller and Liller (1968). If this is done, we find that:

1. The range in excitation of the sharp-emission-line Markarian galaxies is the same as that of galactic H II regions. None of the objects are as highly excited as the envelopes of some planetary nebulae or the highest-excitation radio galaxies and Seyfert nuclei.
2. There is no correlation between the excitation of an object and its apparent magnitude.
3. There is no correlation between the concentration types *d* and *s* and the excitation. However, there is a marginal positive correlation between Markarian's estimate of the strength of the ultraviolet continuum and the excitation of the emission lines.

These results are definitely consistent with the hypothesis that the emission lines in the majority of the sharp-emission-line galaxies are excited by the radiation from hot stars. Are they distant irregular galaxies? This does not seem likely for two reasons. First, the only galaxy suspected by Markarian of being an irregular, No. 7, has a typical redshift for the group. Other objects in Table 1 with comparable redshifts do not appear to be morphologically similar. In addition, there are in Table 1 objects such as Markarian 32 ($V_R = 918$ km sec^{-1}) with such low redshifts that they should be directly comparable with the irregulars in Holmberg's list. In fact, Markarian 32 has a much more compact image and a much smaller linear size than a Type I irregular of comparable absolute magnitude. For example, the Wolf-Lundmark system has $M_p = -11.8$ and a major diameter of 3 kpc, about 4 times that of Markarian 32. Second, in many cases the emission lines in the Markarian galaxies are concentrated to the nuclear regions. In an irregular galaxy the emission knots do not exhibit any marked central condensation.

We therefore draw the preliminary conclusion that the Markarian galaxies with sharp emission lines are not, characteristically, distant Type I irregular galaxies. However, several galaxies are known with properties resembling those of the Markarian objects. In particular, DuPuy (1968) has recently discussed the general properties of the Haro galaxies (Haro 1965). These are blue objects with spectra composed of sharp emission lines; in some cases there are also absorption lines of early spectral type. In Figure 1 the sizes and absolute magnitudes of the Haro galaxies are compared with those of the Markarian galaxies. The two groups of galaxies are seen to be rather similar. *Normal* galaxies are, at a given absolute magnitude, about 3 times as big as the Haro and Markarian galaxies, if we use the data published by Holmberg (1964). However, the Haro and Markarian galaxies have, on the average, much greater redshifts than the normal galaxies; it is not clear how far this will influence the size estimates.

Two of the Markarian galaxies, Nos. 27 and 32, are intrinsically fainter and smaller

than the Haro galaxies. These two objects resemble some of the Zwicky compact galaxies (Sargent 1970) and the compact objects described by Arp (1965) and by Kinman (1965). These intrinsically faint, compact, emission-line galaxies do not appear to be necessarily associated with larger normal galaxies. They present interesting problems for the theories of galaxy formation and nucleosynthesis.

c) Galaxies with Absorption and Emission Lines

The five galaxies with both absorption and emission lines in Table 1 are Markarian Nos. 12, 16, 38, 39, and 60. They divide into two groups. Three intrinsically bright objects, Nos. 12, 38, and 39, are all spirals according to the MCG. The two remaining objects are intrinsically faint and are small objects with little structure on the *Sky Survey* plates. They are possibly distant irregular galaxies, although, as with the sharp-emission-

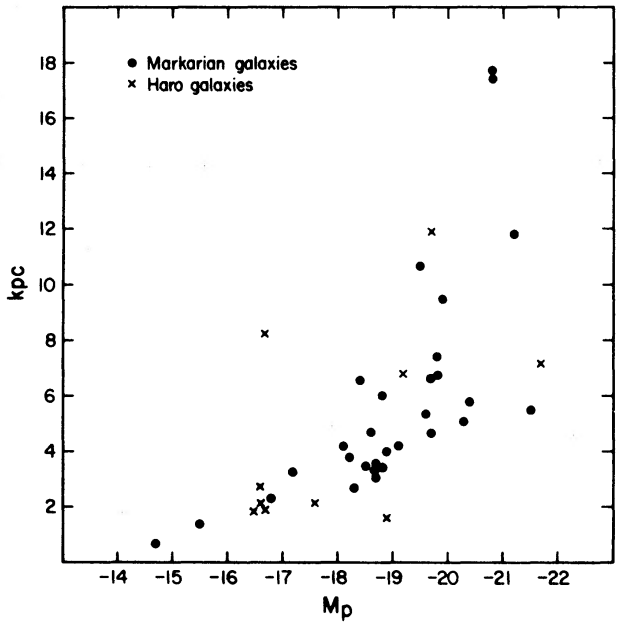

FIG. 1.—Data in Table 1 are used to plot mean size in kpc against M_p for the Markarian galaxies (*black dots*). Crosses show the behavior of the Haro galaxies, from the data published by DuPuy (1968).

line galaxies, they are small for their absolute magnitudes. As is mentioned in the Notes to Table 1, No. 60 is possibly a member of the Coma cluster.

d) Galaxies with Absorption Lines

The four galaxies with absorption lines only are Markarian 18, 29, 47, and 48. Three of them, Nos. 18, 29, and 48, show only H and K of Ca II in absorption in their spectra, while No. 47, which has a short tail, has an early-type absorption spectrum. All four galaxies have roughly the same absolute magnitude, $\langle M_p \rangle \sim -19$. They could all be fairly normal dwarf galaxies, ellipticals in the case of Nos. 18, 29, and 48, and irregular in the case of No. 47. As with most of the objects in Table 1, it would be advantageous to have photographs at a higher scale than the *Sky Survey*.

IV. CONCLUSIONS

In his original paper Markarian suggested that the ultraviolet continua of types *s* and *sd* are produced by an unknown, nonstellar source, while the *ds* and *d* spectra are produced by early-type associations of gas and stars. Markarian's view is almost certainly correct as far as the *s*1 spectra are concerned because work on Seyfert galaxies has

shown that there is definitely a strong nonthermal contribution to the continuous radiation (Oke and Sargent 1968). The situation with regard to the remaining objects, principally those with sharp emission lines, is not yet clear. Although many of these galaxies are morphologically unusual, it is likely that the emission lines are excited by hot stars. However, more detailed spectroscopic and photometric studies are required to be sure of this.

We mentioned in § I that Markarian estimated that there is one galaxy every 12 square degrees which is between 13 and 16 mag with an ultraviolet continuum. We have found that the mean absolute magnitude of these objects is $\langle M_p \rangle = -19.6$. Thus, we estimate that their space density is roughly 0.001 Mpc^{-3}. This is about one-thirtieth of the space density of normal galaxies and is a lower limit for the reasons given in § III.

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