Statistics of the 3900-MHz sources in the Zelenchukskaya survey

V. R. Amirkhanyan and A. G. Gorshkov

Shternberg Astronomical Institute, Moscow

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The Zelenchukskaya catalog and the RATAN-600 deep sky survey yield a relation between the source count and the 3900-MHz flux density in good accord with low-frequency surveys. A mutual-position analysis, corrected for survey boundary effects, indicates that the apparent positions of the Zelenchukskaya sources are uncorrelated with one another.

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1. INTRODUCTION

During March-April 1980 a sky survey was carried out simultaneously at three frequencies (3.9, 8.7, 14.4 GHz) with the RATAN-600 radio telescope near Zelenchukskaya, a cooperative facility of the Shternberg Astronomical Institute. The survey covered the strip of the celestial sphere between $\delta = 4°00'$ and $5°50'$ (1980.0) for all α (0^h–24^h) except within $\pm 1^h$ of culmination of the sun (the observations were made in the meridian). This strip measures 0.17 sr in area. Observations were conducted for at least three days at each declination; the antenna was then shifted by 10' in δ (the beamwidth in δ was 40' at 3.9 GHz). The data supplied by the receivers were recorded digitally on magnetic tape. In addition, preliminary processing was performed on an M-400 computer in real time.

In this letter we analyze the roster of radio sources discovered by processing the information recorded at 3.9-GHz frequency.[1] For a single observation the signal detection threshold at 3.9 GHz was 0.1 Jy. A source was considered genuine if the signal at some one declination, an adjacent δ, or a declination two intervals away was at least twice the threshold level on each scan at the same (within the errors) right ascension. In Fig. 1 curves 1 and 3 represent the differential and integrated completeness P of the survey according to this criterion. For comparison, curve 2 shows the differential completeness for a single scan at each δ. By making multiple scans, 98% differential and integrated completeness could be reached at lower flux densities: 0.12 and 0.10 Jy, respectively.

2. SOURCE COUNTS

To construct the (log N, log S) diagram we have selected from the published list[1] the 479 objects located at galactic latitude $|b| > 10°$. Of these, 263 sources have not previously been recorded in any survey. The full flux-density range covered by the Zelenchukskaya survey has been divided into intervals; the number of sources in each interval is given in the second column of Table I. In the first two intervals a correction has been applied for completeness; the number of sources actually recorded is parenthesized. We have normalized these values to the number of sources with flux density S per steradian in a static Euclidean model (hundreds of such objects with $S \geq 1$ Jy):

$$\Delta N_0 = 100\,(S^{-1.5} - (S + \Delta S)^{-1.5}).$$

TABLE I. Differential Source Counts

S, Jy	ΔN	$\Delta N/\Delta N_0$
0.08		
0.091	69 (43)	0.66 (0.41)
0.122	122 (109)	0.62 (0.6)
0.165	116	0.93
0.223	102	1.34
0.301	37	0.77
0.407	26	0.83
0.549	18	0.93
0.741	15	1.2
3.32	10	0.51

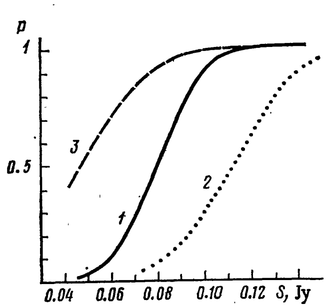

FIG. 1. 1, 2) Differential completeness of the survey for three scans and one scan at each declination, respectively; 3) integrated completeness for three scans.

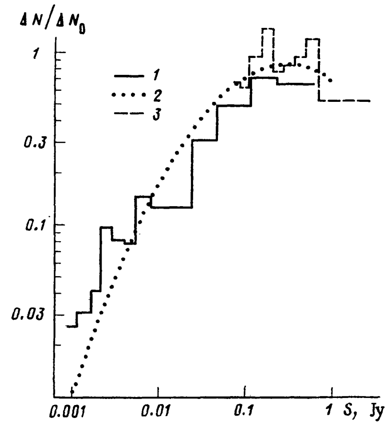

FIG. 2. Radio source counts at 3900 MHz. 1) The original deep sky survey[2]; 2) the deep survey, as adjusted [Eq. (3)]; 3) the present Zelenchukskaya survey.

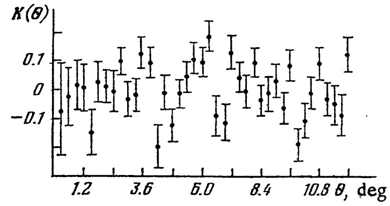

FIG. 3. The correlation function K(θ).

Here and below, S is expressed in janskys. The resulting differential count is given in the third column of the table and as the dashed curve 3 in Fig. 2.

It is of interest to compare the Zelenchukskaya results against the deep sky survey conducted with the RATAN-600 at the same frequency.[2] The (log N, log S) relation derived from the deep survey by multiple scans at each δ is shown by the solid curve 1 in Fig. 2. This curve lies below our results in the overlapping flux-density range. The reason is that the effective survey area for observations at a single δ depends on the slope of the (log N, log S) relation, and that dependence has not yet been taken into account.

If we adopt a true (N, S) relation of the form

$$dN = \rho S^{-\gamma(S)}\, dS,$$

and express the beam pattern with respect to declination as

$$F(\delta) = \exp(-\alpha(\delta - \delta_0)^2),$$

then we can easily obtain an expression for the number of sources with apparent flux density S that fall within the antenna beam when it is set at a declination δ_0:

$$dN = 2\pi\rho \int_{-\infty}^{\infty} [S \exp(\alpha(\delta - \delta_0)^2)]^{-\gamma(S\exp(\alpha(\delta-\delta_0)^2))} \exp(\alpha(\delta - \delta_0)^2) \times \cos\delta\, d\delta\, dS \quad (1)$$

In the special case where γ = const and where $\cos\delta$ does not vary significantly within the antenna beam, Eq. (1) will reduce to

$$dN = 2\pi\rho \cos\delta_0 \sqrt{\pi/[\alpha(\gamma - 1)]}\, S^{-\gamma} dS. \quad (2)$$

Accordingly the quantity $2\pi \cos\delta_0 \sqrt{\pi/[\alpha(\gamma-1)]}$ will represent the effective survey area.

Now let us specify the actual dependence of γ on S as $\gamma(S) = a + b \log S$. Then upon minimizing with respect to the three parameters ρ, a, b the sum of the squared derivations of the expression (1) from the observed deep-survey statistics, we will obtain the true (N, S) relation

$$dN = 105.8 S^{-2.79-0.3 \lg S}\, dS. \quad (3)$$

This result as well is plotted in Fig. 2 (curve 2).

Notice that the count of low-S sources has dropped by a factor of 1.5-2, but at levels of hundreds of millijanskys the count has risen by 1.2 times and now is in good agreement with our survey. This result conflicts sharply with the P(D) analysis of Woll,[3] who finds a higher source number density at the weak end of the (log N, log S) curve, even after applying a correction toward the low side.[4] We are aware of one other deep survey providing a direct source count; it was carried out with the VLA at 5-GHz frequency.[5] When converted to 5 GHz, the 3.9-GHz source distribution given by Eq. (3) is in good accord with the VLA survey.

In showing no tendency to flatten out near 100 mJy, and in its low number density of sources at levels of several millijanskys, the 3900-MHz (log N, log S) curve is consistent with the results of low-frequency surveys.

3. APPARENT DISTRIBUTION OF SOURCES IN ZELENCHUKSKAYA CATALOG

If the positions of the radio sources were to show a significant mutual correlation, one could infer that definite scales exist for which the source density is enhanced — in other words, that the sources are clustered. In fact, Seldner and Peebles[6] report the possible detection of such clustering on scales of 1°-5.3°. The lack of any correlation would suggest that the apparent distribution is random but would not foreclose the possibility that clusters exist. Several factors act to mask any clusters. Quasars, for example, have a luminosity function of approximately $P^{-5/2}$, so that each flux-density interval will contain objects with all redshifts, and clusters not only of quasars but also of radio galaxies might be smeared out.

To analyze the apparent distribution of sources in the Zelenchukskaya catalog we have excluded sources having $S < 0.14$ Jy as well as those close to the galactic plane ($|b| < 10°$). The cutoff in S has been imposed because the two parts of the catalog differ in completeness; for sources with $S > 0.14$ Jy, the whole catalog is complete. Our final list contains 334 sources.

Since the survey zone is ≈2° wide and the mean density of objects is only 0.59 deg^{-2}, the theoretical distribution ought to be strongly affected by the boundaries. An analytic correction can be applied, but the task is cumbersome if the survey boundaries have a complex configuration. We have therefore determined theoretical distributions from 40 independent catalogs obtained by numerical simulation assuming a Poisson distribution of sources over the celestial sphere.

Two methods of analysis were employed. First, following Seldner and Peebles[6] we constructed a correlation function of the form

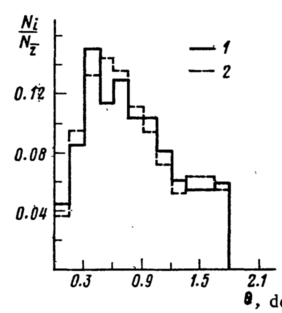

FIG. 4. Histograms for the distance to the nearest neighbor source: 1) the Zelenchukskaya catalog; 2) a simulated catalog with a Poisson source distribution.

$$K(\theta_i) = N_{i\,\text{экс}}/N_{i\,\text{теор}} - 1,$$

where $N_{i,exp}$, $N_{i,theor}$ denote the number of source pairs separated by $\theta_i \pm \Delta\theta/2$ in the catalog under study and in the model catalogs. Both distributions are nearly Poisson, so that $\sigma_{N_i} = N_i^{-1/2}$; the expected χ^2 value is close to $n-1$, where n is the number of θ_i intervals. Figure 3 shows the resultant curve for $\Delta\theta = 30'$ and $n = 40$. Clearly $K(\theta)$ shows no appreciable departures from 0. The value $\chi^2 = 39.5$ confirms this conclusion. We therefore accept the hypothesis that the Zelenchukskaya catalog sources have a Poisson distribution. This first method is equally powerful throughout the range of θ investigated.

The second method is more powerful for scales close to the mean number density of catalog sources. It involves testing the distribution of objects whose nearest neighbor lies in the integral $\theta_i \pm \Delta\theta/2$. This distribution, plotted as curve 1 in Fig. 4, may be compared against the corresponding distribution for the simulated catalogs (curve 2). The value $\chi^2 = 6.57$ for 10 degrees of freedom indicates that at the 5% significance level we may accept the hypothesis of a Poisson source distribution.

Both methods, then, demonstrate with confidence that the apparent positions of the radio sources in the Zelenchukskaya catalog are uncorrelated.

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Hα photometry of SS 433

S. S. Asadullaev, A. A. Aslanov, V. G. Kornilov, and A. M. Cherepashchuk

Shternberg Astronomical Institute, Moscow

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Narrow-band ($\Delta\lambda_{1/2} = 75$ Å) photon-counting photometry of the binary system SS 433 (V1343 Aquilae) in the stationary Hα emission line and in the adjacent continuum was carried out in 1981–1982 at different orbital phases φ and precession phases Ψ. The Hα intensity varies by a factor 2.4 over the 13^d orbital cycle, reaching minimum at $\varphi = 0.0$–0.1, when the normal star eclipses the accretion disk. Hence most of the stationary Hα emission originates inside the binary system, presumably within the accretion disk. The mean stationary Hα intensity varies with Ψ.

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1. INTRODUCTION

Photoelectric photometry of the object SS 433 (V1343 Aquilae) at the frequencies of its stationary emission lines can yield information on the structure of the accretion disk and gas streams in this massive eclipsing binary system,[1] the precession phenomena, and the mass-loss rate.[2] Margon et al.,[3] followed by Anderson et al.,[4] are the first to have studied the variability of the stationary Hα line; from photographic spectroscopy of SS 433 they have found that the intensity at the peak of the Hα profile, expressed in units of the adjacent continuum, depends on the phases of the $13^d.086$ orbital period and the 164^d precession period.

Furthermore, spectroscopic observations by Crampton and Hutchings[5] have shown that the profiles of the stationary hydrogen lines themselves depend on the phase of the precession period: at the epochs T_3 when the moving, "relativistic" emission lines reach their greatest separation, the stationary Hβ line has a single-component profile, while at the epochs T_1, T_2 when the moving lines coincide, the Hβ profile has multiple components and is two or three times wider. Dopita and one of us have found[6] that during flares in the optical continuum[7,8] both the width and the intensity of the stationary Hα line become several times as great.

Kemp et al.[9] have utilized an interference filter ($\Delta\lambda \approx 12$ Å) to perform photoelectric photometry at the peak of the stationary Hα line. When all available observations are folded with the orbital period, the curve for the variation in the peak intensity of stationary Hα has an eclipse form, and lags $0^p.2$ behind the continuum light curve. But the central intensity of the stationary Hα emission does not uniquely characterize the total intensity of this line,[6] a quantity that must be known if the absolute parameters of the system are to be determined. We therefore decided to make precise measurements of the total intensity of the stationary Hα line and to study how the line varies at different phases of the orbital and precession periods.

2. OBSERVATIONS

SS 433 was observed in October 1981 (precession-period phase $\Psi = 0.55$, with the epoch T_3 of maximum separation of the moving emission lines taken as phase zero) and in August 1982 ($\Psi = 0.35$) with a photon-counting

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