RADIO EMISSION OF THE NUCLEI OF BARRED SPIRAL GALAXIES

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[*Manuscript received May* 27, 1966]

Summary

The results of radio observations of 98 barred galaxies at 11, 21, and 75 cm are presented. The observations were carried out with the 210 ft radio telescope of the Australian National Radio Astronomy Observatory and with the Mills Cross of the Sydney University Molonglo Radio Observatory. Radio emission originating within 1·5 minutes of arc of the centre of corresponding galaxies was detected in 21 cases. It is concluded that the central parts of galaxies (possibly their nuclei) are responsible for the radio emission. Spectral indices of detected sources were determined. Radio indices show that radio emissivity of the majority of the investigated galaxies is higher than that of normal galaxies.

I. Introduction

For some years after the discovery of radio galaxies, collisions between galaxies were accepted by many as the cause of the intense radio emission (Baade and Minkowski 1954; Shklowski 1954; and others). Ambartsumian (1956*a*) was the first to reject the idea of random collisions as an explanation of the observed phenomena. He came to this conclusion by considering certain observational data, particularly that a collision is an extremely rare event among the superluminous galaxies to which the radio galaxies belong. Subsequently he proposed and developed (Ambartsumian 1956*b*, 1958, 1962) a theory stressing the importance of the activity of the nuclei in the formation and evolution of galaxies. Some forms of nuclear activity result in powerful radio emission. Nowadays the hypothesis of nuclear activity is widely accepted and there is much observational evidence in favour of it. The jet in M87 and the outburst in the nucleus of M82 are good examples of such activity. Blue objects around some galaxies, discovered in Byurakan (Ambartsumian and Shahbasian 1958; Sahakian 1965), may be also considered as results of the nuclear activity. Finally we may note that quasi-stellar objects, which would be isolated nuclei according to Ambartsumian, probably represent the earliest stages of the formation of galaxies.

In all the above cases we have emphasized some form of nuclear activity. In the investigation carried out in Byurakan with the 20 in. Schmidt telescope by Kalloglian and Tovmassian (1964) and by Tovmassian (1965) the nuclei of normal barred galaxies were studied. It was found that the central parts of such galaxies have several different forms. The galaxies were classified into five groups denoted by types 1–5. The galaxies of type 1 have no central condensation. Galaxies of type 2 have a small degree of concentration to the centre of the bar, but the concentration is rather irregular in shape. Galaxies of type 3 though having strong concentration

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TABLE 1

LIST OF GALAXIES INVESTIGATED AT 21 CM

Galaxy No.	NGC, IC No.	Type	m_{pg}	Galaxy No.	NGC, IC No.	Type	m_{pg}
1	NGC 55*†	SBm	8·1	50	NGC 4394	SBb	11·9
2	NGC 175	SBa	12·8	51	NGC 4421	SBa	12·3
3	NGC 255	SBc	12·5	52	NGC 4435	SBO	12·2
4	NGC 289*†	SBc	11·9	53	NGC 4442	SBO	11·6
5	NGC 357	SBa	12·9	54	NGC 4477	SBO	11·7
6	NGC 434	SBO	13·3	55	NGC 4546	SBO	11·8
7	NGC 613*†	SBc	11·0	56	NGC 4548	SBb	11·5
8	NGC 685*†	SBd	12·1	57	NGC 4643	SBO	11·8
9	NGC 782	SBb	12·8	58	NGC 4665	SBa	11·7
10	NGC 936*†	SBa	11·2	59	NGC 4754	SBO	11·9
11	NGC 986*†	SBa	11·9	60	NGC 4856	SBa	11·7
12	NGC 1073*†	SBc	11·5	61	NGC 4902	SBb	11·8
13	NGC 1079	SBa	12·3	62	NGC 4947	SBb	12·7
14	NGC 1097	SBb	10·3	63	NGC 5068*†	SBc	11·0
15	NGC 1187	SB	11·2	64	NGC 5566	SBa	11·7
16	NGC 1249*†	SBd	12·0	65	NGC 5850	SBb	12·3
17	NGC 1291*†	SBO	10·2	66	NGC 5854	SBa	12·8
18	NGC 1300	SBb	11·2	67	NGC 5921	SBb	11·9
19	NGC 1313*	SBd	10·6	68	NGC 5970*	SBb	12·5
20	NGC 1341	SBa	13·3	69	NGC 6684	SBO	11·7
21	IC 1954*†	SBb	12·2	70	IC 4710*	SBd	12·3
22	NGC 1365*	SBc	10·6	71	IC 4721*†	SBc	12·6
23	NGC 1398	SBb	11·0	72	IC 4837*†	SBc	12·8
24	NGC 1437	SBa	12·8	73	NGC 6744*†	SBc	9·8
25	NGC 1493*†	SBc	12·1	74	NGC 6754	SBb	13·3
26	NGC 1536	SBc	13·5	75	NGC 6770	SBb	13·1
27	NGC 1559*†	SBd	11·8	76	NGC 6782	SBO	12·8
28	NGC 1617	SBa	11·8	77	NGC 6808	SBa	13·6
29	NGC 1640	SBb	12·7	78	NGC 6902	SBa	12·7
30	NGC 1672*	SBb	11·3	79	NGC 6942	SBO	12·9
31	NGC 1688	SBc	12·7	80	NGC 6970*	SBa	13·4
32	NGC 1796	SBb	13·2	81	NGC 7155	SBO	13·1
33	NGC 1808*†	SBa	11·1	82	NGC 7329*	SBb	12·4
34	NGC 2369	SBa	12·7	83	IC 5240*	SBa	12·5
35	NGC 2397	SBa	13·1	84	NGC 7410	SBa	11·8
36	NGC 2442*	SBb	11·1	85	NGC 7412*†	SBb	12·0
37	NGC 2525	SBc	12·4	86	NGC 7418*	SBc	11·9
38	NGC 2983	SBa	12·8	87	NGC 7421	SBb	12·9
39	NGC 3185*	SBa	12·7	88	NGC 7462*†	SBc	13·0
40	NGC 3347*	SBb	12·2	89	NGC 7479	SBb	11·7
41	NGC 3351*†	SBb	11·0	90	NGC 7496	SBb	12·1
42	NGC 3367*†	SBc	12·4	91	NGC 7552*†	SBa	11·8
43	NGC 3384	SBO	11·4	92	NGC 7582*†	SBb	12·0
44	NGC 3412	SBO	11·8	93	NGC 7599*†	SBc	12·1
45	NGC 3783	SBa	13·1	94	NGC 7713	SBd	11·9
46	NGC 4064	SBa	12·5	95	NGC 7723	SBb	12·1
47	NGC 4106	SBO	12·7	96	NGC 7741	SBc	12·2
48	NGC 4116	SBc	12·3	97	NGC 7743	SBa	12·5
49	NGC 4267	SBO	12·3	98	NGC 7764*†	SBm	13·0

* Observed also at 11 cm. † Observed also at 75 cm.

towards their centres are by no means starlike on our photographs. The cases where prominent so-called starlike nuclei are present are designated types 4 and 5. The nuclei of type 4 have a noticeable surface brightness but those of type 5 are indistinguishable from stars.

An investigation of about 80 southern barred spirals has been made by the author (Tovmassian 1966*a*) at the Siding Springs Observatory in Australia with the 40 in. telescope, the scale of which is about four times greater than that of the 20 in. Schmidt telescope of the Byurakan Observatory.

Since the differences in optical appearance of the nuclei could be considered as evidence of their activity and evolution, it was of interest to see whether any phase of this activity is accompanied by radio emission. Any relation between the optical appearance and the presence of radio emission from the nuclei would obviously be of help in understanding their nature. In a previous investigation (Tovmassian 1966*b*) we have already seen that abnormal spectra and colours of the central parts of some galaxies are associated with enhanced radio emission in those galaxies.

In the present investigation radio observations were made of 98 barred galaxies that have been studied optically in Byurakan, Armenia, USSR, or Siding Springs, Australia. The radio observations were made at 21 and 11 cm with the 210 ft radio telescope of the Australian National Radio Astronomy Observatory of the CSIRO at Parkes. In addition, some of the galaxies were observed at 75 cm using the 1-mile-long east–west arm of the Mills Cross of the Sydney University Molonglo Radio Observatory. The comparison with optical results and discussion will be given elsewhere (Tovmassian 1966*c*).

II. Observations

All 98 investigated galaxies have been observed at 21 cm with the 210 ft steerable dish at Parkes. The list of investigated galaxies together with their types and photographic magnitudes (de Vaucouleurs and de Vaucouleurs 1964) is given in Table 1. Eight galaxies in our list had been observed by Mathewson and Rome (1963) and four by Heeschen and Wade (1964), but we have repeated their observations to ensure uniformity. In fact, fairly good agreement exists between the present and previous observations. The list also includes three barred galaxies observed in a previous investigation (Tovmassian 1966*b*). The observations were carried out in two series in May and July of 1965. The beamwidth of the 210 ft telescope at 21 cm is about 14′ between half-power points. The receiver used consisted of a degenerate parametric amplifier (Gardner and Milne 1963) followed by a crystal mixer and had a bandwidth of 10 Mc/s. The receiver was switched between the aerial feed and a backward-looking reference horn. The system noise temperature was 100°K and, with a 2 sec time constant, peak-to-peak noise fluctuations were 0·15 degK. The observations consisted of declination scans about 1° in extent centred on the declination of the galaxy. Subsequently, similar scans were made in right ascension. Multiple observations (in some cases up to 10) enabled the detection of radio sources near the positions of the observed galaxies with flux densities as low as 0·1 flux unit (1 flux unit $= 10^{-26}\,\mathrm{W\,m^{-2}\,(c/s)^{-1}}$). An example of a 21 cm record is shown in Figure 1.

The receiver was calibrated by injecting a known noise signal from a discharge lamp into the input of the receiver. The value of this standard signal was checked two or three times a day by observations of well-known radio sources (Hydra A, Herc A, 3C 327, and others).

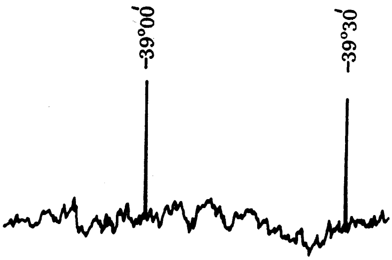

Fig. 1.—Declination scan of NGC 986 at 21 cm.

In order to verify the positions of sources, in September 1965 we observed at 11 cm those 37 galaxies from which, it was thought, emission at 21 cm had been detected. The beam of the 210 ft telescope at 11 cm is about 7′·5. The 11 cm receiver (Cooper, Cousins, and Gruner 1964) uses a broad-band degenerate parametric amplifier. The bandwidth of the system is about 40 Mc/s and its system temperature is about 150°K. With the 2 sec time constant used in the observations the peak-to-peak noise fluctuations were about 0·15 degK. As for the observations at 21 cm, the receiver was switched between the aerial feed and a reference horn. The observational procedure at 11 cm was similar to that at 21 cm, except that scans were made not only through the position of the galaxy but also through the positions of sources determined from the 21 cm observations. The range of the scans was about 0°·5, corresponding to the smaller beamwidth. The lower limit of flux density that could be measured in these observations was 0·1 flux unit. Figure 2 shows a typical record at 11 cm.

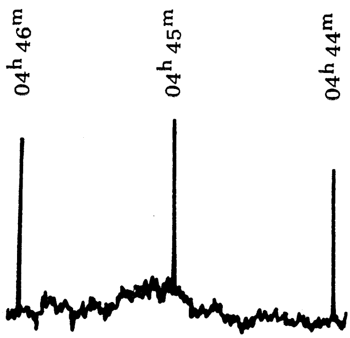

Fig. 2.—Right ascension scan of NGC 1672 at 11 cm.

The observations at 11 cm provided more precise values of both coordinates of the detected radio sources. Further improvement of the value of the right ascensions of some of the detected sources was achieved by observations at 75 cm in July and October of 1965 with the 1-mile-long east–west arm of a new Mills Cross of the Sydney University Molonglo Radio Observatory (Mills *et al.* 1963). The beam of this telescope at half-power points is about 1′·5 in right ascension and 4° in declination. The sources were observed at transit. With a 1 sec time constant it was possible to detect sources with flux densities greater than ~ 0·7 flux unit. A record of NGC 1097 at 75 cm is shown in Figure 3. In addition to improving the accuracy of the position measurements, the 11 and 75 cm observations provided flux densities and thus the spectra of the sources in this wavelength range.

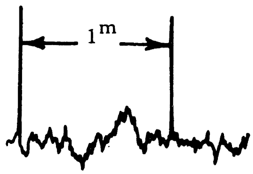

Fig. 3.—Record of NGC 1097 at 75 cm.

All detected radio sources were very weak, their flux densities were under 0·7 flux unit at 21 cm, under 0·45 flux unit at 11 cm, and under about 1 flux unit at 75 cm, and for this reason the values for their flux densities have an uncertainty of about 30%. There was also considerable uncertainty in estimating the angular sizes (most of the sources were not resolved and their angular sizes cannot exceed 2–3 minutes of arc). Owing to the weakness of the observed sources, the accuracy of the position measurements is affected by noise as well as by telescope pointing errors (0′·6 according to Bolton, Gardner, and Mackey 1964) and is ~ 1′·5 to 2′ at 21 and 11 cm. The accuracy of right ascension measurements for the 75 cm observations is about 0′·5.

The identification of the detected source with the galaxy in question was considered to be certain if its position differed from that of the galaxy by not more than 1′·5 when it was observed at 11 and 21 cm only. For observations at 75 cm it was accepted if the difference in their right ascensions was not more than 1′. (The possibility of errors in optical positions has been taken into account.) There were 21 (out of 37) cases that satisfied these conditions.

III. Results

The list of the galaxies from which radio emission was detected with certainty is given in Table 2. The positions of the galaxies, the differences between the radio and optical positions, and the flux densities at 11, 21, and 75 cm are also presented. The numbers of observations for each measurement are given in parentheses after the flux densities. The remaining columns give the angular diameter along the major axis and the ratio of major to minor axes (from the catalogue of de Vaucouleurs and de Vaucouleurs 1964) and the radio diameters.

(*a*) *The Certainty of Identification*

All identifications are considered as very reliable because the probability of random coincidences of detected radio sources with the investigated galaxies is very small. Indeed, by extrapolating the $\log N$–$\log S$ distribution of Figure 2 in the paper of Price and Milne (1965) to a flux density of 0·1 flux unit we find that the number

TABLE 2

GALAXIES DETECTED AT 21 CM

C = complex region, U = unresolved

Galaxy No.	NGC No.	R.A. (1950) h m	ΔR.A. m	Dec. 1950 ° ′	ΔDec. ′	Flux Density (flux units)* 11 cm	21 cm	75 cm	Optical Diameter D ′	Ratio D/d	Radio Size
1	55	00 12·5	0·0	−39 30	+1·5	0·45(4)	0·70(3)	1·20(1)	30·2	6·2	U
2	289	00 50·4	+0·4	−31 29	−0·9	<0·10(4)	0·15(5)	<0·70(1)	3·5	1·4	U
3	613	01 32·0	−0·4	−29 40	0·0	0·28(4)	0·34(10)	0·70(1)	5·3	1·4	U
4	986	02 31·6	−0·2	−39 15	0·0	0·23(4)	0·28(9)	1·1 (1)	3·0	1·4	1′·3×U
5	1073	02 41·2	−1·2	+01 10	+0·3	0·22(4)	0·33(4)	<1·0 (1)	4·5	1·0	U
6	1097	02 44·3	−0·7	−30 29	+0·2	0·42(6)	0·57(2)	1·1 (1)	7·9	1·5	1′·9×U
7	1313	03 17·6	0·0	−66 40	−1·0	0·24(4)	0·42(4)	—	7·8	1·3	U×12′
8	1365	03 31·8	−1·2	−36 18	0·0	0·43(4)	0·68(2)	—	9·3	1·8	U
9	1493	03 55·9	0·0	−46 21	−1·5	<0·10(5)	0·22(8)	<1·0 (1)	2·5	1·1	U
10	1559	04 17·0	0·0	−62 55	+1·0	0·35(6)	0·46(4)	<1·0 (1)	2·8	1·7	U
11	1672	04 44·9	0·0	−59 20	−0·5	0·35(4)	0·45(2)	—	4·4	1·3	U
12	1808	05 05·9	0·0	−37 34	−0·2	0·28(2)	0·58(8)	1·4 (1)	5·2	1·9	1′×U
13	2369	07 16·0	−0·7	−62 16	+1·3	—	0·22(5)	—	3·5	2·2	U
14	2442	07 36·5	0·0	−69 25	+0·3	0·28(1)	0·45(4)	—	5·9	1·1	U
15	3185	10 14·9	+0·8	+21 56	−0·5	<0·10(7)	0·16(6)	—	2·0	1·4	U
16	5068	13 16·2	+0·5	−20 47	+1·5	0·16(4)	0·22(4)	<1·0 (1)	6·3	1·1	U
17	6744	19 05·0	0·0	−63 56	−1·1	0·22(4)	0·28(2)	<1·0 (2)	14·4	1·6	U
18	7418	22 53·8	+1·5	−37 17	+0·9	0·26(10)	C	—	3·2	1·2	U
19	7462	23 00·0	+0·9	−41 06	−1·5	<0·10(8)	0·21(4)	<0·70(1)	3·5	7·6	U
20	7552	23 13·5	0·0	−42 53	+1·0	0·29(4)	0·34(5)	<0·70(1)	2·9	1·5	U
21	7582	23 15·8	0·0	−42 38	+1·3	0·26(8)	C	<0·70(1)	3·8	3·0	U

* Number of observations shown in parentheses after each value.

of sources per steradian with flux densities higher than 0·1 flux unit at 21 cm is about 8000.* (These results are based on the observations at 21 cm with the same 210 ft telescope and equipment and have a lower limit of flux density of 0·5 flux unit.) Hence the expected number of radio sources within the limits of $\pm 1'\cdot 5$ around 100 points randomly chosen in the sky is equal to 0·6. In fact we have 21 coincidences and it is therefore most unlikely that they are due to pure chance. Furthermore, in most cases the differences between the optical and observed radio positions are somewhat less than the adopted limit of $\pm 1'\cdot 5$. It is interesting to note that if we

TABLE 3

SPECTRAL INDICES, RADIO INDICES, AND RADIO AND PHOTOGRAPHIC MAGNITUDES FOR THE DETECTED GALAXIES

NGC No.	α	m_{21}	R_{21}	M_{21}
55	−0·53	11·9	+5·1	−13·7
289	—	13·6	+2·1	−18·4
613	−0·49	12·7	+2·1	−18·8
986	−0·31	12·9	+1·5	−19·2
1073	−0·64	12·8	+1·6	−19·2
1097	−0·56	12·2	+2·4	−19·3
1313	−0·89	12·5	+2·3	−11·5
1365	−0·73	12·0	+1·9	−19·6
1493	—	13·2	+1·4	—
1559	−0·44	12·4	+1·2	—
1672	−0·40	12·4	+1·6	—
1808	−0·86	12·1	+1·8	−18·1
2369	—	13·2	+1·7	—
2442	−0·74	12·4	+2·1	—
3185	—	13·5	+1·3	−17·4
5068	−0·50	13·2	+2·6	−15·5
6744	−0·38	12·9	+3·9	−16·4
7418	—	12·1*	+0·6*	—
7462	—	13·2	+1·5	—
7552	−0·25	12·7	+1·4	−19·0
7582	—	12·1*	+1·6*	−19·3*

* Determined from observations at 11 cm assuming $S = f^{-0\cdot 5}$.

increase the area to 400 sq min of arc ($\pm 10'$) the number of chance coincidences expected would be 28. In fact an additional 27 sources were found within these limits—in excellent agreement with the prediction—but were not considered identifications.

One further argument may be advanced against the possibility of chance coincidences. Although 48 of the 98 galaxies have our preliminary classification (Tovmassian 1966*a*) of type 3, not one of the 21 galaxies from which we detected

* We obtain a similar value using preliminary results of source counts made at 11 cm with the 210 ft dish by Ekers, and kindly made known to us prior to publication. In this case the number of sources with flux densities more than 0·5 flux unit is about 430 per steradian and the slope of the log N–log S relation is about 1·8. By extrapolation, the number of sources with flux densities in excess of 0·1 flux unit would be about 5600—a little less than at 21 cm.

radio emission belongs to this type. It is interesting that the mean value of the apparent photographic magnitudes of the 21 galaxies with radio emission is $11^{m}\cdot4$ and is about the same ($11^{m}\cdot6$) for the 21 brightest galaxies of type 3.

We may further conclude that the presence of radio emission in galaxies with only a particular structure in their nuclear regions cannot be a casual phenomenon.

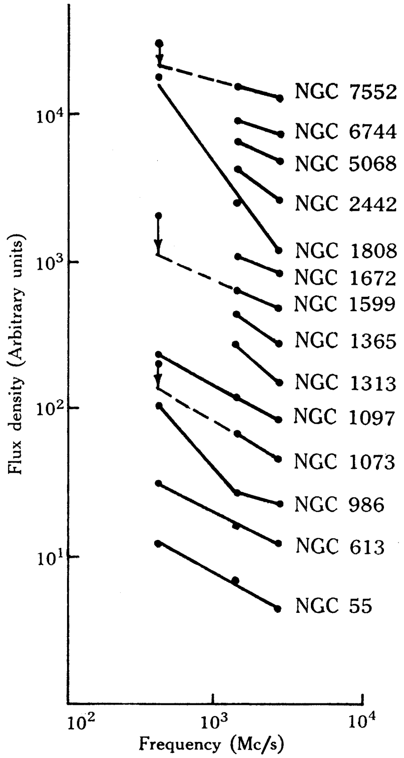

Fig. 4.—Radio spectra of barred galaxies plotted with displaced flux density origins.

(*b*) *Angular Sizes*

An inspection of Table 2 shows that in almost all cases the angular sizes of the detected sources are less than those of the corresponding galaxies. However, we cannot exclude the possibility of overlooking an extended component with low surface radio brightness. Nevertheless, the observed radio emission appears to originate in the nuclear regions of galaxies rather than in their whole volume. This is the same result we obtained in a radio investigation of the galaxies with abnormal spectra and colours in their central region (Tovmassian 1966*b*).

(*c*) *Spectral Indices*

Spectral indices of some of the detected radio sources and their spectra in the range of 11–21 cm or 11–75 cm are given in Table 3 and Figure 4 respectively. The sharp break in the spectrum of NGC 986 is probably due to confusion with nearby sources in the observations at 75 cm. Spectral indices are distributed almost uniformly between $-0\cdot2$ and $-0\cdot9$ (see Fig. 5).

(d) *Radio Indices*

The radio indices $R = m_r - m_{pg}$ of the studied galaxies at 21 cm are also presented in Table 3. In the calculation the radio magnitude m_{21} was determined using the relationship

$$m_r = 53 \cdot 45 - 2 \cdot 5 \log S,$$

as defined by Hanbury Brown and Hazard (1959). S is the source flux density in $W m^{-2} (c/s)^{-1}$ at 1410 Mc/s. The photographic magnitudes of the galaxies have been corrected for absorption in our Galaxy by $\Delta m = -0 \cdot 25 \operatorname{cosec} b$ and for internal absorption in the galaxies themselves according to Holmberg's (1957) results.

The radio magnitudes m_{21} of NGC 7418 and NGC 7582 have been calculated using the flux densities at 11 cm, assuming their spectral indices are $-0 \cdot 5$.

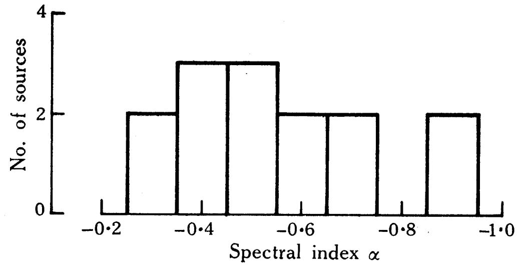

Fig. 5.—Distribution of spectral indices.

The radio indices calculated at 1410 Mc/s can be related to those of Hanbury Brown and Hazard at 158 Mc/s by the formula $R_{158} = R_{1410} - 1 \cdot 43$ (Mathewson and Rome 1963).

The mean value of the radio indices of the studied galaxies, neglecting NGC 55 and NGC 6744, where there are appreciable differences from the remainder, is $+1 \cdot 7$. This value is about $1 \cdot 5$ magnitudes less than the value obtained by Mathewson and Rome (1963) for 16 Sb and Sc galaxies.

(e) *Absolute Radio Magnitudes*

The absolute radio magnitudes at 21 cm for the galaxies with known red shifts are given in the final column of Table 3. Hubble's constant was taken as $75 \text{ km sec}^{-1} \text{Mpc}^{-1}$.

(f) *Conclusions*

As we have previously noted, preliminary results of the optical investigation of the studied galaxies indicate that the intensity of their radio emission is closely connected with the appearance of and thus with the physical conditions in their nuclei. Radio emission is frequently present in galaxies with a definite structure of their central parts. The sizes of the detected sources also indicate that the observed radio emission is due to the nuclei (central parts) of the corresponding galaxies and does not depend on their morphological types. For this reason it would be useful to introduce some radio classification of the nuclei of galaxies.

The results of the optical work on the central parts of the investigated galaxies and a detailed comparison of the optical and radio data will be given in two forthcoming papers (Tovmassian 1966*a*, 1966*c*).

IV. Acknowledgments

The author wishes to thank Dr. E. G. Bowen and Mr. J. G. Bolton for making available the facilities of the Australian National Radio Astronomy Observatory of the CSIRO at Parkes. The help of Mr. P. R. Crosthwaite and Mr. D. J. Cole with the receivers used for these observations is acknowledged. He also expresses his gratitude to Professor B. Y. Mills for permission to use the east–west arm of the Mills Cross at the Sydney University Molonglo Radio Observatory, to Mr. A. G. Little for help during the observations at Molonglo, and to Mr. R. Ekers for providing the results of source counts with the 210 ft telescope at 11 cm, prior to publication. Professor V. A. Ambartsumian's interest in this work and useful discussions are gratefully acknowledged.

V. References

Ambartsumian, V. A. (1956*a*).—Trans. 5th Symp. on Cosmogony, Moscow, p. 413.
Ambartsumian, V. A. (1956*b*).—*Izv. Akad. Nauk armyan. SSR* **23**, 161.
Ambartsumian, V. A. (1958).—Solvay Conf. Rep., Brussells.
Ambartsumian, V. A. (1962).—*Trans. int. astr. Un.* **11B**, 145.
Ambartsumian, V. A., and Shahbasian, R. K. (1958).—*Izv. Akad. Nauk armyan. SSR* **26**, 277.
Baade, W., and Minkowski, R. (1954).—*Astrophys. J.* **119**, 206, 215.
Bolton, J. G., Gardner, F. F., and Mackey, M. B. (1964).—*Aust. J. Phys.* **17**, 340.
Cooper, B. F. C., Cousins, T. E., and Gruner, L. (1964).—*Proc. Instn Radio Engrs Aust.* **25**, 221.
Gardner, F. F., and Milne, D. K. (1963).—*Proc. Instn Radio Engrs Aust.* **24**, 127.
Hanbury Brown, R., and Hazard, C. (1959).—*Mon. Not. R. astr. Soc.* **119**, 297.
Heeschen, D. S., and Wade, C. M. (1964).—*Astr. J.* **69**, 277.
Holmberg, E. (1957).—*Meddn Lunds astr. Obs.* (2) No. 136.
Kalloglian, A. T., and Tovmassian, H. M. (1964).—*Soobshch. byurak. Obs.* **36**, 31.
Mathewson, D. S., and Rome, J. M. (1963).—*Aust. J. Phys.* **16**, 360.
Mills, B. Y., Aitchison, R. E., Little, A. G., and McAdam, W. B. (1963).—*Proc. Instn Radio Engrs Aust.* **24**, 156.
Price, R. M., and Milne, D. K. (1965).—*Aust. J. Phys.* **18**, 329.
Sahakian, K. A. (1965).—*Astrophys. USSR* **1**, 126.
Shklowski, I. S. (1954).—*Izv. Akad. Nauk. SSSR* **98**, 353.
Tovmassian, H. M. (1965).—*Astrophys. USSR* **1**, 197.
Tovmassian, H. M. (1966*a*).—The nuclei of southern barred galaxies. *Astrophys. USSR* **2**(3) (in press).
Tovmassian, H. M. (1966*b*).—*Aust. J. Phys.* **19**, 565.
Tovmassian, H. M. (1966*c*).—On the correlation of radio emission from barred galaxies with appearance of their nuclei. *Astrophys. USSR* **2**(4) (in press).
de Vaucouleurs, G., and de vaucouleurs, A. (1964).—"Reference Catalogue of Bright Galaxies." (Univ. Texas Press.)