OBSERVED REDSHIFT DISTRIBUTIONS AND 
COSMOLOGICAL EVOLUTION OF RADIO SOURCES

J. MACHALSKI, M. JAMROZY
Astronomical Observatory, Jagellonian University
ul. Orla 171, PL-30244 Cracow, Poland

Abstract. It is shown that the new observed redshift distributions of various flux-limited samples of radio sources in general are consistent with the predictions of two basic evolutionary models published by Condon (1984) and Dunlop & Peacock (1990), i.e. none of them can be rejected at the confidence level of about 95 per cent. However, the models allowing a free-form evolution and suggesting both density and luminosity evolution are more consistent with the observational data at lower redshifts, while the 'pure luminosity evolution' model fits better the data at higher redshifts. This leads to a suspicion that the same evolution governing all radio sources, suggested by Condon (1984), might not be the case.

A lot of research was carried out during the last two decades to learn how the population of radio galaxies and quasars evolves at high redshift. One of the conclusions was that there is a 'redshift cutoff' in the distribution of all high-luminosity radio sources, in the sense of a decrease of their comoving space density over the redshift range 2–4. However, this is not clear whether the 'cutoff' and the decrease are the same for all evolving populations.

Two basic evolutionary models published by Condon (1984) and Dunlop & Peacock (1990) [hereafter C84 and DP90 models] predict the redshift cutoff in different ways. The C84 model allows all sources to evolve in the same way, while the DP90 models (originally marked RLF1,2,3,4,5; Dunlop & Peacock analyzed the data available at the time using different sets of starting parameters of the local Radio Luminosity Function) allow flat- and steep-spectrum sources to evolve independently. The DP90, 'pure luminosity evolution' (PLE) model assumes a high-luminosity evolving population of elliptical galaxies, and a low-luminosity non-evolving population of spiral/irregular galaxies. The models of Condon and Dunlop & Peacock differ also in accounting for flat- and steep-spectrum sources.

We made an effort to select a number of the flux-limited samples of radio sources for which redshift data are fairly complete or can be assumed to be representative. The old and new redshift samples are summarized in Table 1. The observed redshift distributions of these samples are displayed in Figures 1 and 2.
TABLE 1. The samples

| Sample     | Freq. (GHz) | $F_{1\text{m}}$ (Jy) | $\alpha$ | A (sr) | No. all | No. with z | med. z |
|------------|-------------|-----------------------|----------|--------|---------|------------|--------|
| PR+CJ1     | 5           | $\geq 0.7$            | $< 0.5$  | 1.84   | 108     | 97         | 1.08   |
|            |             |                       | $\geq 0.5$ |        | 92      | 90         | 0.40   |
| HMIH       | 5           | 0.175–0.7             | $< 0.5$  | (0.4)  | 114     | 68         | 1.45   |
| WP         | 2.7         | $\geq 2.0$            | $< 0.5$  | 9.81   | 68      | 68         | 0.85   |
|            |             |                       | $\geq 0.5$ |        | 165     | 163        | 0.22   |
| PKS        | 2.7         | $\geq 0.145$          | $< 0.5$  | 0.075  | 24      | 22         | 1.33   |
|            |             |                       | $\geq 0.5$ |        | 87      | 80         | 0.69   |
| GB/GB2     | 1.4         | $\geq 0.55$           | $< 0.75$ | 0.44   | 74      | 64         | 0.80   |
|            |             |                       | $\geq 0.75$ |       | 158     | 141        | 0.57   |
|            | 1.4         | 0.2–0.55              | all      | 0.09   | 135     | 85         | 0.79   |
|            |             |                       | all      | 0.62   | 239     | 201        | 0.50   |
| LRL        | 0.178       | $\geq 10.9$           | all      | 4.05   | 181     | 179        | 0.48   |

References to Table 1:
(1) Downes, Peacock, Savage & Carrie, 1986, MNRAS,218,31
(2) Hook, McMahon, Irwin & Hazard, 1996, MNRAS,282,1274
(3) Laing, Riley & Longair, 1983, MNRAS,204,151
(4) Machalski, 1997, A&AS (submitt.)
(5) Pearson & Readhead, 1988, ApJ,328,114
(6) Polatidis et al., 1995, ApJS,98,1
(7) Wall & Peacock, 1985, MNRAS,216,173
(8) this paper

The n(z) distributions, predicted from the C84 as well as RLF3 and PLE models, are shown as continuous curves overlayed on the observed redshift distribution of particular samples. The latter two models are chosen because of their very discrepant predictions. Though the division of sources into ‘flat-spectrum’ and ‘steep-spectrum’ populations, in the face of unified models, is strongly unjustified – we retain this division because the models were originally designed this way and can be used to predict n(z) distributions for sources with different spectra. At the frequencies of 5 and 2.7 GHz the distributions are separated by $\alpha = 0.5$, while at 1.4 GHz – $\alpha = 0.75$ was chosen.

The goodness-of-fit (chi-squared, Kolmogorov-Smirnov) tests applied to the observed and predicted distributions have shown that (1) None of the models can be rejected at the confidence level of about 95 per cent. (2) Considering all available n(z) distributions, the C84 model fits the observations better than do this the DP90 RLF1–5 and PLE models. (3) The PLE model fits better the redshift data of the samples with lower flux limits, i.e. comprising sources at higher redshifts. The C84 model fits better the data of the strong samples (with sources at lower redshifts) where the PLE model cannot be accepted (cf. n(z) distributions of steep-spectrum sources in the 5 GHz 0.7Jy and 2.7 GHz 2Jy samples).
Figure 1. **Left panel:** The n(z) distributions at 5 GHz. The solid curves show the distributions predicted from the C84 model; the long-dash and short-dash curves – those from the RLF3 and PLE models, respectively. **Right panel:** the same as in left panel but at 2.7 GHz

Two conclusions can be drawn from the above analysis:

1. The evolutionary models allowing both density and luminosity evolution (C84, RLF3) are more consistent with the observational data at lower redshifts, while the PLE model fits better the data at higher redshifts. This is not consistent with the scheme in which all radio sources evolve in the same way (e.g. Condon 1984).

2. All redshift-complete samples, available up to date, probe almost the same radio luminosity range (the data in Table 1 show overall increase of the median redshift with a decrease of the flux limit at each observing frequency). Therefore, these data are still not sufficient to determine whether the high-redshift cutoff of the form manifested by luminous sources holds for less luminous sources, and/or is
different for separable populations, e.g. different FR-type radio galaxies, quasars, CSS sources, GPS sources, etc. Future, more complete, redshift data at the flux levels of about 1 – 5 mJy should improve our knowledge about space distribution of radio sources and its evolution.

Figure 2. **Left panel:** The same as in Fig.1 but at 1.4 GHz. **Right panel:** the same as in Fig.1 but at 408 and 178 MHz.