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THE ASTROPHYSICAL JOURNAL, 308:46–52, 1986 September 1

RADIO SOURCE COUNTS AT 6 CENTIMETERS TO 0.1 MILLIJANSKYS

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Received 1985 November 15; accepted 1986 February 12

ABSTRACT

We have used the Very Large Array of NRAO to make deep maps of two areas of the sky at $\lambda = 6$ cm. The 6 cm source counts are complete down to 0.1 mJy and are in reasonable agreement with earlier counts on a different region of the sky. The slope of the differential source counts from 10 to 0.1 mJy is -1.65 ± 0.1.

Subject headings: cosmology — radio sources: general

I. INTRODUCTION

Ever since the early work of Ryle (1968), it has been recognized that counts of radio sources can provide important cosmological information, especially about the evolution of radio sources (see, e.g., Doroshkevich, Longair, and Zel'dovich 1970; Peacock and Gull 1981; Condon 1984). The steady improvement in the sensitivity of both filled-aperture and aperture-synthesis radio telescopes has allowed the extension of counts to sources fainter than 1 mJy at ~1450 MHz (Condon and Mitchell 1984; Windhorst 1984; Windhorst *et al.* 1985) and at 4885 MHz (Fomalont *et al.* 1984). Counts of these faint sources have helped to constrain models for the formation and evolution of radio sources but have also raised new questions (Kulkarni 1978; Wall, Pearson, and Longair 1980; Peacock and Gull 1981; Danese, DeZotti, and Mandolesi 1983, Fomalont *et al.* 1984; Condon 1984; Windhorst *et al.* 1985). Among these unresolved issues are the early evolution of radio sources (was there a sharp turn-on of sources?), the differential evolution of sources of different spectral indices, the possible existence of a new population of flat-spectrum sources, the contribution of nearby ordinary (radio-quiet) galaxies to source counts, and the limitations radio sources set on searches for fine-scale anisotropy in the cosmic microwave background. Radio source counts at flux densities below 1 mJy may help resolve these issues.

This paper reports the results of a series of observations centered at 4885 and 4860 MHz, begun in late 1980, made with the Very Large Array (VLA) of the National Radio Astronomy Observatory. Section II below describes the observations and the maps constructed from them, § III the determination of source fluxes, and § IV the source counts.

II. OBSERVATIONS

The source counts we discuss here are by-products of two observational programs with different aims. The first set of observations (Knoke *et al.* 1984; Martin, Partridge, and Ratner 1986) was made with the VLA in its C configuration on the nights of 1980 October 1 and 2, and later in its D configuration in 1984 September to obtain observations of the microwave background on a larger angular scale. The second set was made in the D configuration in 1983 June, to search for the Sunyaev-Zel'dovich effect (Partridge *et al.* 1986).[2]

Details of the various observing programs and of the aperture-synthesis maps resulting from them are given in Table 1 and in §§ II*a* and II*b*. The phase stability for the observations was better than 5° for more than 99% of the data.

a) C-*Configuration Data*

These observations were made on an area centered at right ascension $3^{\mathrm{h}}10^{\mathrm{m}}00^{\mathrm{s}}$, declination $+80°08'00''$ (1950 coordinates). The high declination allowed continuous observations for a 12 hr period each night and insured that the baseline traces in the u–v plane were approximately circular, so that the synthesized beam was approximately radially symmetric.

We have surveyed this general region of the sky earlier at wavelengths of 3.7 and 11 cm (Martin, Partridge, and Rood 1980). The center of our current survey area was chosen, on the basis of these earlier observations, to avoid sources whose flux densities at 11 cm were $\gtrsim 5$ mJy. This earlier survey at 3.7 and 11 cm permits us to place constraints on the spectral indices of some sources detected at the VLA, and these are described in § III*d*.

The maximum available bandwidth of 55 MHz was employed. We obtained 20 hr of data in excellent weather. At the frequency we employed, 4885 MHz, the full width at half-power of the primary beam of the individual telescopes of the array was 9'.06 (Napier and Rots 1982). The synthesized beam of the array was approximately Gaussian down to 15% of peak power, with full width between half-power points of 6".0 in right ascension and 5".6 in declination. The maximum sidelobe power was 1.5% of the peak power (see Knoke *et al.* 1984).

We calibrated flux densities in this region using two radio

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[1] The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation.

[2] While this paper was in preparation, we learned of similar VLA observations on Abell 2218 carried out in 1983 June by Birkinshaw, Gull, and Padman (1986), and of a survey of 2218 by M. Birkinshaw (1986) using the Cambridge One-Mile Telescope (a 5C survey).

TABLE 1

Observations and Map Parameters

Date	Field Center (1950) R.A.	Field Center (1950) Decl.	Configuration	Center Frequency and Bandwidth (MHz)	Duration (hr)	Cell Size	Synthesized Beam	rms Noise (μJy per beam)
1980 Oct 1–2	$03^{h}10^{m}00^{s}$	+80°08′00″	C	4885, 55	20	1″.5	6″.0 × 5″.6	15
1983 Jun 8–9	Various near 3^{h}, +80°		D	4860, 100	0.1–0.3	5	various	~100
1984 Sep 7–13	03 10 00	+80 08 00	D	4860, 100	25	5	18.7 × 17.6	11
1983 Jun 8–9	16 35 42	+66 20 00	D	4860, 100	13	5	18.9 × 15.7	12

sources whose 6 cm flux densities had been monitored near the time of our observations by members of the VLA staff. As our primary flux calibrator, we used 0212+735, for which we assumed flux density $S = 2.23$ Jy at 4885 MHz in 1980 early October. A secondary calibrator was 1928+738, for which we determined flux density 3.08 Jy. These values are based on the absolute flux density scale of Baars *et al.* (1977) and were determined by comparison with 3C 48 and 3C 286. They are accurate to ±2% (at one standard deviation). Observations of the survey area were interspersed every 20 minutes by runs on one of our calibrators.

Using a variety of criteria, more fully described in Knoke *et al.* (1984), we eliminated visibility data spoiled by interference spikes, abrupt phase changes in one or more correlators, faulty records, noisy correlators, and correlators with constant nonzero offsets. Our general philosophy was to eliminate rather than retain questionable data. In all, we eliminated ~97,000 visibility records, or a total of 18% of our raw data. We note that these observations were made early in the history of the array: our more recent data were freer of problems such as phase jumps.

The visibility data were Fourier-transformed, then used to make total-intensity (Stokes parameter I) maps of each night's data separately and of the merged data for both nights. The maps of the C-configuration data were made with 1″.5 cells and were 2048 cells on a side. We thus mapped a region of the sky ~51′ square. In making maps, we used natural weighting, in which the visibility data are interpolated onto a grid and weighted in proportion to the number of measured points in each grid box. While this choice of weighting resulted in a synthesized beam 18% broader than would have been obtained with uniform weighting of the visibility data, it provided maximum sensitivity to weak sources in the map. Finally, following standard NRAO practice, we deconvolved the images using the "CLEAN" algorithm of Clark (1980). We CLEANed only the inner 1024 × 1024 cells, ≈25.6 × 25.6 arcmin^2, of the C-configuration map.

b) D-*Configuration Data*

The same region centered at right ascension $03^{h}10^{m}00^{s}$, declination +80°08′00″ was surveyed again at 4860 MHz for 25 hr in 1984 September using the VLA in its D configuration. Since we used both sets of correlators and both polarizations, we had available an effective bandwidth of 100 MHz for these observations. In this configuration, with natural weighting, the VLA had a synthesized beam size 18″.7 × 17″.6. Our flux densities were calibrated using 3C 286 as a primary calibrator and are again based on the absolute flux density scale of Baars *et al.* (1977).

A few brief "snapshot" observations of the stronger sources discovered in this field were also made in 1983 June (see § III).

In addition, 13 hr of data were obtained on another field centered at right ascension $16^{h}35^{m}42^{s}$, declination +66°20′00″, the nominal center of Abell cluster 2218 (Partridge *et al.* 1986). The effective bandwidth was again 100 MHz. The synthesized beam was 18″.9 × 15″.7 for this field. We again used 3C 286 as our primary calibrator. We dropped ~9% of our visibility records because of interference, correlator offsets, etc.

One novel feature of these D-configuration observations was the offset we introduced between the phase center and the field center, i.e., the center of the primary beam. In the case of the 03^{h} field, the offset was 6′ to the north; in the case of the 16^{h} field, the offset was 4′ to the west.[3] This process shifted instrumental noise associated with the phase center away from the position of maximum sensitivity (see Partridge *et al.* 1986).

Maps of 512^2 cells of 5″ on a side were constructed of the edited D-configuration visibility data. As for the other maps, natural weighting was used, and the resulting images were CLEANed. The inner portion (256 × 256 cells = 21.3 × 21.3 arcmin^2) of the map of the 3^{h} field is shown in Figure 1 (the map of the 16^{h} field will appear in Partridge *et al.* 1986).

III. SOURCES AND THEIR FLUX DENSITIES

In the map of the 3^{h} field constructed from C-configuration data we detected 26 possible sources, with peak flux densities ranging down to 66 μJy per synthesized beam area (uncorrected for the primary beam response). Of these, 19 appeared in both the map made from the first night's data and in the map made from the second night's data at or above 3 times the map noise. All these 19 candidate sources were clearly visible also in the D-configuration map of the same field; we accepted as real only candidates which appeared in both C- and D-configuration maps. In the map of the 16^{h} field, we detected 24 candidate sources, with peak fluxes ranging down to 60 μJy per beam (uncorrected for the primary beam response).

To limit the possibility that statistical fluctuations in the map brightness might erroneously be counted as sources, we set thresholds $S_{\rm th}$ on the uncorrected flux per synthesized beam. For the maps of the 3^{h} field, candidate sources were included in the final counts only if their peak flux density was $\geq S_{\rm th} = 75$ μJy per beam and if they appeared in both the C-configuration merged map and the D-configuration maps. This threshold is ~4.8 times the rms noise in the higher resolution C-configuration map and ~6.8 times the rms noise in the D-configuration map. The chance that we have included a noise spike or spurious source is much less than 1%.

Likewise, for the 16^{h} field, we set a threshold $S_{\rm th} = 60$ μJy

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[3] The observations of the 16^{h} field were made before an automatic offset procedure had been implemented at the VLA. The 4′ offset was introduced by time-dependent pointing corrections (and is described in Partridge *et al.* 1986).

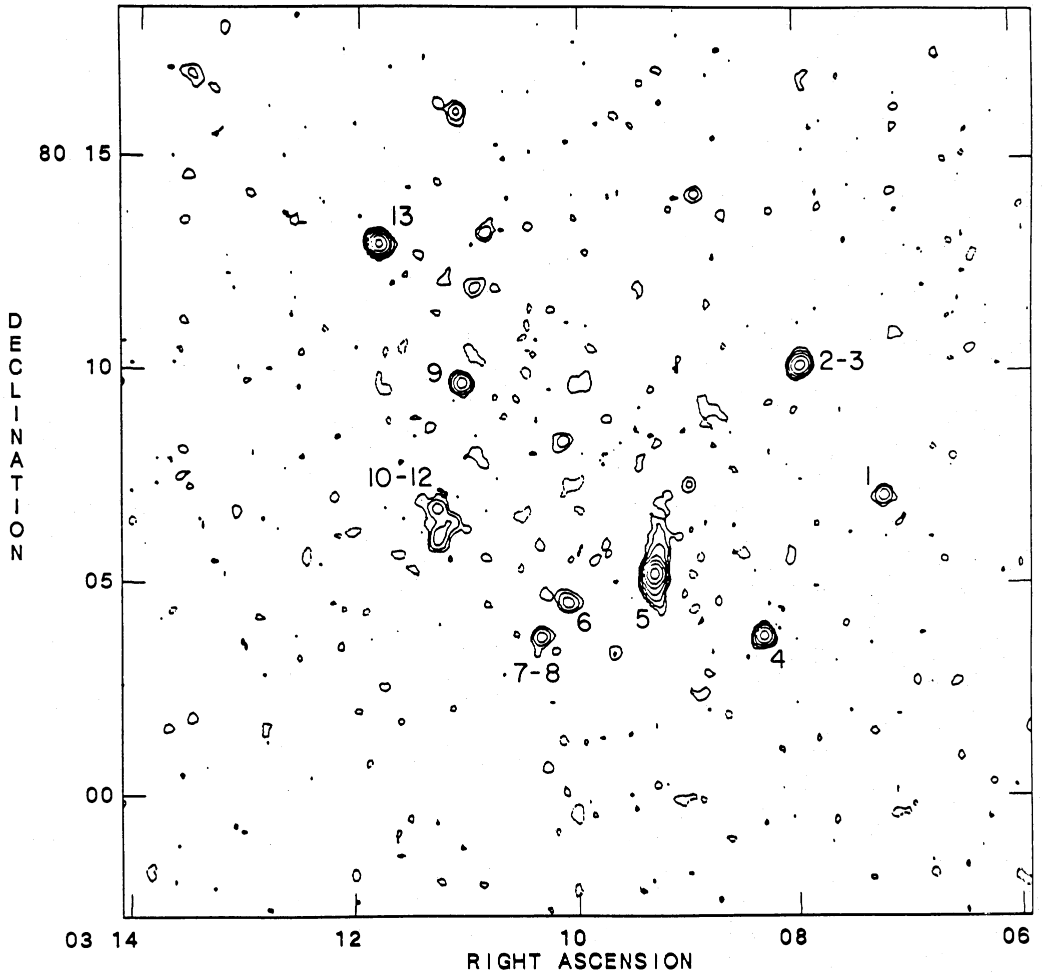

FIG. 1.—Map of the 3^h field. The inner 256^2 cells of the 6 cm map made with the VLA in the D configuration are shown. The source numbers correspond to those in Table 2 (peak flux, 1.78 mJy per beam; levels, 2×10^{-5} times -2, -1, 1, 2, 4, 8, 16, 32, and 64 Jy per beam).

per beam, ~4.9 times the rms noise of the map. If the noise statistics are Gaussian, the chance that we included a spurious source is less than 0.1%.

a) *Determination of Fluxes*

Once the sources were identified, we determined flux densities for them as follows: we first fitted each source separately with a two-dimensional Gaussian model to obtain an integrated flux for it. The fitted parameters were half-widths along the major and minor axes, position angle, peak flux, and integrated flux density, the last of which we write as S_u. Trials with different fitting programs with different procedures for background flux subtraction gave consistent results for S_u. Note that this means of determining flux densities compensates for the loss of sensitivity for point sources caused by the "smearing" of the synthesized beam produced by the nonzero bandwidth and integrating time we used (see Condon, Condon, and Hazard 1982). In the case of the 3^h field, since there were no significant differences in the fluxes determined from the C-configuration and D-configuration maps for unresolved sources, these were averaged to give the values of S_u in Table 2.

Next, it is necessary to take account of the fact that sources far from the field center appeared in the map with reduced flux densities because the primary beam power pattern fell off away from the map center. To calculate the primary beam pattern at a radial distance r arcmin from the map center, we used the power-law formula for the inverse of the primary beam power $P^{-1}(r)$ given by Napier and Rots (1982). Source flux densities corrected for primary beam response using $S_c = P^{-1}(r)S_u$ are given in the fifth column of Table 2.

The quantity $P(r)$ is known to ± 0.02 (or better than 22% accuracy) out to 7ʹ.7 from the field center, where $P(r) \approx 0.09$. As the distance from the field center increases, the corrected flux densities S_c become less certain both because P^{-1} is not known precisely and because instrumental noise is, in effect, amplified by P^{-1}. As a consequence, we restricted our counts to the inner 8ʹ of the maps (i.e., $r \leq 8'$). With this condition imposed, we found 13 candidate sources above the 75 μJy per beam threshold in the 3^h field, and 19 above the 60 μJy per beam threshold in the 16^h field. These sources and their positions are listed in Table 2 (see also Fig. 1 for the 3^h field).

b) *Subsequent "Snapshot" Observations of Some Sources*

To confirm our calculated fluxes for sources at $r > 5'$, we made several brief (~20 minute) observations of some of the brighter of these sources with the antennas of the array pointed at each individual source in turn. After the resulting maps were

TABLE 2

SOURCES AT 6 CENTIMETERS

Number (1)	R.A. (1950)[a] (2)	Decl. (1950)[a] (3)	Uncorrected Flux S_u (mJy) (4)	Corrected Flux S_c (mJy) (5)	Directly Measured "Snapshot" Flux (mJy) (6)	Adopted Flux (mJy) (7)
1	$3^h07^m09^s$	+80°07′04″	0.16 ± 0.03	1.37 ± 0.26	1.3 ± 0.4	1.35
2	07 53	10 12	0.32 ± 0.06	1.03 ± 0.19	2.2 ± 0.5	2.2
3	07 56	10 05	0.34 ± 0.07	1.05 ± 0.21		
4	08 16	03 49	0.46 ± 0.03	1.73 ± 0.10	1.4 ± 1.0	1.6
5	09 16	05 15	2.23 ± 0.13	3.23 ± 0.19	...	3.2
6	10 03	04 36	0.18 ± 0.04	0.26 ± 0.05	...	0.3
7	10 18	03 46	0.25 ± 0.05	0.45 ± 0.10	0.5 ± 0.1	0.5
8	10 18	03 42	0.12 ± 0.05	0.23 ± 0.10		
9	11 01	09 43	0.29 ± 0.05	0.40 ± 0.07	...	0.4
10	11 08	06 29	0.15 ± 0.05	0.21 ± 0.07	1.14 ± 1.40	1.1
11	11 14	06 10	0.23 ± 0.05	0.35 ± 0.08		
12	11 15	06 48	0.16 ± 0.04	0.24 ± 0.07		
13	11 47	12 59	0.95 ± 0.08	4.1 ± 0.5	4.9 ± 0.5	4.5
14	$16^h35^m06^s$	+66°19′42″	0.29 ± 0.05	0.45 ± 0.08	...	3.0
15	35 10	19 22	1.82 ± 0.13	2.59 ± 0.18		
16	35 10	18 20	0.12 ± 0.04	0.19 ± 0.06	...	0.2
17	35 19	24 41	0.13 ± 0.02	0.32 ± 0.05	...	0.3
18	35 29	13 34	0.14 ± 0.03	0.65 ± 0.14	...	0.7
19	35 29	20 00	0.89 ± 0.04	0.92 ± 0.04	...	0.9
20	35 35	20 45	2.74 ± 0.06	2.77 ± 0.06	...	3.4
21	35 38	21 07	0.65 ± 0.37	0.67 ± 0.38		
22	35 40	15 46	0.11 ± 0.03	0.20 ± 0.05	...	0.2
23[b]	35 42	22 34	0.08 ± 0.03	0.12 ± 0.04	...	...
24	35 42	22 54	0.11 ± 0.03	0.14 ± 0.04	...	0.14
25	35 43	17 52	0.12 ± 0.03	0.17 ± 0.04	...	0.17
26	35 44	24 10	1.41 ± 0.03	2.50 ± 0.05	...	2.5
27	35 44	22 14	0.12 ± 0.05	0.14 ± 0.06	...	0.14
28	35 52	17 40	0.15 ± 0.03	0.18 ± 0.04	...	0.18
29	35 53	18 58	0.19 ± 0.02	0.20 ± 0.02	...	0.2
30	35 55	21 30	0.10 ± 0.03	0.10 ± 0.03	...	0.1
31[b]	35 58	16 24	0.06 ± 0.04	0.10 ± 0.07	...	...
32	36 04	20 23	3.36 ± 0.05	5.04 ± 0.08	...	5.0

[a] Positions accurate to 5″ or ~1^s (~2 σ values), as determined from comparison of different maps of the field and different Gaussian model fits.

[b] Not included in the final counts because $S_u < 100\ \mu$Jy (see text).

CLEANed, two-dimensional Gaussian fits were made to each source, as above, to provide estimates of the integrated flux for each. These are tabulated for six sources in column (6) of Table 2. The generally good agreement (±20%, or within the errors) with values of S_c for these sources gives us confidence in our corrections for primary beam response.

c) *Optical Identifications*

We inspected the NRAO copy of the Palomar Sky Survey (E plate) in an effort to locate optical images within 5″ (or ~2 σ error circle) of the radio positions listed in Table 2. Subsequently, the Haverford copy of the PSS O print was also examined. Of the 32 fields we searched, 23 were blank on both.

One source (No. 32) was centered on a ~15 mag foreground spiral galaxy, Zw 320.033. Source 20 was located 3″ ± 3″ from the south following member of a close pair of 18th–19th mag apparently stellar objects with a separation of 8″ ± 2″. Sources 25 and 28 were associated with 18th–19th mag galaxies near the center of Abell cluster 2218; this range of magnitude is consistent with membership in the cluster. Two sources, Nos. 5 and 10, are identified with ~18th and ~20.5 mag stellar objects respectively. Numbers 7 and 8, probably components of a single source, coincide with a (barely) nonstellar image of ~17th mag and No. 23 with a nonstellar image of ~20th mag.

The identified fraction, 9/32 = 28%, is consistent with other work employing the Sky Survey to identify mJy radio sources (see, e.g., Perryman 1979; Windhorst, Kron, and Koo 1984).

d) *Comparison with* 3.7 *and* 11 cm *Observations*

The 3^h region was mapped at wavelengths of 3.7 and 11 cm in 1977 October (Martin, Partridge, and Rood 1980) with the Green Bank three-element interferometer. The rms noise of these maps was much higher than that of our VLA maps, ~0.5 and ~0.6 mJy per synthesized beam area at 3.7 and 11 cm respectively. Nevertheless, we examined the 1977 maps for images at the locations of the five brightest sources in the 3^h field (Nos. 1, 2–3, 4, 5, and 13 of Table 2). The results of this work are shown in Table 3. Only one of the VLA sources was detected at either 3.7 or 11 cm—source 5 is seen marginally at 3.7 cm and appears to have a flat spectrum. If we make the *assumption* that the sources are not variable, comparison of our 1980 and 1984 VLA flux densities with the upper limits from the earlier work permits us to set limits on the spectral indices of these five sources, as shown in Table 3.

IV. SOURCE COUNTS

Before we compare our results to earlier work, we must consider and correct for three effects which influenced our source counts. We first consider two effects which would have

TABLE 3

ESTIMATED LIMITS ON SPECTRAL INDEX

Source	6 cm (4885 MHz) Flux (mJy)	11 cm (2695 MHz) Flux (mJy)	Spectral Index α_6^{11}	3.7 cm (8085 MHz) Flux (mJy)	Spectral Index $\alpha_{3.7}^6$
1	1.35	$\lesssim 3.5$	< 1.6	< 2.1	> -0.9
2–3	2.2	$\lesssim 5.0$	< 1.4	< 2.1	> 0.1
4	1.6	$\lesssim 3.5$	< 1.3	< 2.9	> -1.2
5[a]	3.2	$\lesssim 3.5$	< 0.15	3 ± 1	$0.13^{+.8}_{-.6}$
13[a]	4.5	$\lesssim 2.5$	< -1.0	< 2.1	> 1.5

[a] Sources 5 and 13 appear to have flat and peaked spectra respectively (or to be variable). The former source is associated with an ~ 18th mag nonstellar optical image; the latter is unidentified optically.

caused us to miss weak sources, then one which would cause an overcounting in the case of multicomponent sources.

a) Selection Effects

Clearly, many of the weaker sources found near the map center would not have been detected had they been further from the center, because of the decrease in the primary beam response $P(r)$ with increasing r. To account for this variable sensitivity, we adopt the method suggested by Katgert *et al.* (1973) and used by Condon, Condon, and Hazard (1982). In the notation of the latter paper, we define the effective number of sources in the nominal solid angle of our survey, $\Omega_s = 201$ arcmin^2:

$$N_{\text{eff}} = \left(\sum_{i=1}^{n} \Omega_i^{-1} \right) \Omega_s \, ,$$

where Ω_i is the solid angle in which the ith source would have been detected above our threshold S_{th} on peak flux density. The value of Ω_i is given by

$$\Omega_i = \pi r_i^2 \, ,$$

where r_i is found from

$$C(r_i) P^{-1}(r_i) = \frac{S_i}{S_{\text{th}}} \, ,$$

with S_i the peak flux of the ith source, in μJy per beam. The error in the calculated quantity N_{eff} is given by $(\Sigma \Omega_i^{-2})^{1/2} \Omega_s$ (Condon, Condon, and Hazard 1982).

Since the criterion for the identification of sources was based on peak flux and not S_u, we must explicitly include the reduction in peak flux (but not integrated flux) caused by beam smearing due to finite bandwidth and integrating time. Since the correction is not large for $r \leq 8'$, we adopt the expression introduced by Knoke *et al.* (1984),

$$C(r) = \left[1 + \left(\frac{0.0114 r}{\theta} \right)^2 \right]^{1/2} \left[1 + \left(\frac{0.002 r}{\theta} \right)^2 \right]^{1/2} ,$$

in which the integration window, the bandpass, and the synthesized beam pattern are all approximated as Gaussian functions. Here, for point sources, θ is the synthesized beam width. For the D-configuration data, for which $\theta \approx 18''$, $1.0 \leq C(r) \leq 1.05$ for $0 \leq r \leq 8'$. The quantity $C(r)$ is larger for the C-configuration data, for which $\theta \approx 6''$: $1.0 \leq C(r) \leq 1.37$.

b) Completeness Limits

Next, we must consider the fact that the integrated flux density S_u of a source was generally larger than its peak flux density S_p, especially in the case of a resolved source. In the case of the higher resolution (~6″) C-configuration map of the 3^{h} field, the mean of the ratio S_u/S_p for the 13 sources in Table 2 was 1.6, with a standard deviation of 0.3. Hence our threshold of 75 μJy in S_p corresponds to an effective threshold of 120 ± 23 μJy in integrated flux. We cannot, however, claim 120 μJy as the completeness limit for our catalog of sources, because of the possibility that we could have missed sources with a peak flux $S_p < 75$ μJy but integrated flux $S_u > 120$ μJy. If we assume that the ratio S_u/S_p has a Gaussian distribution with the mean and standard deviation given above, then we may easily calculate the completeness at any value of S_u. For the C-configuration data, the probability of omitting a source drops below 0.5% as the threshold on S_u rises above 180 μJy, which we take as the completeness limit of our catalog. At this limit, lack of completeness is a negligible source of error compared to statistical fluctuations in the counts of sources.

For the D-configuration maps, S_u/S_p is much closer to unity because the synthesized beam is larger (~18″). Hence the limit on S_u may be set closer to the threshold on S_p. We find $S_u/S_p = 1.1 \pm 0.2$,[4] in good agreement with the value (1.14) given by Fomalont *et al.* (1984). On the basis of a similar statistical assumption, we take a completeness limit of 100 μJy for the 2218 field. Hence sources 23 and 31 are not included in the final counts in Table 4.

c) Multiple Sources

Although sources 2 and 3 were clearly resolved in our C-configuration survey, their very small separation suggests they are physically related. In addition, we note that most surveys at $\lambda \approx 6$ cm have been made with angular resolution poorer than ours. In the surveys of Willis and Miley (1979) and of Fomalont *et al.* (1984), for instance, sources 2 and 3 would not have been resolved. Hence for comparison with earlier work we treat this double as a single radio source. Similarly, the three close pairs of sources (7 and 8, 14 and 15, and 20 and 21) were treated as single sources. The case of sources 10, 11, and 12 is less clear (see Fig. 1). We could treat them as a close triple (three sources each ~200 μJy) or as a single, stronger source (with $S \approx 1$ mJy). Only No. 10 is identified optically, with a ~20th mag object. Finally, we must take account of the fact that the 16^{h} field was centered on a cluster of galaxies. Some of the galaxies in the cluster are presumably radio sources. The optical images of sources 25, 28, and 29 suggest that they are constituent galaxies of the cluster. Hence we elect to exclude

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[4] The presence of noise in the map permits values of $S_u < S_p$.

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TABLE 4

SOURCE COUNTS AT 6 CENTIMETERS

FLUX DENSITY INTERVAL (mJy) (1)	AVERAGE FLUX (mJy) (2)	ALL SOURCES[a]		EXCLUDING CLUSTER SOURCES; MERGING MULTIPLE SOURCES[a]		NUMBER EXPECTED[a] (7)	NORMALIZED SOURCE COUNTS[a] (8)
		N (3)	$N_{\rm eff}$ (4)	N (5)	$N_{\rm eff}$ (6)		
0.1–0.18	0.13	5	18.1 ± 8.6	3	12.9 ± 7.7	598[b]	$2.2 \pm 1.3 \times 10^{-2}$
0.18–0.6	0.31	12	37.6 ± 12.3	6	16.8 ± 6.9	706	$2.4 \pm 1.0 \times 10^{-2}$
0.6–2.0	1.13	7	8.7 ± 3.3	5	5.75 ± 2.6	116	$4.9 \pm 2.2 \times 10^{-2}$
>2.0	3.4	6	6.0 ± 2.45	7	7.0 ± 2.65	22.8	$3.1 \pm 1.2 \times 10^{-1}$

[a] In cols. (3) and (4) we include all 30 sources in the catalog; in cols. (5), (6), and (8), multiple sources are merged and sources thought to be associated with Abell cluster 2218 are excluded (see text). The number expected in our survey area is calculated from $dN = 90S^{-2.5}dS$.

[b] Note that only one of the two areas surveyed contributes to the lowest flux density interval.

these three sources from our counts. To take account of the uncertainties in our treatment of two possible triple sources 10, 11, and 12 and 25, 28, and 29, we display the possible range of source counts and of effective number $N_{\rm eff}$ in Table 4.

Since we have so few sources, we divide them into only four bins of corrected flux density S_c, each containing roughly one-fourth the sources. Also, following Fomalont *et al.* (1984), we normalize our counts to the relation for the differential source count:

$$dN = 90S^{-2.5}dS \text{ sr}^{-1} .$$

The index -2.5 holds in a static, homogeneous, Euclidean model, and dN is normalized at fluxes greater than 100 mJy. Our normalized source counts are given in the final column of Table 4 and shown in Figure 2.

Clearly, as shown in Table 4, our source counts fall well below the Euclidean extrapolation of the counts above 100 mJy. Our results suggest a slope of -1.65 ± 0.1 rather than -2.5 in the differential source count law for $0.1 \leq S \leq 10$ mJy.

Our normalized source counts are generally higher than those of Fomalont *et al.* (1984) by as much as a factor of 2, but, given the large statistical uncertainties in both sets of counts, the agreement is reasonable. However, we also appear to have (slightly) higher counts than would be predicted by an extrapolation of the NRAO (Ledden *et al.* 1980) and Bonn (Pauliny-Toth *et al.* 1978) source counts.

Nevertheless, our results on two fields, taken in conjunction with those of Fomalont *et al.* (1984), show that field-to-field variations in the faint source counts at 6 cm are less than a factor of 2 in regions of solid angle 200 arcmin$^2 \approx 10^{-5}$ sr.

Our results are consistent with a flattening of the normalized source counts at $S \lesssim 2$ mJy, with $dN \propto S^{-2.0 \pm 0.2}$. Such a relationship is in good quantitative agreement with the results of Windhorst *et al.* (1985) at 21 cm. They find $dN \propto S^{-2.1}$ for 21 cm flux densities $S < 5$ mJy. Our results match theirs well if we assume a mean spectral index of ~ 0.7 between 21 cm and 6 cm, as suggested by the 50 cm and 21 cm observations of Windhorst (1984). Thus our results do not provide evidence for the emergence of a new population of flat-spectrum radio sources.

Our results are not complete enough to permit us to comment on the possibility raised by Fomalont *et al.* (1984) that the sources at $S \lesssim 100$ μJy "may represent the contribution of a new population—that is, normal galaxies—" to the source counts. That possibility will be further considered in a separate paper (Martin, Partridge, and Ratner 1986) in which

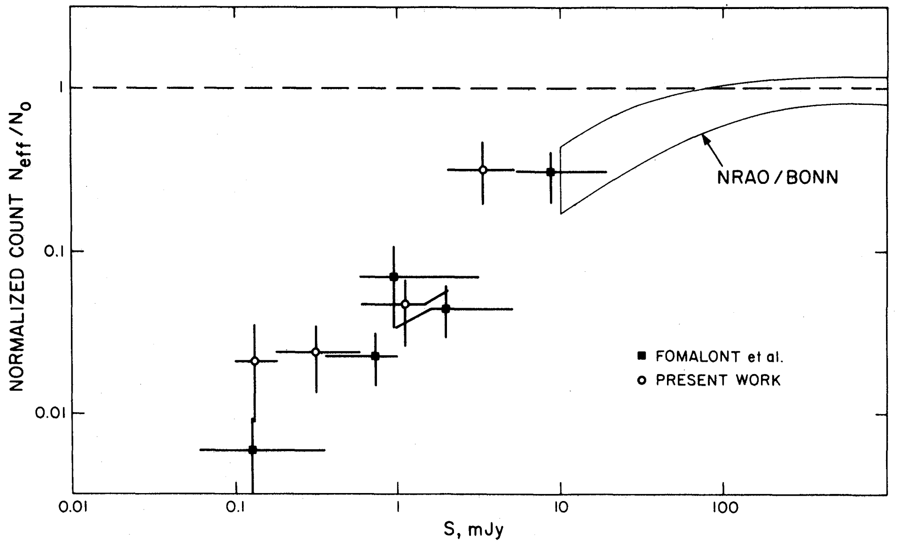

FIG. 2.—Counts of radio sources at 6 cm, normalized to $90S^{-2.5}$, the Euclidean value. The values plotted are from the second and last cols. of Table 4. The NRAO/Bonn counts are from Ledden *et al.* (1980) and Pauliny-Toth *et al.* (1978) and are shown schematically only.

we treat the observable effects in our maps of sources below our detection threshold.

This work was supported in part by NSF grants AST 80-0737 to Haverford College and PHY 84-09671 to Harvard University. The optical identifications at NRAO were made by Roger Foster, who also assisted with the flux density computations. Hank Donnelly and Paul Martenis helped with the data analysis at Haverford College. We acknowledge with thanks helpful conversations with H. M. Martin of NRAO and many helpful suggestions from R. Windhorst.

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