THE 10 GHz LOG N - LOG S CURVE OBTAINED AT NRO

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ABSTRACT. Using 45-m radio-telescope at NRO, we obtained log N - log S curves at 10 GHz for flat- and steep-spectrum sources separately. A simple model-fitting of evolution is given.

1. INTRODUCTION

The log N - log S curve of radio sources is an important method in observational cosmology. Here S means the flux density of radio sources and N = N(S) the differential number-spectrum per unit solid angle of the sky. One recent trend in these studies is to apply this method separately to QSO, radio galaxies and/or normal galaxies. This separation is made possible by a close correlation between radio spectral indices α (defined as $S \propto \nu^{-\alpha}$) and types of radio sources. At higher frequencies this correlation becomes closer and also in the larger flux-density regions QSO's dominate radio galaxies. So far the highest frequency of log N - log S curves was 5 GHz. To double this frequency we made observations at 10 GHz using 45-m telescope at NRO. Preliminary result was published in Aizu et al. (1986).

2. OBSERVATIONS

As the beam width 2.7' of the 45-m telescope at 10 GHz is too narrow for a survey work of moderate size under limited observation time (Seielstad 1983) we made flux-density measurements for complete samples obtained at 5 GHz. It is convenient to divide these samples into three

† Nobeyama Radio Observatory, a branch of the Tokyo Astronomical Observatory, University of Tokyo, is a facility open for general use by researchers in the field of astronomy and astrophysics.

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parts A, B, and C:

A. Strong sources. These are NRAO-Bonn strong survey (Kühr et al. 1981) of the northern sky and Parkes survey (Bolton et al. 1979) of the southern sky of declination range 0° ∿ -30°. The Galactic plane $|b| < 10°$ is excluded. Different survey areas have different limiting flux densities (Aizu et al. 1986). For most sources flux densities at 10 GHz are available (Kühr 1981). We add newly fifteen sources. Altogether A sample has a solid angle of 5.02 sr and includes 758 sources, of which 121 are southern ones.

B. Intermediate sources. Owen et al. (1983) made a fast survey for a selected area with a solid angle .0691 sr. In 1983 and 1984 we measured flux densities of 101 sources with $S_5 \geq 100$ mJy. A part of data of these measurements were already published (Tabara et al. 1984).

C. Weak sources. Ledden et al. (1980) made a confusion-limited survey for a selected area with a solid angle 0.00956 sr, and Condon and Ledden (1982) made a detail study with VLA. In 1984 and 1985 we measured flux densities of 121 sources with $S_5 > 15$ mJy. Details of our new measurements will be published elsewhere.

3. LOG N - LOG S

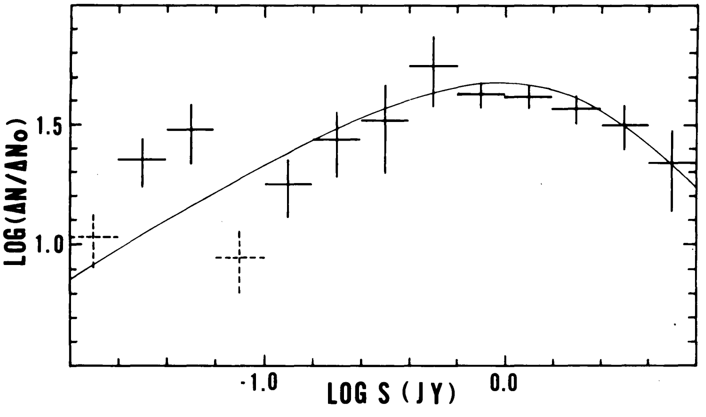

Fig.1. Log N-log S curve for flat sources at 10 GHz. Dashed cross means the statistical completeness of data is poor. A thin curve is given by a simple model calculation.

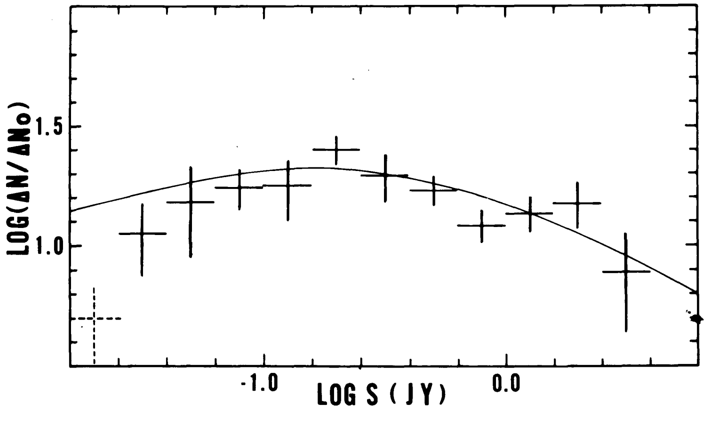

Fig.2. The same for steep sources. Symbols have the same meaning as in Fig.1.

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The log N - log S curves are shown in Fig.1 for flat-spectrum sources and in Fig.2 for steep-spectrum sources. Here "flat" means the spectrum index between 5 and 10 GHz $\alpha \leqq 0.5$ and "steep" means $\alpha > 0.5$.

In these figures we normalize N to the uniform Euclidean distribution $N_0 = \text{const} \times S^{-2.5}$ where S is in Jy. Here we assume const = 1 for convenience. Note that actually $\log(\Delta N(S)/\Delta N_0(S))$ are plotted in Fig.1, where $\Delta N(S) = \int_{S_1}^{S_2} N(S)dS$, and $\Delta N_0 = (S_1^{-1.5} - S_2^{-1.5})/1.5$. Here S_1 and S_2 are lower and upper bounds of a bin respectively. Dashed crosses are cases where the completeness is low.

Although the statistics is poor we could point out the followings:
(1) The overall features of these curves are similar to those at 5 GHz (Owen et al. 1983), but for $S > 1$ Jy the flat-spectrum sources dominate the steep-spectrum sources by a factor of three.
(2) The maximum for flat sources occurs at $S = 1$ Jy and for steep sources at 0.2 Jy. Comparing the two curves we find that in the region of $S < 0.2$ Jy the slope of the steep sources is flatter than that of the flat sources. These features (1) and (2) agree well with curves predicted by Condon (1984).
(3) For both kind of sources there are large dips around $S_{10} = .063 \sim 0.1$ Jy , which are transition regions from B sample to C sample. Although this may due to a new feature of C sample it is possible that this is simply statistical fluctuations.

4. MODEL

Theoretically the log N - log S curve can be expressed with a luminosity function (abbreviated to LF) N(L, z) at the redshift z in the comoving system as $N(S)ds = \iint N(L, z)dLdV(z)$, where dV(z) is the comoving volume element per unit solid angle at z, and the region of the double integral is limited by $S < 1/(4\pi R^2(1+z)^{\alpha-1}) < S + dS$.

The local LF N(L, z=0) for QSO including BL Lac objects and for radio galaxies are constructed from A sample. Redshifts are restricted to a range 0 to 1.45. These LF are expressed in an analytical form $N(L) = A\,L^{-C}\exp(-BL)$, where parameters A, B, and C and luminosity ranges L_0 and L_1 are given in Table 1. The general LF are obtained as a solution of a continuity equation on the $L \sim t$ plane $\partial N/\partial t + \partial(pN)/\partial L = q$ (Cavaliere et al. 1970). Here p is the rate of luminosity change and q the birth rate function. The local LF is used

Table 1. Parameters of analytical form of luminosity functions

	QSO	Radio galaxies
A	14.88	4.421
B	0.0125	0.0063
C	1.886	2.297
Log L_0	$31.8 \sim 33.0$	30.6
Log L_1	35.8	34.6

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as a final condition, and the formation redshift z_c is incorporated in our model under an assumption $N(L, z) = 0$ for $z > z_c$. As for p and q we adopt, as a first trial, simple forms $p = -L/t_1$ and $q = N/t_2$, where t_1 and t_2 are constants. Then the solutions have the form $N(L, z) = N(L)\exp(M\tau + BL(1-\exp(-M'\tau)))$, where M and M' are parameters and $\tau = 1 - (1+z)^{-1.5}$ is the look-back time in unit of $2/(3H_0)$ (Compare with Cavaliere and Szalay 1986). Here we assume the Hubble constant $H_0 = 75$ km $s^{-1}Mpc^{-1}$, and the deceleration parameter $q_0 = 0.5$. This form is similar to that currently used by many authors (for example, Schmidt and Green 1983). With suitable choice of parameters we can fit the forms of log N - log S curves as shown in Fig.1 and 2. It turns out that z_c is around 4 in both cases.

In conclusion, although improvement of statistics and more detailed theoretical studies are needed, the log N - log S curve method at higher frequencies is hopeful for us to obtain important parameters in the formation and evolution of QSO and radio galaxies.

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