

## THE LOG $N$ -LOG $S$ CURVE FOR 3CR RADIO GALAXIES AND THE PROBLEM OF IDENTIFYING FAINT RADIO GALAXIES

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### ABSTRACT

A new study of the galaxies associated with radio sources in the 3CR catalog has been made. If we exclude the quasi-stellar objects, there remain 253 extragalactic sources of which 140 have been identified with galaxies and 113 remain unidentified. The slope of the log  $N$ -log  $S$  curve for the 253 sources is  $1.81 \pm 0.13$ . Of the 140 identified galaxies, redshifts are available for  $\sim 100$ , and their mean redshift  $\bar{z} \approx 0.14$ . Since the radio galaxies give a reasonable Hubble plot, we estimate that the mean redshift for the 140 identifications  $\bar{z} \approx 0.19$ .

It is shown that the log  $N$ -log  $S$  curve for the identified sources has a slope of  $1.50 \pm 0.14$ , while if we restrict ourselves to those with measured redshifts the slope is  $1.16 \pm 0.16$ .

It is the 113 unidentified sources comprising now only 45 percent of the total which are responsible for the steep slope. That slope is frequently assumed to be due to evolution at redshifts  $z \approx 1-3$ . On that assumption, and still supposing that the sources are bright ellipticals, the mean redshifts and apparent brightnesses of these galaxies are calculated, and it is shown that with existing ground-based telescopes it will be impossible to observe them; i.e., at present it is impossible to establish *directly* that evolution is responsible for the steep log  $N$ -log  $S$  curve for galaxies.

*Subject headings:* cosmology — galaxies: general — galaxies: redshifts — radio sources: general

### I. INTRODUCTION

The counting of radio sources down to different flux levels constitutes a potential test of cosmological models provided the sources are extragalactic and at appreciable redshifts. To reach an unambiguous conclusion it is necessary that the optical and radio properties and the distances of a large fraction, or ideally all, of the sources in a given survey are obtained.

Realistically, because of limitations on telescope time, the small number of optical astronomers working on the problem, and the faintness of the optical objects, the only radio source survey covering a large fraction of the sky in which this information is likely to become available in the foreseeable future is the 3C (revised) survey (Bennett 1962). This survey goes down to 9 Jy at 178 MHz and lists 304 sources thought to lie outside our Galaxy. According to the latest compilation by Spinrad and Smith (1975) about 140 of these have by now been identified with galaxies and 51 with QSOs. The remaining 113 objects either have remained unidentified or have only tentatively been identified.

It is generally agreed that the slope of the log  $N$ -log  $S$  curve for all of these sources is steeper than the Euclidean value and is about 1.8 (Longair and Rees 1972). At least two classes of objects are involved: galaxies and QSOs. The majority of the QSOs have measured redshifts. If those redshifts are cosmological

in origin, the analysis originally due to Schmidt (1968) shows that large-scale evolutionary processes are at work at large redshifts. However, the nature of the redshifts of these objects is still a matter for debate (cf. Field, Arp, and Bahcall 1974; Burbidge 1973). If we subtract the sources identified with QSOs from the 3CR Survey, the log  $N$ -log  $S$  slope is still steeper than the Euclidean with a value of  $1.81 \pm 0.13$ . As will be discussed in § II, this steepness arises largely from the so-called unidentified sources. Are they galaxies or QSOs at great distances, or are they comparatively nearby objects? For significant cosmological conclusions to be drawn, the former possibility must hold. In that case various authors (cf. Rees 1972; Longair 1971) have argued that they may have cosmological redshifts as high as  $z \approx 3$ . We shall discuss in § III the question that arises as to whether they can be identified and their redshifts obtained.

In order to make realistic estimates of the possibility of optical investigation of sources at appreciable redshifts, we need to assume a value for the deceleration parameter  $q_0$ . The most recent observations (Gunn and Oke 1975) suggest that  $q_0$  (if positive) is small compared with unity, and thus in what follows we shall assume that the cosmological constant  $\Lambda = 0$  and put  $q_0 = 0$ .

### II. THE SOURCE COUNT FOR RADIO GALAXIES

We first consider the log  $N$ -log  $S$  slope for optically identified radio galaxies in the 3CR catalog with

$S > 10$  Jy, and with galactic latitudes  $b$  restricted by  $|b| > 7^\circ$ , as in the Molonglo Radio Source Catalogs 2 and 3 (Sutton *et al.* 1974). We have excluded the  $|b| < 7^\circ$  group because it may pose problems with optical identification due to closeness to the galactic plane. It is, of course, possible to consider more limited regions, e.g.,  $|b| > 15^\circ$ ,  $|b| > 20^\circ$ , etc., but we find that the slopes do not differ significantly from those discussed below.

For the 86 galaxies with known redshift in the compilation of Spinrad and Smith with  $S > 10$  Jy, we find that the slope  $\alpha$  of the  $\log N$ - $\log S$  curve is  $1.16 \pm 0.16$ ; while if we include all of the galaxies which have been identified whether or not redshifts have been obtained, 119 in all,  $\alpha = 1.50 \pm 0.14$ . The slopes have been computed by using the maximum likelihood method of Crawford, Jauncey, and Murdoch (1970). The error bars are at the  $1\sigma$  level. Similar results were obtained earlier for the 3CR sources by Véron (1966) and Jauncey (1967) and from the 6 cm survey by Pauliny-Toth and Kellermann (1972).

The plot of  $\log z$  against  $\log S$  for all sources gives a scatter diagram as noted earlier by Hoyle and Burbidge (1970) for a smaller sample. The average redshift of all 100 galaxies of the 3CR catalog is  $\sim 0.14$ . If we limit the sample to the 86 galaxies mentioned above or to smaller samples with  $|b| > 15^\circ$ , the average remains unchanged, indicating no significant change in the distribution of redshifts with lower latitudes. For small redshifts  $Sz^2$  is proportional to the radio luminosity  $L_R$  of the source. A plot of  $\log z$  against  $\log L_R$  for the sample in question shows a definite trend with a straight-line slope of  $\frac{1}{2}$ . This is to be expected since  $S$  is uncorrelated with  $z$ . However,

such a plot also shows that the number of points in equal intervals of  $\log L_R$  is very nearly constant. This observation can be used to deduce the radio luminosity function  $f(L_R)$  as follows.

At a given flux level  $S$  the sources with a given luminosity  $L_R$  will have a maximum redshift given by

$$z \propto (L_R/S)^{1/2}. \quad (1)$$

Hence the number of sources with luminosity in the range  $(L_R, L_R + dL_R)$  is given by

$$dN \propto (L_R/S)^{3/2} f(L_R) dL_R, \quad (2)$$

provided the source distribution is uniform. Using the observed result that  $dN \propto d \log L_R \propto dL_R/L_R$ , we get from the above

$$f(L_R) \propto L_R^{-5/2}. \quad (3)$$

That is, the number of sources with radio luminosity in the range  $(L_R, L_R + dL_R)$  is proportional to  $L_R^{-5/2} dL_R$ . Von Hoerner (1973) finds a luminosity function for radio galaxies of this form based on the data compiled by various groups (Longair 1966, 1971; Carswell and Wills 1967).

Hoyle (1971) has argued that with this luminosity function the number of sources in a redshift range  $z, z + dz$  which will be observed down to a given flux level  $S$  will be proportional to  $d \log z$ . In Figure 1 we have plotted the number of sources with redshift less than  $z$  against  $\log z$ , for all radio galaxies with known  $z$ . It is remarkable that the linear relation holds over a wide range of  $z$  except at the high or the low end. The departure at small  $z$  is due to a cutoff or a change in

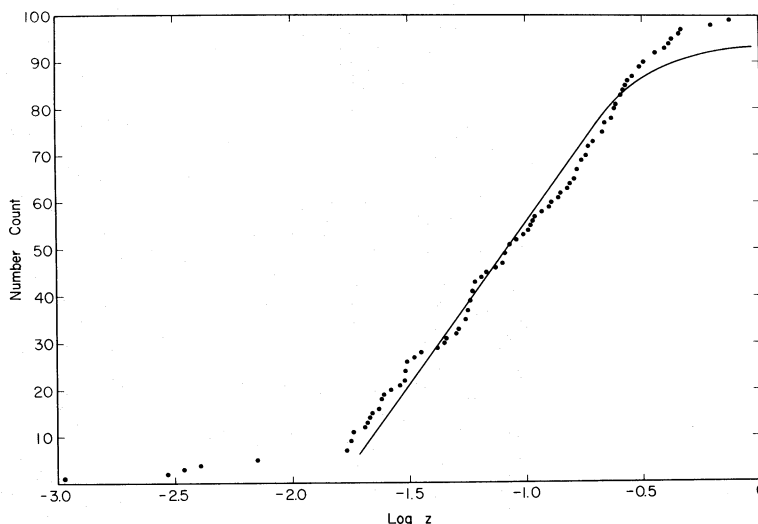


FIG. 1.—The number of radio galaxies in the 3CR catalog with redshifts less than  $z$  is plotted against  $\log z$ . The continuous curve represents a theoretical curve for the Friedmann model with  $q_0 = 0$ . In this model the number of sources with redshifts in the range  $z, z + dz$  is given by  $dN = A[d \ln z / (1+z)^3 (1 + \frac{1}{2}z)]$  for a luminosity function  $f(L_R) = BL_R^{-5/2}$ , where  $A = B/(9\pi S^3)^{1/2}$ ,  $S$  being the flux such that all sources down to this flux level have measured redshifts. For reasons mentioned in the text this curve does not give a good fit at very small redshifts. The matching value of  $z = 0.04$  is chosen somewhat arbitrarily to illustrate this. Similar curves can be drawn for other Friedmann models and for the steady-state model. No evolution in the radio source density or luminosity is assumed in the theoretical curve.

the form of the luminosity function at the faint end<sup>1</sup> and to statistical fluctuations at small numbers, while at large  $z$  the curve tends to flatten off as a result of the expansion of the universe. This latter behavior is simulated by a wide range of Friedmann models (without recourse of evolution of source density or luminosity), and the steady-state model. In Figure 1 the continuous curve corresponds to the Friedmann model with  $q_0 = 0$ , and has been drawn in such a way that its slope matches that of the observed curve at  $z = 0.04$  and the number of sources with redshifts less than 0.04 also matches the observed value at  $z = 0.04$ .

Longair and Rees (1972) rightly argue that the luminosity function alone cannot steepen the log  $N$ -log  $S$  curve over the Euclidean value unless one uses the concept of a local hole. However, with the information now available on redshifts, it is possible to study the source count problem in greater detail than with the simple log  $N$ -log  $S$  curve. It hardly needs emphasizing that the primary aim of the source count problem was to study how the volume of a sphere of surface area  $4\pi R^2$  depends on  $R$  in a non-Euclidean universe. In any given model there is an exact relation between  $R$  and  $z$  and hence, provided we have a complete sample of objects up to a given maximum redshift, we can measure the required dependence less ambiguously than with the log  $N$ -log  $S$  curve. However, completeness down to a given flux level necessarily requires a knowledge of the luminosity function.

### III. THE UNIDENTIFIED SOURCES

We have shown that the source count for identified 3CR radio galaxies is not an embarrassment to any standard cosmological model without evolution. However, if we include the unidentified sources in the count, the log  $N$ -log  $S$  curve does steepen to a slope of  $1.81 \pm 0.13$ .

What are the unidentified sources? Are they nearby weak sources or distant strong ones? Is their apparent excess at small flux levels due to a paucity of weak, very nearby sources or to a real excess of distant, strong sources? The issue could be resolved if these sources could be optically identified and their redshifts measured.

Suppose these sources are really distant ones with large redshifts. How large must they be? It has been argued (Rees 1972) that the bulk of the 3CR sources are distant ones with redshifts 0.3–3 (depending on the type of evolving model assumed). However, as was mentioned earlier, the average redshift for the 100 radio galaxies with known  $z$  is only 0.14. The redshift-magnitude relation for these sources is a reasonable Hubble plot. Indeed, all the identified radio galaxies

<sup>1</sup> At low redshifts the number of sources in a given redshift range is smaller if there is a luminosity-function cutoff at the faint end. Since the theoretical curve (with assumed cutoff) has been fitted to the observed curve where the number count is large enough to be stable against statistical fluctuations, it is not surprising that the numbers at lower redshifts fall off more rapidly in it than in the observed curve.

of the 3CR survey show a Hubble relation. The magnitudes of the radio galaxies which do not have measured redshifts are slightly higher than those for which the redshifts have been measured. On the basis of the Hubble plot, the average redshift for the entire class is expected to be higher than 0.14 but not considerably so. Since the magnitudes of almost all identified galaxies are known,<sup>2</sup> on the basis of the Hubble relation of the form

$$V = 5 \log [z(1 + \frac{1}{2}z)] + 21 \quad (4)$$

obtained by putting  $q_0 = 0$ , we have estimated the redshifts of the remaining 40 radio galaxies and the overall average is 0.19.

Clearly, the onus of large redshifts must therefore fall on the 113 unidentified sources. If the average redshift for (140 + 113) sources is required to be  $\bar{z}$ , say, the average redshift of the unidentified objects  $\bar{z}_u$  must be

$$\bar{z}_u = \frac{253\bar{z} - 140 \times 0.19}{113} \quad (5)$$

For  $\bar{z} = 0.3$ ,  $\bar{z}_u = 0.43$ ; for  $\bar{z} = 1$ ,  $\bar{z}_u = 2.00$ ; and for  $\bar{z} = 3$ ,  $\bar{z}_u = 6.48$ .

While  $\bar{z}_u = 0.43$  appears reasonably within the range of redshifts observed for galaxies,  $\bar{z}_u = 2$  or  $\bar{z}_u = 6.5$  are very much higher. The question therefore arises as to whether it will ever be possible to establish observationally that the unidentified sources are very distant galaxies. In what follows, we discuss the observational problem.

### IV. THE PROBLEM OF IDENTIFYING AND OBTAINING REDSHIFTS FOR VERY DISTANT GALAXIES

The problem of identification of radio sources with very faint objects has several parts. We first require a very accurate radio position. It is then necessary that optical plates be taken in the red down to very faint optical magnitudes. Work of this kind has been attempted by several groups in recent years (Kristian, Sandage, and Katem 1974; Longair and Gunn 1975; Spinrad and Smith 1974), using the large reflectors, and in general they are able to get down to about  $V = 23$  mag, as estimated on the plates. It is doubtful whether systematic studies can be made to much fainter apparent magnitudes ( $\sim 25$ ) until we have the Large Space Telescope (LST). Finally, after an identification is made, a redshift must be measured. So far the farthest galaxies which have had their redshifts measured are those associated with 3C 295 ( $z = 0.461$ ) and 3C 123 ( $z = 0.637$ ), which have  $V \approx 21$  mag, estimated on the plates and  $V \approx 21.5$  mag when measured quantitatively.

We first ask what the redshifts of galaxies with  $V = 23$  mag are likely to be.

In what follows we shall assume that these galaxies are correctly identified and that they are intrinsically

<sup>2</sup> The only exceptions are the sources 3C 33.1, 3C 44, 3C 103, 3C 210, and 3C 330.

bright ellipticals of the type usually identified as radio galaxies.

In calculating their redshifts we assume that  $q_0 = 0$ . We also suppose that galaxies are evolving, and were more luminous in the past. Following Brown and Tinsley (1974) we suppose that a galaxy of present luminosity  $L_0$  had a luminosity at an earlier epoch given by

$$L(t) = L_0(t/t_0)^{-b}, \quad (6)$$

where  $t_0$  is the present epoch and  $b$  a constant. For elliptical galaxies they estimate  $b \sim 1$ . In any given Friedmann model  $t/t_0$  can be related to the redshift  $z$  of the galaxy for  $t =$  epoch of emission and  $t_0 =$  epoch of reception. For a Friedmann model with  $q_0 \approx 0$ ,  $t/t_0 = (1+z)^{-1}$  so that for  $b \approx 1$  we get from equation (6) above

$$L(z) = L_0(1+z). \quad (7)$$

The luminosity function for galaxies is not well determined. As a crude estimate we may use the cluster luminosity function discussed by Abell (1974) which at the bright end in question has the form

$$\Delta n = A \times 10^{0.8M} \Delta M. \quad (8)$$

Here  $A$  is a constant and  $\Delta n =$  number of galaxies in the range of absolute magnitudes  $M$ ,  $M + \Delta M$ . (At lower luminosities  $\Delta n \propto 10^{0.25M} \Delta M$ .) Note that the functional form of equation (8) is preserved under luminosity evolution of the type given by equation (6).

Suppose a typical galaxy of present luminosity  $L_0$  but at redshift  $z$  sends out radiation flux  $I(\lambda_0)\Delta\lambda_0$  in the wavelength range  $\lambda_0$ ,  $\lambda_0 + \Delta\lambda_0$  at the receiver. If  $I(\lambda)$  is the normalized energy spectrum, the amount of light emitted by the galaxy in the range of wavelengths  $\lambda$ ,  $\lambda + \Delta\lambda$  is  $L_0(1+z)I(\lambda)\Delta\lambda$ . However,  $\lambda = \lambda_0/(1+z)$ , and we get

$$I(\lambda_0)\Delta\lambda_0 = \frac{L_0 I[\lambda_0/(1+z)]\Delta\lambda_0}{4\pi(c/H_0)^2 z^2 (1 + \frac{1}{2}z)^2}. \quad (9)$$

From equation (9) we get

$$m(\lambda_0) = 25 + 5 \log (c/H_0)_{\text{Mpc}} + 5 \log [z(1 + \frac{1}{2}z)] + M_0(\lambda_0) - 2.5 \log \frac{I[\lambda_0/(1+z)]}{I(\lambda_0)}, \quad (10)$$

$M_0(\lambda_0)$  denotes the absolute magnitude of the galaxy in the range  $(\lambda_0, \Delta\lambda_0 + \lambda_0)$  at the present epoch. Note that the  $(1+z)$  factor in the luminosity evolution cancels the band width dilation part of the  $K$ -correction (i.e., the nonselective part  $b$  discussed by Oke and Sandage (1968)).

If we set  $m = 23$  and  $M_0(\lambda_0) = -23$  (for the brightest galaxies), we still need to know the last term in equation (10) in order to estimate  $z$ , the redshift out to which the galaxy will be visible on the photographic plate. The form of  $I(\lambda_0)$  has been discussed by several authors (cf. Oke and Sandage 1968; Schild and Oke

1971; Oke 1971; Whitford 1971). They find it relatively flat over  $5500 < \lambda_0 < 10,000 \text{ \AA}$  but falling rapidly for  $\lambda_0 < 5500 \text{ \AA}$ . Thus, if we set  $\lambda_0 = 7000 \text{ \AA}$ , at  $z = 1$  we need the ratio  $I(3500 \text{ \AA})/I(7000 \text{ \AA})$ . From the data in this range ( $\lambda_0 < 4000 \text{ \AA}$ ) we make a crude estimate for the last term of  $\sim 1.5$  mag.

With this estimate and with  $c/H_0 = 6000 \text{ Mpc}$ , the relation (10) for  $M = -23$  becomes

$$23 = 43.9 + 1.5 + 5 \log z(1 + \frac{1}{2}z) - 23, \quad (11)$$

which gives

$$z = 0.91.$$

Thus, unless the radio galaxies are considerably brighter than estimated by equation (10) or have  $I(\lambda_0)$  flatter in the ultraviolet region, it is unlikely that any with  $z > 1$  can be seen on the present plates. This emphasizes the difficulty of identifying the very remote sources.

We see therefore that identifications to  $V = 23$  mag are not likely to find galaxies for us which have redshifts as large as those which are required to prove that the steepening of the  $\log N$ - $\log S$  curve is due to evolution beyond  $z = 1$ .

Suppose that using the LST we could eventually go to  $V = 25$  mag. If we set  $m(\lambda_0) = 25$  in equation (10),  $z$  will increase provided that the last term is unchanged. We find that  $z = 1.76$  provided that

$$-2.5 \log I(2500)/I(7000) \approx 1.5 \text{ mag}. \quad (12)$$

If this correction is 2.0 mag, then  $z \approx 1.5$ ; and if it is 2.5 mag, then  $z \approx 1.28$ . These values are also not really large enough to test the evolutionary hypothesis according to the results of § III.

This part of the problem is difficult enough, but we also have to consider the question of identification and the problem of obtaining spectra of very faint objects.

The identifications will depend on two factors: (a) the precision with which some kind of radio centroid can be obtained and the separation between it and the optical object which we consider acceptable, and (b) the number of galaxies down to the limiting apparent magnitude that we expect to find on the plates. Very high resolution maps of radio sources are now being obtained both using the 5 km telescope at the Mullard Radio Observatory (Ryle 1972; Hargrave and Ryle 1974; Pooley and Henbest 1974) and the Westerbork array (see, e.g., Katgert and Spinrad 1974). Angular resolution as high as  $2'' \times 2''$  is available for many sources, and in general resolution better than  $10'' \times 10''$  will be available for all of the sources in the 3C (revised) catalog. At the same time we know that powerful double radio sources typically have separations of 100–200 kpc, which translate at large redshifts to intrinsic angular sizes comparable to or larger than the resolution. If  $l$  is the linear extent of a radio source, or the linear separation between a radio centroid and the optical galaxy, and  $\theta$  is the

corresponding angular distance measured on the plate, then for  $q_0 = 0$ ,

$$l = \frac{cz}{H_0} \frac{(1 + \frac{1}{2}z)\theta}{(1 + z)^2}. \quad (13)$$

Thus, for  $l = 200$  kpc,  $z = 1$ ,  $\theta \approx 18''$ . Note that the actual separation will be less than the value normally calculated by putting  $l = \theta cz/H_0$ . This effect is of interest for the following reason. Not all of the galaxies at small redshifts which have been identified as radio sources lie exactly at the centroid of radio emission. There are sometimes considerable asymmetries, and indeed there may be some ambiguity in a few of the identifications of what are now accepted radio galaxies. The result given above tells us that at large redshifts the optical objects will appear to be displaced farther from the radio positions than they really are in their own rest frame. What separations are acceptable is still a matter of uncertainty.

A further source of difficulty in the identification will arise if it turns out that the surface density of galaxies down to these faint apparent magnitudes is very large. Since no systematic observational studies have been made, we shall make a crude calculation to see how important this effect might be.

We calculate how many galaxies will be visible to  $V = 23$  mag. The number of galaxies with absolute magnitudes in the range  $M$ ,  $M + \Delta M$  will be given by

$$\Delta N = C \times 10^{0.8M} \Delta M \left[ \frac{(1+z)^4 - 1}{4(1+z)^2} - \ln(1+z) \right], \quad (14)$$

where  $C$  is a constant.

For  $M = -23$  we estimated in § III that  $z = 0.91$ . We now consider fainter galaxies as well, say with  $M$  in the range  $-19$  to  $-23$ . At a given apparent magnitude  $m$  they will be visible out to smaller redshifts which can be estimated as above. We divide the interval  $-19 > M \geq -23$  into four equal ranges and represent each range by a single value of  $M$ . Thus, the range  $-23 < M < -22$  will be represented by  $M = -22.5$  and so on. For each  $M$  the  $K$ -correction is estimated from the work of Oke and Sandage and the  $z$  is determined. Using that  $z$  and equation (14), the relative values of  $\Delta N$  are determined.

We now assume that there are  $N$  galaxies brighter than  $M = -19$  per unit volume ( $\text{Mpc}^{-3}$ ) at the present epoch. Then the luminosity function (8) gives  $\sim N/300$  galaxies in the range  $-23 < M < -22$ , per unit volume. Out to redshift  $z = 0.76$ ; which corresponds to  $M = -22.5$ , the proper volume is  $\sim 0.81(c/H_0)^3 \approx 1.75 \times 10^{11} \text{Mpc}^3$ . Hence there are  $\sim 5.25 \times 10^8 N$  such galaxies out to  $z = 0.76$ . But from equation (14) such galaxies form only 0.018 of the total number of galaxies with  $-23 < M < -19$  visible up to  $m = 23$ . Hence the total number of galaxies with  $-23 < M < -19$  seen up to  $m = 23$  is  $\sim 3 \times 10^{10} N$ . What is  $N$ ?

The density of smoothed out matter in the galaxies

over the whole universe is  $\sim 3 \times 10^{-31} \text{g cm}^{-3}$ . If the average galaxy has a mass of  $\sim 10^{10} M_\odot$ , the density of galaxies per  $\text{Mpc}^3$  is  $\sim 0.5$ . The number of bright galaxies ( $M > -19$ ) may be only  $\sim 1$  percent of the above total. Thus,  $N \sim 5 \times 10^{-3} \text{Mpc}^3$ , and the required number is  $\sim 1.5 \times 10^8$ . This is  $\sim 1.2 \times 10^6$  per steradian or 3300 per square degree or  $\sim 1$  per  $\text{arcmin}^2$ . However, if the powerful radio sources are associated with the very brightest galaxies, they comprise only a small fraction, perhaps 1 percent, of the galaxies brighter than  $-19$ , so that those galaxies will only appear at the rate of about 1 per 100 square arcmin on the plates.

All of the numbers are very uncertain, but they do suggest that at  $V = 23$  mag, there will not be so many galaxy images that, given a radio position good to a few arcseconds, we shall not be able to decide between several plausible galaxy candidates. However, if the suggestion that evolutionary effects are taking place at much greater redshifts is correct, then a necessary condition will be that most of the identified sources will have no optical object identified with them at  $V = 23$  mag. The galaxies involved must be much fainter.

We finally mention the spectroscopic problems. Probably the most difficult problem is to obtain spectra of very faint extended absorption-line objects. Despite the great improvement in techniques over the last 20 years, it should still be remembered that only a very few normal galaxies with apparent magnitudes greater than 18 have had their redshifts measured and very few of these have been observed by more than one group, as is necessary for the results to be secure following normal scientific practice. If the galaxy has one or more strong emission lines, the situation is much better. The two ellipticals which have the largest redshifts, those associated with 3C 295 (Minkowski 1960) and 3C 123 (Spinrad 1975), both have a single strong emission line which is identified as  $[\text{O II}] \lambda 3727$ . Much therefore depends on whether there is a strong correlation between optical emission lines in a galaxy and its being a powerful radio source. Of course at the large-redshift end of the source distribution a large proportion of the radio identifications are of N systems whose spectra are dominated by emission lines (cf. Table 5 in Burbidge 1970). In these objects there is no unambiguous evidence for the presence of stars; and this, together with the periodicity in those redshifts discussed elsewhere (Burbidge and O'Dell 1972, 1973), has led to the possibility that their redshifts are not of cosmological origin. However, in this paper, this complication has been ignored, and the evidence that normal galaxies of stars with the same redshift underlie the emission-line regions (Sandage 1973) has been tacitly assumed to be correct.

Thus, if we are to avoid ambiguities, we must hope that the very faint identifications turn out to be real galaxies of stars, but then we shall need to measure absorption lines, with perhaps some emission. At mag 23, however, this will be very hard to do from ground-based telescopes and would require considerable time with a Large Space Telescope.

## V. CONCLUSION

We have shown that the identified galaxies in the 3CR catalog give a log  $N$ -log  $S$  curve that is Euclidean or sub-Euclidean and is explicable without evolution. If the unidentified sources which steepen the log  $N$ -log  $S$  curve are at large redshifts so that evolution can be invoked, they are so distant that there is little or no chance of proving this observationally in the foreseeable future. Thus, the concept of evolution, at least for radio galaxies, which has been so frequently invoked still remains very difficult to establish observationally.

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