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RADIO OBSERVATIONS OF INTERACTING GALAXIES NGC 7714 (MARKARIAN 538) — NGC 7715 (ARP 284, VV 51), AND RADIO QUASAR UB1

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Radio observations from a number of observers, at a multiplicity of frequencies, for a peculiar pair of interacting galaxies NGC 7714 (Markarian 538) — NGC 7715 (Arp 284, VV 51) and radio quasar UB1 are presented. The weighted sum of the spectral index for NGC 7714 and UB1 is $\alpha = -0.99$ and $\alpha = -0.81$, respectively. The available data allows us to suggest that NGC 7715 is a radio variable.

1. *Introduction.* Stocke and Arp [1] have investigated the field of the interacting pair of galaxies NGC 7714 (Markarian 538) — NGC 7715 (VV 51, Arp 284) and the radio quasar UB1 (2333 + 019). They reported that the spectral index for NGC 7714 (Markarian 538) and UB1 is $\alpha = -0.4$ and $\alpha = -0.5$, respectively. Stocke and Arp noted that the two interacting galaxies, and quasars UB1 and UB2, all fall closely along a line connected with a third, but smaller, disturbed galaxy. They have indicated that this alignment of objects suggests some physical association.

Of the pair, NGC 7714 (Markarian 538) appears brighter. It is a member of Markarian's list because it exhibits a UV excess on objective prism plates. Radio emission was first detected by Pfeleiderer [2] at 1400 MHz with the NRAO 91.4 meter radio telescope during the winter of 1969–70. Radio observations of this region have since been made by a number of observers at a multiplicity of frequencies.

2. *Observations.* Kojoyan et. al. [3] observed the NGC 7714–7715 region at 2700 MHz (November 1977) and at 5000 MHz (August 1977) with the NRAO** 91.4 meter radio telescope, obtaining peak flux values

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equaling 113 ± 27 mJy at 2700 MHz and 67 ± 20 mJy at 5000 MHz. The right ascension of the centroid of the flux density at 2700 MHz is $23^{\text{h}}33^{\text{m}}48^{\text{s}}.5$ (1950.0) and agrees with the optical position of NGC 7715 (Table 2). The right ascension of the centroid of the flux density at 5000 MHz is $23^{\text{h}}33^{\text{m}}58^{\text{s}}.4$ (1950.0) which is close to the optical position of UBI (Table 2). Observations with the National Astronomy and Ionosphere Center, Cornell-Arecibo Radio Observatory's* 1000-foot radio telescope during 1978 [4] indicated a flux density of 63 ± 15 mJy for the NGC 7714–7715 pair and 182 ± 36 mJy for UBI at 1390 MHz (see Table 1, Fig. 1).

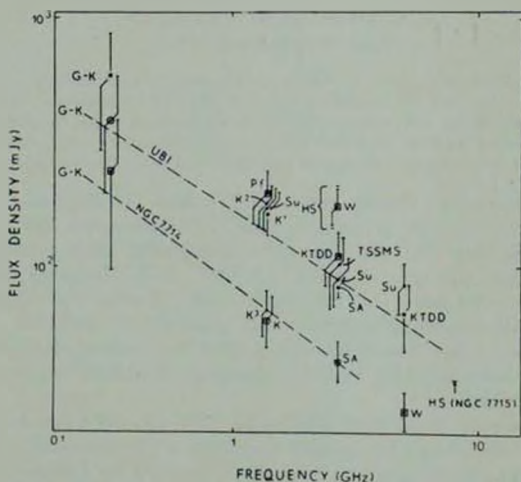


Fig. 1. Radio spectra for NGC 7714 (Mark 538), NGC 7715 (VV51, Arp 284) and UBI (○ — NGC 7714, □ — NGC 7715, • — UBI). Key: Pf — [2], W — [5], HS — [7], Su — [6], KTDD — [3], TSSMS — [8], SA — [1], G-K — [9], K, K¹, K², K³ — [11].

Pfleiderer's [2] observations of the NGC 7714–7715 region at 1400 MHz (NRAO 91.4 m system) resulted in a flux density of 200 ± 50 mJy. The angular separation between the galaxies is about 2 arcminutes, which is less than the ~ 10.5 arcminute beamwidth of the

* The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under contract with the National Science Foundation.

telescope at the frequency of observation. Therefore, it was not possible to distinguish the amount that each member of the pair contributed to the observed flux. Wright [5] observed this region with the Parkes 64-meter system between September 1972 and August 1973 at 2700 MHz, obtaining 180 ± 30 mJy, and at 5000 MHz, recording 27 ± 5 mJy. The respective half-power beamwidths of 8 and 4 arcminutes did not allow for the resolution of the source of radio emission from the NGC 7714–7715 system.

Wright [5] detailed the radio spectrum of the source emanating from the neighborhood of NGC 7715, utilizing his 2700 and 5000 MHz data and apparently Pfeleiderer's observations at 1400 MHz. The spectrum appeared unusual, prompting Wright to suggest that the source of radio emission may be variable.

Sulentic [6] observed this region at 1400, 2700 and 5000 MHz with the NRAO 91.4 meter transit system reporting 179 ± 35 mJy, 91 ± 20 mJy and 86 ± 20 mJy, respectively. The corresponding half-power beamwidths were 10, 5.1 and 2.7 arcminutes. The 1400 and 2700 MHz observations were made during November 1973, and August and November 1974. Observations at 5000 MHz were made in the interval between December 1974 and January 1975.

Stoche and Arp [1] reported a flux density of 43 ± 8 mJy at the nucleus of the NGC 7714 (Markarian 538), and 43 ± 5 and 42 ± 7 mJy for each of two components of UB1 at 2695 MHz. However, in Figure 1 the two values are combined and presented as the flux for UB1 at 2695 MHz. These results were obtained with the three-element NRAO Green Bank System.

Haynes and Sramek [7] observed the neighborhood of NGC 7715 in 1971 with the three-element NRAO Green Bank System at 2695 MHz. They reported that the radio source at the position of NGC 7715 consists of a 35 arcsecond resolved component with a flux density of 130 ± 26 mJy and an unresolved component at the level of 50 ± 10 mJy. At 8085 MHz the upper limit of the unresolved flux density was 40 mJy.

Tovmassian et al. [8] observed the NGC 7714–7715 region at 2700 MHz with the Effelsberg 100-meter radio telescope of the Max Planck Institut Fur Radioastronomie, obtaining a total flux density of 123 ± 33 mJy.

Gopal-Krishna [9] observed the UB1 and NGC 7714–7715 field at 327 MHz by the lunar occultation method. According to Gopal-Krishna the flux density is 0.6 ± 0.3 Jy for UB1 and 0.4 ± 0.2 Jy for NGC 7714. A marginal detection of 0.25 ± 0.15 Jy was indicated at the position of NGC 7715.

Table 1

THE RESULTS OF RADIO OBSERVATIONS OF THE INTERACTING PAIR OF GALAXIES
NGC 7714 (MARKARIAN 538) — NGC 7715 (VV 51, ARP 284) AND OF UBI

Frequency MHz	FLUX mJy	R. A. and Dec. of detected source (1950.0 Epoch)	Size	Beam-Width	Remarks	Reference
1400	200 $\pm$ 50	$\alpha = 23^h 33^m 48^s$ $\delta = 01^\circ 53'$		10.5		[2]
2700 5000	180 $\pm$ 30 27 $\pm$ 5	$\alpha = 23^h 33^m 51^s$ $\delta = 01^\circ 52' 36''$		8' 4'	Position was derived by combining all available data from both frequencies	[5]
2695 8085	130 $\pm$ 26 (resolved) 50 $\pm$ 10 (unresolved) < 40	Near optical position as given in Haynes and Sramek: $\alpha = 23^h 33^m 48^s$ $\delta = 01^\circ 52' 48''$	35" < 3" 1.5 to 3"		Resolved Source Unresolved Source Optical position for NGC 7715 ($\alpha = 23^h 33^m 48^s$) [10] ($\delta = 01^\circ 52' 50''$)	[7]
1400 2700 5000	179 $\pm$ 35 91 $\pm$ 20 86 $\pm$ 20			10' 5.1 2.7	Markarian 538—NGC 7714. The observed position is that given in Markarian and Lipovetsky (1973) for Mark 538— NGC 7714	[6]
2700 5000	113 $\pm$ 27 (peak value) 67 $\pm$ 20	$\alpha = 23^h 33^m 48^s$ $\delta = 01^\circ 52' 48''$ $\alpha = 23^h 33^m 58^s$ $\delta = 01^\circ 52' 48''$		5.1 (NRAO 300 ft.) telescope) 2.7	Corresponds to position for NGC 7715 as determined by Haynes and Sramek Observed position near UBI	[3]

2695	43 ± 8 (43 ± 5) (42 ± 7)	$\alpha = 23^{\circ} 33' 40''.6$ $\delta = 01^{\circ} 52' 42''$ $\alpha = 23^{\circ} 33' 57''.2$ $\delta = 01^{\circ} 54' 02''$ $\alpha = 23^{\circ} 33' 57''.0$ $\delta = 01^{\circ} 54' 19''$	$14'' \times 5''$ $6'' \times 3''$ $8'' \times 3''$
2700	123 ± 33 (total) 2' width 102 (peak)	Region measured extends from $\alpha = 23^{\circ} 33' 46''.8$ to $\alpha = 23^{\circ} 33' 54''.8$ and $\delta = 01^{\circ} 52' 53''$ to $\delta = 01^{\circ} 53' 13''$	
327	600 ± 300 400 ± 200 250 ± 150		$25''$ 20.3
1390	68 ± 14 182 ± 36 170 ± 34 63 ± 15	$\mu = 23^{\circ} 33' 56''.7$ $\delta = 01^{\circ} 51' 42''$ $\alpha = 23^{\circ} 33' 56''.7$ $\delta = 01^{\circ} 52' 42''$ $\alpha = 23^{\circ} 33' 56''.7$ $\delta = 01^{\circ} 53' 42''$ $\alpha = 23^{\circ} 33' 41''.2$ $\delta = 01^{\circ} 52' 42''$	

	NGC 7714—Markarian 538 Two lobes of a double source identified with UB1	[1]
4.4	Total includes NGC 7714— NGC 7715 and UB1 region	[8]
	At the position of UB1 At the position of NGC 7714 At the position of NGC 7715	[9]
(Arecibo 1000 ft tele- scope) 3.5	The R. A. is at the optical position ($=23^{\text{h}}33^{\text{m}}57^{\text{s}}.1$) of UB1 The Dec. offset from the op- tical position ($=01^{\circ}54'11''$) of UB1 is: $-2'29''$ $-1'29''$ $-29''$ At the position of NGC 7714- NGC 7715 pair	[11]

3. *Summary.* NGC 7714–7715 and UB1 observational data is tabulated in Table 1 and the spectra are shown in Figure 1. The weighted sum of the spectral index for NGC 7714 and UB1 is $\alpha = -0.99$ and -0.81 , respectively. Table 2 includes optical positional information of objects NGC 7714, NGC 7715 and UB1. The two interacting galaxies are at about the same declination [4, 7]. The declination of the radio quasar UB1 differs from that of the interacting pair of galaxies by ~ 1.3 arcminutes [1]. The radio spectra of UB1 and NGC 7714 includes the lunar occultation data at 327 MHz [9] and the interferometric data at 2695 MHz reported by Stocke and Arp [1].

Table 2

THE POSITIONS OF THE OBJECTS IN THE STUDIED
FIELD

Name	1950.0 R. A.	1950.0 Dec.	References
NGC 7714	23 ^h 33 ^m 41.2	01°52'42"	[4]
NGC 7715	23 33 48.5	01 52 48	[7]
UB1	23 33 57.0	01 54 19	[1]
(two lobes)	23 33 57.2	01 54 02	

Haynes and Sramek's [7] interferometric observations, made in 1971, showed that NGC 7715 has radio emission at 2695 MHz, while observations reported by Stocke and Arp [1] made with the same interferometer tuned to the same frequency detected radio emission from NGC 7714 (Markarian 538), but not from NGC 7715. Wright [5] obtained 27 ± 5 mJy at 5000 MHz from the neighborhood of NGC 7715. The half-power beamwidth of the telescope was 4 arcminutes. Therefore all three possible emitters—NGC 7714, NGC 7715 and UB1—may have contributed to the flux. However, the reported flux density is less than the expected flux from UB1 alone, as determined by the spectrum (Fig. 1) drawn through the 327 MHz [9] and 2700 MHz [1] points. Wright's [5] observations were carried out between September 1972 and August 1973. Kojoyan et al. [3] obtained measurements of 67 ± 20 mJy in August 1977 with a system whose half-power beamwidth was 2.7 arcminutes. The flux appeared to emanate from UB1. Tovmassian et al. [8] measurements apparently include contributions from both members of the NGC 7714–7715 pair.

4. *Conclusion.* The available data strengthens the suggestion [5], that NGC 7715 may be a variable radio emitter.

A high resolution radio map of the NGC 7714–7715 and UB1 neighborhood, at a multiplicity of frequencies and time intervals, may help to determine the extent of radio variability, if any, and of the

possible relationship between and amongst the individual radio emitters.

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РАДИОНАБЛЮДЕНИЯ ВЗАИМОДЕЙСТВУЮЩИХ ГАЛАКТИК NGC 7714 (МАРКАРЯН 538) — NGC 7715 (АРП 284, VV 51) И КВАЗАРА UB1

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Обсуждаются результаты наблюдений на различных частотах пекулярной пары взаимодействующих галактик NGC 7714 (Маркарян 538) — NGC 7715 (Арп 284, VV 51) и квазара UB1.

Спектральные индексы NGC 7714 и UB1 оказались равны $\alpha = -0.99$ и $\alpha = -0.81$ соответственно. Имеющиеся данные позволяют высказать предположение, что радионизлучение NGC 7715 является переменным.

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