

RADIO EMISSION FROM SOME MARKARIAN GALAXIES AT 430 MHz

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Received 22 April 1974, revised 3 June 1974

Markarian galaxies have been observed with the 1000-foot radio telescope at Arecibo. Approximately 20% of the observed galaxies showed weak radio emission. For the detected galaxies we give their radio indices and radio luminosities.

Key words: radio sources — galaxies

I. Introduction

Markarian galaxies are characterized by excess ultraviolet continuum emission. The overwhelming majority of them have emission lines in their spectra, and these lines are sometimes very broad. About 50 new Seyfert-type galaxies have recently been detected among 500 Markarian galaxies studied in detail spectroscopically. Thus optical observations strongly indicate that violent activity is in process in the nuclei of these galaxies.

Radio observations of a small group of bright ($m_{pg} \leq 13^m$) Markarian galaxies (Markarian 1963) showed that they often have radio emission which is somewhat stronger than that of the normal spiral galaxies (Tovmassian 1966). At 408 MHz their radio luminosities are in the range of 0.4×10^{22} to about 3.5×10^{22} W Hz⁻¹. For some of the fainter Markarian galaxies (Markarian 1967, 1969*a,b*; Markarian and Lipovetsky 1971, 1972) with photographic magnitudes in the range of $13^m.5$ – $17^m.5$ only upper limits for their radio emission have been given based on a search of the 5C catalogues of radio sources by Longair, Malumian, and Sargent (1970). Recent attempts made by Tovmassian (1972) and Thomasson and Malumian (1973) have also failed to detect radio emission from faint Markarian galaxies at wavelengths of 9.5 cm and 75 cm, respectively. The negative results of the latter observers is partly due to errors in the positions

of some galaxies listed by Markarian. As it was recently shown by Peterson (1973), who measured accurately the coordinates of Markarian galaxies, the tabulated positions of Markarian 132 and 142, observed by Thomasson and Malumian, are in error by 7 and 30 arc minutes, respectively. The positions of another six galaxies: Markarian 63, 78, 106, 110, 141, and 270 have positional errors in the range of 1.5–2 arc minutes. Moreover, the galaxy Markarian 231, included in the list of the above authors, is in fact the galaxy Markarian 232 (Markarian 1970), the position of which is given with an error of about 4 arc minutes.

The very recent detection of radio emission from about 30 Markarian galaxies by Tovmassian and Sramek (1974) at a wavelength of 6 cm encouraged us to observe some Markarian galaxies at 430 MHz.

II. Observations and Results

Radio observations were made with the 1000-foot radio telescope at Arecibo, Puerto Rico, of the National Astronomy and Ionosphere Center. The sensitivity of the system was $\sim 14^\circ$ K of antenna temperature per flux unit (one f.u. = 10^{-26} W m⁻² Hz⁻¹). The half-power beamwidth of the telescope was ~ 10 arc minutes. Right-ascension drift curves and declination scans were obtained through the positions of the selected galaxies. Unfortunately only a small number of the bright Markarian galaxies

are in the observable arc of the sky by the Arecibo radio telescope. Thirty-eight Markarian galaxies, listed in Table I, were observed in total.

The observing system permitted the detection of weak radio sources down to 0.1 f.u. Following Condon (1972), who studied the extragalactic confusion at Arecibo, we have also

determined that the rms confusion at 430 MHz with a half-power beamwidth of 10 arc minutes is ~ 0.08 f.u. This low value, and the fact that Tovmassian and Sramek (1974) have detected radio emission at 6 cm from MRK 1, 297, 314, 348, and 483 serve as strong confirmation of the identification of the Markarian galaxies with the observed radio sources in Table II. Calibration of the receiving system was made by observations of the standard sources 3C 76.1, 3C 215, 3C 294, 3C 334, 3C 435, and 3C 454 before and after each observing period. The positional accuracy of the present work is $\lesssim 1$ arc minute.

Radio emission was detected at the positions of seven galaxies (Table II). In three other cases radio sources were found at distances of 2–2.5 arc minutes from the positions of the corresponding optical galaxies. These are considered as probable identifications and are also included in Table II. The Markarian number of each galaxy in Table II is followed by the flux density at 430 MHz, radio index R_{430} , redshift z , and radio luminosity P_{430} . Radio indices are defined by $R_{430} = m_{430} - m_B$. Radio magnitudes are determined by $m_{430} = -53.45 - 2.5 \log S_{430}$ where S_{430} is the flux density at 430 MHz (Hanbury-Brown and Hazard 1961). B magnitudes determined by Weedman (1973) and corrected for galactic absorption ($A = 0.25 \csc b$) are used. For the galaxies Markarian 318, 478, and 483 the photographic magnitudes estimated by Markarian and Lipovetsky (1971,

TABLE I
MARKARIAN GALAXIES OBSERVED AT ARECIBO

MRK	MRK
1	318
36	335
50	337
52	341
64	347
67	348
69	350
268	352
291	353
297	362
298	363
300	372
303	396
304	401
306	448
307	478
308	483
314	492
316	495

TABLE II
FLUX DENSITIES, RADIO INDICES AND RADIO LUMINOSITIES
OF MARKARIAN GALAXIES AT 430 MHz

MRK	$S_{430}^\dagger$ $10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$	R_{430} $m_r - m_B$	z	P $10^{22} \text{ W Hz}^{-1}$
1	0.12	-1.6	0.016	6.0
52	0.20	-1.3	0.007	1.7
314	0.11	-0.7	0.006	0.8
318	0.10	-2.4	0.016	4.9
341	0.25	-1.9	0.015	10.8
348	0.39	-3.3	0.014	14.7
483	1.00	-4.8	—	—
297*	(0.77)	(-2.3)	0.016	(37.8)
307*	(0.20)	(-3.2)	0.019	(13.9)
478*	(0.16)	(-1.8)	0.079	(172.8)

*Uncertain identification.

†Flux density errors are typically $\pm 25\%$.

1972) are used. Radio luminosities are calculated using redshifts determined by Weedman and Khachikian (1968, 1969), and Arakelian, Dibay, and Yesipov (1972, 1973) and assuming a Hubble constant equal to $75 \text{ km sec}^{-1} \text{ Mpc}^{-1}$.

The consideration of radio indices shows that Markarian galaxies are appreciably stronger radio emitters than not only normal spiral galaxies, for which the mean radio index is about +2.5 (Tovmassian and Terzian 1973), but also those which have starlike nuclei.

It should be noted here that the Markarian galaxies with detected radio emission are among those which have very small redshifts ($z \leq 0.016$). Only 27 of the observed 38 galaxies have known redshifts, and only eight of these have $z \leq 0.016$. The other 19 galaxies are situated further in space.

Generally the radio luminosities of the detected Markarian galaxies seem to be higher than the mean radio luminosity of the bright Seyfert galaxies (except NGC 1275), and most of the normal spiral galaxies, as indicated also by Tovmassian (1966).

One of us (H.M.T.) is grateful to NAIC and Cornell University for their hospitality. This research was supported in part by NRAO, which is operated by Associated Universities, Inc., under contract with the NSF, and in part

by NAIC which is operated by Cornell University under contract with the NSF.

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