THE ASTROPHYSICAL JOURNAL, 271:524–530, 1983 August 15

VLA OBSERVATIONS OF A COMPLETE SAMPLE OF EXTRAGALACTIC X-RAY SOURCES. II.

ISABELLA M. GIOIA,[1,2,3] E. D. FEIGELSON,[3,4,5] T. MACCACARO,[1,2,3] R. SCHILD,[1] AND G. ZAMORANI[1,2]
Received 1982 November 23; accepted 1983 January 26

ABSTRACT

A complete sample of 35 X-ray selected sources found with the *Einstein Observatory* has been observed with the Very Large Array at 6 cm to investigate the relationship between radio and X-ray emission in extragalactic objects. Nine sources are detected in the radio above a limiting sensitivity of ~1–2 mJy. Detections include three active galactic nuclei (AGNs), two clusters or groups of galaxies, two individual galaxies, and two BL Lac objects. We have combined the present data with similar data on 42 *Einstein* sources previously obtained, to increase the sample of X-ray sources observed at 6 cm. The frequency of radio emission in X-ray selected AGNs is compared with that of optically selected quasars using the integral radio-optical luminosity function. The result, although not conclusive because of the still limited statistics involved, suggests (at 95% confidence level) that the probability for X-ray selected quasars to be radio sources is higher than for those optically selected. No obvious correlation is found in our sample of X-ray selected poor clusters between the richness or the X-ray luminosity of the cluster and the presence of a galaxy with radio luminosity at 5 GHz larger than 10^{30} ergs s^{-1} Hz^{-1}.

Subject headings: BL Lacertae objects — galaxies: nuclei — galaxies: Seyfert — quasars — radio sources: galaxies — X-rays: sources

I. INTRODUCTION

In Paper I (Feigelson, Maccacaro, and Zamorani 1982) we reported on high-sensitivity radio observations of a sample of faint X-ray selected objects performed to investigate the relationship between radio and X-ray emission in extragalactic objects. The sample observed consisted of the 42 extragalactic X-ray sources with $\delta \geq -20°$ extracted from the Einstein Observatory Medium Sensitivity Survey (see Maccacaro *et al.* 1982 for a description of the survey). The radio observations were carried out with the NRAO Very Large Array, in its standard C configuration, at 6 cm. From the analysis of the observations we found marginal evidence (2 σ significance) that X-ray selected active galactic nuclei (AGNs ≡ QSOs and Seyfert galaxies) are more radio luminous than optically selected QSOs. Such a correlation would be consistent with the hypothesis that the X-ray emission of quasars (which comprises a substantial fraction of their radiative output) has a nonthermal origin. For the second class of extragalactic X-ray sources, clusters or distant groups of galaxies, present in the sample observed with the VLA, the statistics were too poor to allow a meaningful comparison with optically selected clusters.

To further study any relationship between the radio and the X-ray emission in AGNs and to extend the analysis to the X-ray selected clusters of galaxies, we have observed a second sample of faint X-ray sources with the VLA. The sample is defined in § II, and the radio observations are described in § III. The results are given in § IV and discussed in § V. Notes on individual sources are given in the Appendix. A Hubble constant $H_0 = 50$ km s^{-1} Mpc^{-1} and a deceleration parameter $q_0 = 0$ are used throughout the paper.

II. THE SAMPLE

The *Einstein Observatory* Medium Sensitivity Survey (Maccacaro *et al.* 1982) carried out with the Imaging Proportional counter (IPC) has been recently updated: 49 new X-ray sources have been classified using exactly the same selection criteria as for the original sample. In particular, it is required that the significance of the detection exceed the 5 σ level. A detailed description of this new sample of X-ray sources and their optical identifications will be given in Gioia *et al.* (1983). Excluding sources south of declination $\delta = -20°$ and those sources which are positively or most likely identified with Galactic stars, we are left with 35 objects which constitute the complete sample chosen as targets for VLA observations. So far, optical spectroscopic work has enabled us to positively identify 32 of these new

[1]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138.
[2]Istituto di Radioastronomia, CNR, Bologna, Italy.
[3]Visiting astronomer at the National Radio Astronomy Observatory (NRAO), which is operated by Associated Universities, Inc., under contract with the National Science Foundation (NSF).
[4]Department of Astronomy, Pennsylvania State University, University Park, PA.
[5]Center for Space Research, Massachusetts Institute of Technology.

X-ray sources. The remaining three unidentified sources are likely to be of extragalactic origin. In fact, none of the optical candidates lying inside or immediately outside the X-ray error circles is bright enough to have a ratio of X-ray to visual fluxes consistent with the maximum values observed for normal stars (see Maccacaro *et al.* 1982 and Stocke *et al.* 1983 for details). Following the classification used by Maccacaro *et al.* (1982), these sources are indicated as Class 1 in Table 1.

Since the selection criteria adopted to select the sources in the two samples for observation with the VLA are the same, we can combine the 42 sources of Paper I with the 35 sources presented here. The resulting sample constitutes the largest unbiased sample of extragalactic X-ray sources with X-ray fluxes of the order of 10^{-13} to 10^{-12} ergs cm^{-2} s^{-1} in the 0.3–3.5 keV band, for which high-sensitivity radio observations are available.

III. RADIO OBSERVATIONS AND DATA ANALYSIS

The observations of the second X-ray sample were carried out on 1981 November 28, 29, and 30 with the NRAO VLA using a 50 MHz bandwidth centered at 4885 MHz. Data for a few sources were not available, either because of a computer failure during the observing run or because of subsequent problems in recovering the (u, v) data. These sources were observed on 1982 January 12. A description of the instrument is given by Thompson *et al.* (1980). The array was in the standard C configuration with an average of 25 antennas operating. Baselines range from 0.2 to 3.5 km, and beamwidths have HPBW equal to 4″–6″. For each source, one "snapshot" scan of duration 11–13 minutes was obtained. Calibration sources were given 3–5 minutes integration at approximately 30–40 minute intervals to monitor instrumental and atmospheric phase and gain changes. Our primary flux density calibrator was 3C 286, whose flux density at 4885 MHz was taken to be 7.41 Jy (Baars *et al.* 1977). Calibration source flux densities were bootstrapped from this value. After calibration the (u, v) data were sorted and Fourier-transformed to produce "dirty" maps with all spacings equally weighted. For each source, we produced an $8' \times 8'$ map centered on the X-ray position. The noise of each dirty map was determined from the rms fluctuations in the central $2' \times 2'$ area. When only noise was present, an upper limit of 5 times rms for the flux density of an unresolved radio source in the X-ray box was given. When a strong source was present elsewhere in the field, the map was "cleaned" (Clark 1980) prior to the calculation of the upper limits. Upper limits determined by either procedure are generally of the order of 1–2 mJy. In some cases they are larger because of the presence of one or more strong radio sources well outside the mapped area. Flux densities for the radio sources detected within the X-ray error boxes have been computed after applying the "cleaning" procedure. For those sources whose sizes clearly exceeded the HPBW, the flux densities were computed by summing the cleaned components. No correction to the flux densities for primary beam attenuation was applied, since it is $\leq 3\%$ within 1′ of the pointing position.

IV. RESULTS

The results of the radio observations for both samples (the previous 42 sources of Paper I and the present 35 sources) are presented in Table 1. An asterisk marks the second sample objects whose radio data are published here for the first time. Column (1) gives the *Einstein* X-ray name; column (2) gives the suggested optical counterpart; the radio source position is given in column (3); column (4) gives the radio flux density (or the upper limit) at 6 cm. Additional optical and X-ray data on the sample are given elsewhere (Stocke *et al.* 1983; Gioia *et al.* 1983).

Nine of the 35 targets have been detected (i.e., the measured flux density is larger than the 5 times rms) within the 90% confidence error circle associated with the X-ray position. Details on individual sources are given in the Appendix. Two radio sources are spatially resolved with sizes larger than 5″; they both show a triple structure and are identified with AGNs. Contour maps for these two sources are shown in Figures 1*a* and 1*b*. The remaining sources are unresolved or slightly resolved at the moderate resolution of the C configuration. For each of the nine detected sources the radio position is coincident, within the errors, with the optical position of the object independently proposed as the identification of the X-ray source. This, and the statistical arguments given in Paper I, give us confidence that none of the proposed radio/X-ray associations are spurious. As an aside we note that because of the 1′ positional accuracy of the IPC, 10 minute "snapshot" observations with the VLA are an efficient complement to optical work in identifying faint extragalactic X-ray sources.

As can be seen from Table 1, radio detection rate for the whole sample is about 30%. As will be discussed later, the radio-optical luminosity function will be used to investigate the relation between X-ray and radio emission. From the results obtained here, there is a suggestion that serendipitous extragalactic X-ray sources often have associated radio emission on the order of a few mJy to several hundred mJy, even if it is not yet clear to what extent there is a direct physical relationship between the processes which give rise to the emission at these two wavelengths.

V. DISCUSSION

a) Active Galactic Nuclei

By combining the two samples, we have radio observations for 50 X-ray selected active galactic nuclei

TABLE 1

RESULTS OF RADIO OBSERVATIONS

X-Ray Source Name (1)	Optical Identification (2)	Radio Source Coordinates (1950.0) (3)	S(6 cm) (mJy) (4)
* 1E0013.4+1558	Cluster	...	< 1.0
* 1E0026.4+0725	Cluster	$00^{h}26^{m}26^{s}.5$ $+07°25'37''$	2.7
* 1E0037.7−0157	AGN	...	< 1.7
* 1E0038.0+3242	Class 1	...	< 1.1
* 1E0038.7+3251	AGN	...	< 2.4
* 1E0038.8−0159	AGN	00 38 52.7 −01 59 34 00 38 52.7 −01 59 36 00 38 52.6 −01 59 52	322.0
* 1E0104.2+3153	AGN/Galaxy[a]	...	< 0.9
1E0111.9−0132	AGN	...	< 2.1
1E0112.9−0147	AGN	...	< 15.8
* 1E0116.3−0116	Galaxy	01 16 20.3 −01 15 52	1.1
1E0126.4+0725	Cluster	01 26 23.6 +07 25 11	14.7
1E0135.0+0339	AGN	...	< 0.8
1E0136.3+0605	AGN	01 36 18.4 +06 06 22 01 36 18.9 +06 06 20 01 36 19.4 +06 06 17	16.3
1E0144.2−0055	AGN	...	< 0.8
* 1E0159.1+0330	Cluster	...	< 13.0
* 1E0302.5+1716	Class 1	...	< 1.3
* 1E0302.7+1658	Galaxy	03 02 43.2 +16 58 27	3.3
* 1E0317.0+1835	BL Lac	03 17 00.8 +18 34 45	17.0
* 1E0331.0−0522	AGN	...	< 1.1
1E0412.4−0803	AGN	04 12 27.3 −08 03 08	1.9
1E0438.6−1049	AGN	04 38 37.6 −10 50 22	26.8
1E0439.3−1102	Cluster	04 39 17.8 −11 03 14	16.5
1E0440.0−1057	AGN	...	< 1.6
1E0447.1−0917	AGN	...	< 1.0
1E0449.4−1823	AGN	04 49 24.7 −18 23 45	1.1
1E0450.3−1817	AGN	04 50 23.2 −18 16 57	2.6
* 1E0457.9−0555	AGN	...	< 0.8
1E0809.8+4809	AGN	...	< 21.4
1E0838.6+1324	AGN	...	< 1.8
1E0849.0+2845	AGN	08 49 04.5 +28 45 19	336.0
1E0849.2+2829	AGN	...	< 1.5
1E0849.8+2820	AGN	...	< 1.4
1E0850.0+2828	AGN	...	< 1.9
1E0850.2+2825	AGN	08 50 17.8 +28 25 14	37.0
1E0904.5+1650	Cluster	...	< 1.4
1E0937.8+1153	AGN	...	< 1.5
* 1E1018.1+2010	AGN	...	< 1.2
* 1E1112.6+4059	AGN	...	< 1.1
* 1E1137.5+6555	Cluster	...	< 1.4
1E1201.5+2823	Cluster	...	< 1.0
* 1E1205.8+6427	AGN	...	< 2.0
1E1207.9+3945	AGN[b]	12 07 55.1 +39 45 49	5.8
1E1208.3+3945	Galaxy	...	< 0.5
1E1208.7+3928	Cluster	12 08 44.0 +39 28 19	1.4
* 1E1218.1+7538	Galaxy	...	< 1.2
* 1E1218.7+7522	AGN	...	< 1.0
* 1E1220.0+7542	Cluster	12 19 56.9 +75 42 53	1.9
1E1223.5+2522	AGN	...	< 0.9
* 1E1235.4+6315	BL Lac	12 35 26.3 +63 15 12	15.2
* 1E1253.6−0539	AGN	...	< 13.5
1E1327.4+3208	AGN	...	< 14.0
1E1402.3+0416	BL Lac	14 02 19.7 +04 16 22	17.7
1E1415.0+2513	AGN	...	< 0.9
1E1415.1+2527	AGN	...	< 1.0
1E1416.2+2525	Cluster	14 16 16.4 +25 25 48	9.2
1E1416.7+2524	AGN	...	< 1.0
* 1E1430.4+0527	AGN	...	< 1.0
* 1E1439.8−0520	AGN	...	< 1.3

TABLE 1—*Continued*

X-Ray Source Name (1)	Optical Identification (2)	Radio Source Coordinates (1950.0) (3)	S(6 cm) (mJy) (4)
1E1454.0+2232	Cluster	14 54 00.3 +22 33 15	2.8
* 1E1522.1+3003	Cluster	...	< 1.2
1E1525.1+1550	AGN	...	< 25.0
1E1533.5+1440	AGN	...	< 1.3
1E1549.8+2022	AGN	...	< 0.9
* 1E1553.6+1558	AGN	...	< 1.3
* 1E1604.8+1552	AGN	...	< 1.5
* 1E1611.8−0324	AGN	...	< 1.7
* 1E1614.8+0533	AGN	{16 14 54.2 +05 34 07 16 14 53.6 +05 34 06 16 14 52.9 +05 34 04}	16.0
1E1617.9+1731	AGN	...	< 1.0
1E1745.2+2747	AGN	...	< 1.4
1E1910.5+6736	Cluster	...	< 2.0
* 1E2124.8−1459	AGN	...	< 1.3
* 1E2125.9−1456	AGN	...	< 1.1
* 1E2134.0+0017	Class 1	...	< 3.4
1E2141.6+0400	AGN	...	< 1.0
1E2223.6−0517	AGN	...	< 5.0
* 1E2348.6+1957	AGN	23 48 41.3 +19 57 05	2.2
* 1E2349.9+1951	Galaxy	...	< 1.0

[a] It is unclear if the X-ray emission of this source comes from a galaxy or a quasar, both of which are present in the IPC error circle. This object was not included in the statistical analysis of AGNs.

[b] The suggested counterpart for this X-ray source is a faint stellar object identified by Arp as a quasar (De Ruiter *et al.* 1977). This object was not included in the statistical analysis of AGNs because its redshift has not yet been confirmed (see Stocke *et al.* 1983).

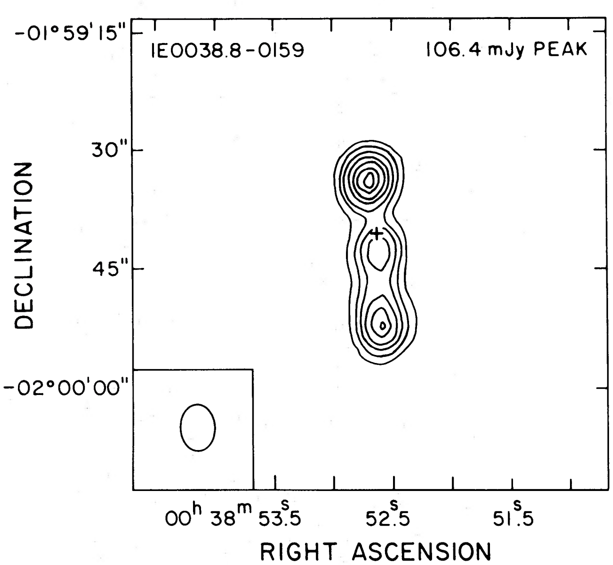

Fig. 1*a*

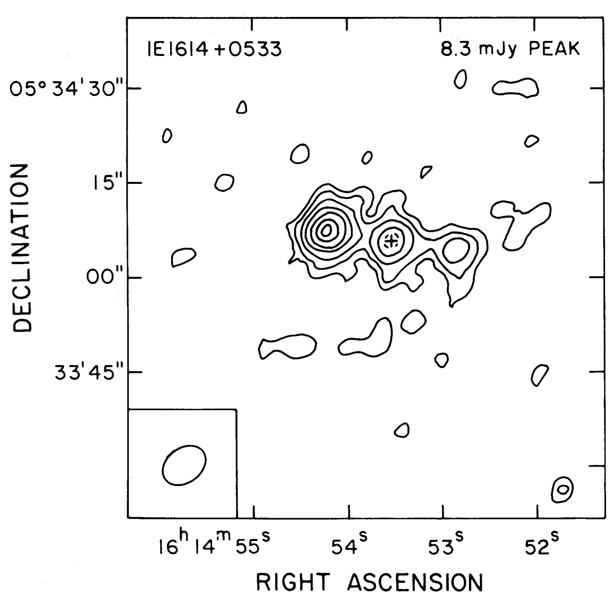

Fig. 1*b*

FIG. 1.—(*a*) Radio contour map for 1E0038.8−0159. Contour levels are 10%, 20%, 30%, 45%, 60%, 75%, 90% of the peak flux density. The HPBW is shown in the lower left corner. Optical position is indicated (*plus sign*). (*b*) Radio contour map for 1E1614.8+0533. Contour levels are 5%, 10%, 20%, 35%, 50%, 75%, 90% of the peak flux density.

with $1 \times 10^{-13} < F_x < 25 \times 10^{-13}$ ergs cm^{-2} s^{-1} and 15.0 $< m_v < 21.3$. Ten of them have been detected at 6 cm (1E0104.2+3153 and 1E1207.9+3945 are omitted from consideration, as discussed in Table 1). As in Paper I, we prefer to quote our results in terms of the integral radio-optical luminosity function $G(>R)$, which is defined as the fraction of objects for which R is larger than a given value: R is the ratio between the radio (5 GHz) and the optical (2500 Å) fluxes both computed in the source rest frame (see Schmidt 1970). The best estimates and the error bars for the values of the $G(>R)$ function have been computed applying the "detections and bounds" method of Avni *et al.* (1980). From the Sramek and Weedman (1980) sample of optically selected QSOs, we obtain $G(>R=10^{0.8}) = (13.4^{+3.8}_{-3.0})$% (228 objects, 19 detections); for our complete sample of 50 AGNs we obtain $G(>R=10^{0.8}) = (27.0^{+11.4}_{-8.9})$%.

A comparison between these two results is not straightforward; in fact, the intrinsic optical luminosities of the X-ray selected AGNs are, on the average, lower than those of the sample of the optically selected quasars here used as comparison (see Fig. 2). This implies that if the $G(>R)$ function is dependent on the optical luminosity, the difference in the rate of radio emission between X-ray selected and optically selected AGNs will be overestimated or underestimated depending on whether $G(>R)$ decreases or increases with the optical luminosity. Inspection of Figure 2 suggests that such dependence may indeed exist in the sense that objects which are more luminous in the optical have a higher chance to be detected in the radio. In order to reduce the effects of the possible dependence of $G(>R)$ on the optical luminosity and to improve the consistency of the two distributions, we have discarded the objects with the lowest optical luminosity in the X-ray selected sample and those with the highest optical luminosity in the optically selected sample. For the subsample of 30 X-ray selected AGNs with $L_{2500\,Å} > 10^{29.5}$ ergs s^{-1} Hz^{-1} (corresponding to M_v brighter than -23.0) we obtain $G(>R=10^{0.8}) = (40.2^{+19.8}_{-15.2})$%. For the subsample of 197 optically selected quasars with $L_{2500\,Å} \leq 10^{32}$ ergs s^{-1} Hz^{-1} we obtain $G(>R=10^{0.8}) = (9.9^{+3.1}_{-2.5})$%. Because of the relatively small number of X-ray selected QSOs, the difference between the two samples is significant only at the 95% level of confidence (2 σ). However, the fact that the percentage of X-ray selected quasars with $\log R > 0.8$ is higher than in the optically selected sample is in qualitative agreement with the existence of the correlation between radio and X-ray emission found in large samples of previously known quasars (Ku, Helfand, and Lucy 1980; Zamorani *et al.* 1981). Moreover, by using the optical luminosity function and the evolution law from Marshall *et al.* (1983), the radio-optical luminosity function computed by Avni (1983) for the Sramek and Weedman sample, and the correlations between radio and X-ray luminosities from Giommi *et al.* (1983), we find that $\sim (50 \pm 15)$% of the quasars with an X-ray flux of a few times 10^{-13} ergs cm^{-2} s^{-1} are expected to have $\log R > 0.8$. Thus the observed value of 40.2% is also quantitatively consistent with what is known about the correlations between radio, optical, and X-ray properties of quasars.

To summarize, we have some indications that the radio-optical luminosity function of X-ray selected quasars with $\log R > 0.8$ may be different from that of optically selected quasars ($40.2^{+19.8}_{-15.2}$% vs $9.9^{+3.1}_{-2.5}$%), but only larger samples of X-ray selected quasars can definitively prove it.

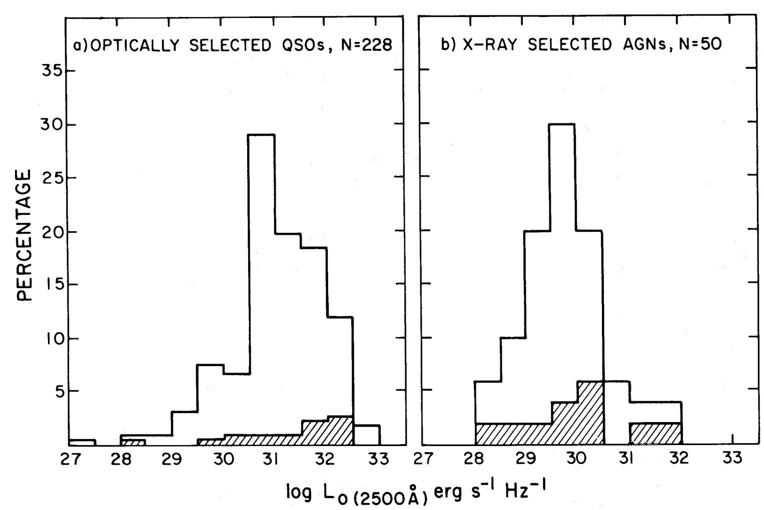

FIG. 2.—Distribution of the logarithmic monochromatic optical luminosities at 2500 Å for (*a*) 228 optically selected quasars and (*b*) 50 X-ray selected AGNs. Shaded area indicates radio detections.

b) *Clusters of Galaxies*

As part of a systematic study of the properties of X-ray selected clusters of galaxies, CCD images of all the X-ray sources considered to be associated with a cluster or a group of galaxies have been obtained. A detailed description of the observations and their analysis will be given elsewhere (Schild *et al.*, in preparation). Here we will use some preliminary results to investigate the link between X-ray, radio, and optical properties.

In the interest of clarity, we briefly summarize the relevant characteristics of the observations and of the data reduction. The optical data were obtained with the Center for Astrophysics CCD camera (Geary and Kent 1981) on the Whipple Observatory 0.61 m telescope during observing runs in 1981 November and 1982 May, in photometric conditions. The use of an autoguider on the telescope results in a point spread function of 1''.8 FWHM so that image quality is relatively unaffected by seeing. Preliminary reduction to standard photometric systems indicates that, for galaxies, the images have a magnitude limit of $m_R = 20.0$ and the source detection is probably complete to $m_R = 19.0$ (for our standard red exposure with a filter which approximates the *F* band of the photographic system). Details of the photometric system can be found in Schild and Kent (1981).

To obtain normalized galaxy counts, the images have been analyzed in the following manner. Galaxies have been counted, down to the CCD plate limit, in a circle of 1 Mpc diameter centered on the X-ray centroid. At the mean redshift of the clusters in our sample ($z \approx 0.15$), the chosen region corresponds to the largest useful circle inscribed within the CCD frame (3'.7). For the nearer clusters, several adjacent CCD frames were taken to obtain counts over the appropriate region of sky. The raw counts have then been corrected for the presence of background and foreground galaxies using Kron's (1980) counts and for different samplings of the cluster luminosity functions using the luminosity function of field galaxies of Davis and Huchra (1982). Finally, the *corrected* counts have been used to define three richness classes. Class A, the richest class, contains four clusters with more than 40 members. Class B, intermediate, contains five clusters with 20 to 40 members. Class C, the poorest class, contains five clusters with less than 20 members. An extreme example of a poor cluster belonging to this class is 1E0126.4+0725. Shahbazian 41, the optical counterpart of this X-ray source, consists of only two large galaxies ($M_v \approx -19$) plus numerous compact companions and is similar to the Local Group.

Given the small number of clusters observed (14) and detected (7) with the VLA, we attempt to obtain only qualitative information on the link between their optical, radio, and X-ray properties. In Figure 3, radio (5 GHz) versus X-ray (2 keV) luminosities are plotted for the 14 clusters in our sample. The richness class of each cluster is also indicated. Inspection of Figure 3 shows that no evident correlation exists between 5 GHz luminosity and X-ray luminosity or richness in X-ray selected poor clusters of galaxies. On the other hand, we note that the correlation between X-ray luminosity and cluster richness, known to be present in rich as well as in poor clusters (Bahcall 1980 and references therein), is present also in our data.

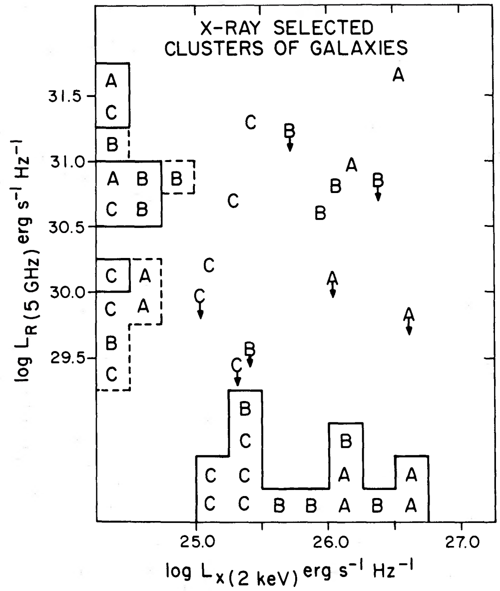

FIG. 3.—Logarithm of monochromatic radio luminosity at 5 GHz versus logarithm of monochromatic X-ray luminosity at 2 keV for the X-ray selected clusters of galaxies. Richness classes are also indicated. The histograms show the projections of the points into each axis. Dashed boxes indicate upper limits.

These results do not contradict the recent finding of Burns, Gregory, and Holman (1981), who have observed in the soft X-rays a sample of radio-selected poor clusters of galaxies and have thus approached the investigation of the link between radio and X-ray properties from a different angle. These authors have detected in the X-rays 10 out of 11 targets and have concluded that a significant correlation exists between radio and X-ray emission.

The current findings suggest that, while a cluster containing a bright radio source has a high probability of being detected in X-rays, an X-ray selected cluster does not necessarily host a bright radio source.

We would like to thank the VLA staff for their help and advice and the VLA time allocation committee for a prompt reallocation of time to observe the sources missed due to a computer failure. We are indebted to M. Reid and S. Rosenthal for their patient assistance in using the AIPS system at CfA. We thank D. Harris, J. Stocke, and our colleagues at the Istituto di Radioastronomia of Bologna for many helpful comments on an original manuscript, and Y. Avni, P. Giommi, J. Grindlay, J. Liebert, J. Steiner, and J. Stocke for communicating results prior to publication. E. Bohlen is thanked for her careful help in making finding charts. We are grateful to J. Flora for assistance in the preparation of this manuscript.

This work was supported in part by NASA contracts NAS8-30751 and NAS8-30752, and by the Italian PSN (Piano Spaziale Nazionale).

APPENDIX

NOTES ON INDIVIDUAL SOURCES

1E0013.4+1558 .... The X-ray source is identified with a nearby cluster of galaxies ($z = 0.08$). A 10 mJy source (empty field on Palomar Observatory Sky Survey = POSS), unrelated to the X-ray source, is located 4'.9 NW of the X-ray source location.

1E0026.4+0725 .... This unresolved radio source is coincident with the brightest galaxy of the group ($z = 0.170$).

1E0038.7+3251 .... This radio observation is degraded somewhat by the strong source 3C 19 which is located at 6'.7 NW of the X-ray position.

1E0038.8−0159 = 4C−02.04 .... The central component of this triple radio source, shown in Fig. 1*a*, is consistent with a cataloged QSO with a visual magnitude equal to 18.5 at $z = 1.69$ (Hewitt and Burbidge 1980). The entire source is about 19" long.

1E0116.3−0116 .... This unresolved radio source coincides with a bright galaxy.

1E0159.1+0330 .... This upper limit is poor due to the proximity of PKS 0159+034 (~ 250 mJy) which is 2'.1 SE of the X-ray location. This field is at the south edge of Abell 293.

1E0302.5+1716 .... A source of about 400 mJy (= MC3 0302+173, Sutton *et al.* 1974), unrelated to the x-ray source, appears 7'.5 NW of the X-ray position. Empty field on POSS prints.

1E0302.7+1658 .... The unresolved radio source coincides with a faint galaxy at $z = 0.20$.

1E0457.9−0555 .... A 9 mJy source, unrelated to the X-ray source, is located 3' N of the X-ray location. Empty field on the POSS prints.

1E1220.0+7542 .... This weak unresolved radio source coincides with the brightest galaxy in a distant group at $z = 0.24$.

1E1253.6−0539 .... The radio upper limit is poor due to the presence of 3C 279 at ~ 8'.5 north of the X-ray location.

1E1614.8+0533 .... The central component of this triple radio source, shown in Fig. 1*b*, is coincident with a QSO at $z = 0.855$. The radio source is elongated (~ 21") in the E-W direction.

1E2348.6+1957 .... This faint radio source, unresolved in our observation, coincides with a bright spiral (Seyfert 1) galaxy at $z = 0.045$ (Huchra, private communication).

REFERENCES

Avni, Y. 1983, in preparation.
Avni, Y., Soltan, A., Tananbaum, H., and Zamorani, G. 1980, *Ap. J.*, **238**, 800.
Baars, J. W. M., Genzel, R., Pauliny-Toth, I. I. K., and Witzel, A. 1977, *Astr. Ap.*, **61**, 99.
Bahcall, N. A. 1980, *Ap. J. (Letters)*, **238**, L117.
Burns, J. O., Gregory, S. A., and Holman, G. D. 1981, *Ap. J.*, **250**, 450.
Clark, B. G. 1980, *Astr. Ap.*, **89**, 377.
Davis, M., and Huchra, J. 1982, *Ap. J.*, **254**, 437.
De Ruiter, H. R., Willis, A. G., and Arp, H. C. 1977, *Astr. Ap. Suppl.*, **28**, 211.
Feigelson, E. D., Maccacaro, T., and Zamorani, G. 1982, *Ap. J.*, **255**, 392 (Paper I).
Geary, J. C., and Kent, S. M. 1981, *SPIE Symposium*, **290**, 51.
Gioia, I. M., *et al.* 1983, in preparation.
Giommi, P., *et al.* 1983, in preparation.
Hewitt, A., and Burbidge, G. 1980, *Ap. J. Suppl.*, **43**, 57.
Kron, R. 1980 *Ap. J. Suppl.*, **43**, 305.
Ku, W. H., Helfand, D. J., and Lucy, L. B. 1980, *Nature*, **288**, 323.
Maccacaro, T., *et al.* 1982, *Ap. J.*, **253**, 504.
Marshall, H. L., Avni, Y., Tananbaum, H., and Zamorani, G. 1983, *Ap. J.*, **269**, in press.
Schild, R., and Kent, S. 1981, *SPIE Symposium*, **290**, 186.
Schmidt, M. 1970, *Ap. J.*, **162**, 371.
Sramek, R. A., and Weedman, D. W. 1980, *Ap. J.*, **238**, 435.
Stocke, J., Liebert, J., Gioia, I. M., Griffiths, R. E., Maccacaro, T., Danziger, I. J., Kunth, D., and Lub, J. 1983, *Ap. J.*, **273**, in press.
Sutton, J. M., Davies, I. M., Little, A. G., and Murdoch, H. S. 1974, *Australian J. Phys.*, *Ap. Suppl.*, **33**, 1.
Thompson, A. R., Clark, B. G., Wade, C. M., and Napier, P. J. 1980, *Ap. J. Suppl.*, **44**, 151.
Zamorani, G., *et al.* 1981, *Ap. J.*, **245**, 357.

E. D. FEIGELSON: Department of Astronomy, Pennsylvania State University, University Park, PA 16802

I. M. GIOIA, T. MACCACARO, and R. SCHILD: Harvard-Smithsonian Center For Astrophysics, 60 Garden Street, Cambridge, MA 02138

G. ZAMORANI: Istituto di Radioastronomia, CNR, Via Irnerio, 46, 40126, Bologna, Italy