ON COSMOLOGICAL EVOLUTION OF QUASARS

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1. INTRODUCTION

Hereafter the term "quasar" is applied to both optically selected (and/or spectroscopically confirmed) UVX objects, and to radio-detected objects of that kind. A recent attempt to model number-counts of radio-selected QSOs (Condon, private communication) has revealed that the counts cannot be modelled by simply translating the general radio luminosity function (RLF) leaving the cosmological evolution unchanged. While it may be true that the radio sources in QSOs evolve in the same way as do all radio sources (i.e. translation function), the radio sources are probably not always in QSOs. In particular, it may be that increasing the luminosity (especially the core luminosity) of a radio source increases the probability that it is in a QSO. If that is true, a radio detection rate of optical QSOs should be strongly dependent on the optical (core) luminosity, i.e. on the absolute magnitude.

Recently published data on faint optically- and radio-selected QSOs (Sec.2) seem to provide a straightforward observational evidence fot the above hypothesis. In Sec.3 the radio detection rate of QSOs at constant redshift is discussed. This detection rate, in a function of apparent magnitude, can be considered as a ratio of radio-loud QSOs to all QSOs in a function of their absolute magnitude M_B. A question of whether such detection rate is also dependent on redshift is considered in Sec.4.

2. THE DATA USED

(1) Optical QSO samples:

Bright QSO sample (BQS) of Schmidt and Green (1983) complete to an effective mean limit of B=16.16 mag.

Medium-bright QSO sample (MBQS) of Mitchell et al.(1984) complete to B=17.65 mag.

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"AB" and "BF" samples selected by Marshall et al. (1984) complete to B=18.25 mag and B=19.80 mag, respectively. Hoag and Smith's (1977) (HS) and Sramek and Weedman's (1978) (SW) samples were partly used at high redshifts. These complete samples were supplemented with QSO candidates up to J=22.5 mag found in SA57 and SA68 (cf. Koo et al.1986).

(2) Radio QSO samples selected at 1.4 GHz:

"2-Jy" sample (BDFL) almost complete to B≃20 mag, comprising majority of 3CR quasars.

"GB2" sample of QSOs stronger than 0.25 Jy (Machalski and Condon 1986) and with complete photometry up to B=18.0 mag.

"LBDS" sample (Kron et al. 1985) with $S \gtrsim 1$ mJy and complete to J≃23 mag.

The Parkes (PKS) sample of Peacock et al. (1986) was partly used.

3. DEPENDENCE OF RADIO EMISSION OF QSOs ON M_B

This dependence can be determined for objects either with radio luminosity higher than a chosen limiting luminosity, P_{lim}, or with/above chosen radio-to-optical luminosity ratio R. A meaning of both characteristics is different; the first dependence specifies a probability of radio emission (at $P \geq P_{lim}$) as a function of M_B, the second one – a degree of correlation between optical and radio luminosities.

a) Determination of the detection rate (at logP(W/Hz)≥26.4) on M_B (H_o=50; q_o=0.5) for 1<z<2.2 (Table 1 below) suggests

ΔM_B B_{lim}	Opt. sample	N	N(sr^{-1})	Radio sample	N	N(sr^{-1})	Ratio (%)
-23,-25 22.52	SA57	18±3	205000	LBDS	2.5±0.5	800	0.4
-25,-27	SA57	2	22800	LBDS	1	325	1.1
20.52	BF	18	34300	GB2	47	≳240	>0.8
-27,-29	MBQS	8	>270				
18.52	AB	5	440	GB2	7	>35	>8.0

that the probability of radio emission increases about 20 times if M_B increases from -23 mag to -29 mag, reaching about 10% at the highest M_B. A straightforward confirmation of this fraction comes from the radio measurements of the BQS QSOs (BQS sample is large one though not deep enough to detect a QSO with M_B=-27 mag at z=2.2). There is one radio-loud QSO among 13 QSOs with $-29<M_B<-27$ and within 1<z<2.2, i.e. ∿8%. The GB2 data give only a lower limit to the detection rates since the flux-density limit of the sample (250 mJy) is much

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greater than 52 mJy necessary to detect a source with logP= 26.4 at z=2.2. The numbers in Table 1 emphasize how the existing QSO statistics are poor yet.

b) The data in Sec.2 enable one to calculate the radio detection rate for const R (hereafter the R-parameter is determined between $1.2\,10^{15}$ Hz and $5\,10^{9}$ Hz). Sky densities of the optical and radio (logR≥3) QSOs in a function of apparent B or J magnitude, for z<1 and 1<z<2.2, are shown in Fig.1. The

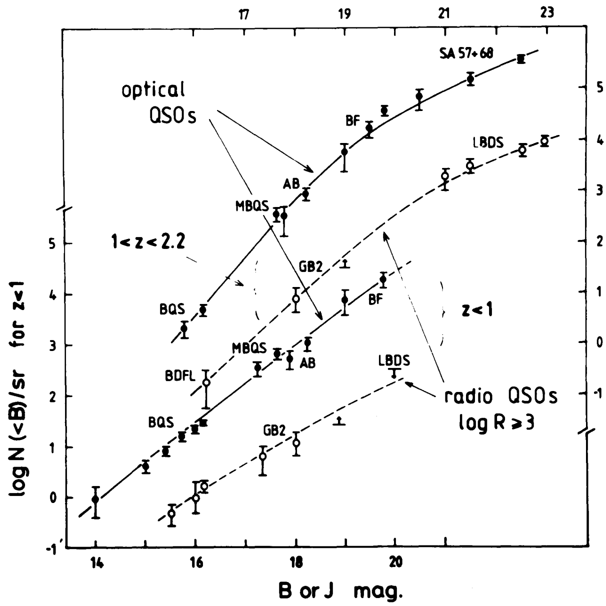

Fig.1. Detection rate of QSOs with logR≥3 in two intervals of redshift

SA57+68 and LBDS survey's data indicate that there is a rapid change of differential sky density of both optical and radio QSOs around 20–21 mag. The detection rate decreases slowly with decreasing magnitude, from about 10% for the brightest objects to about 3% at the fainter end. A similar situation is seen in z<1 range, though there are almost not radio-loud QSOs fainter than B≃20 mag at z<1. 10:3 ratio of the detection rates at different redshifts suggests a large degree of correlation between optical and radio luminosities. After appoximation that the curves in Fig.1 represent detection rates at constant z, one can transform the N(<B) vs. B relation into the volume density vs. M_B relation. Resultant optical luminos ty functions for both optical and radio QSOs in two redshift intervals are shown in Fig.4. These functions clearly show very similar cosmological evolution of the both populations in the optical domain.

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4. DEPENDENCE OF RADIO EMISSION ON REDSHIFT

Another aspect of the radio emission of QSOs is a problem of the variation of detection rate with redshift. Again the data in Sec.2 were used to look for this dependence. Observed sky densities of the optical and radio ($\log P \geq 26.4$) QSOs vs. magnitude for two intervals of M_B are shown in Fig.2. For lower

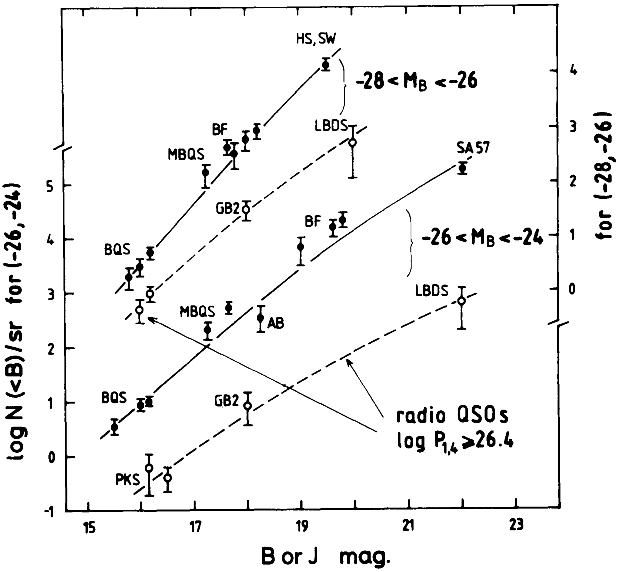

Fig.2. Detection rate of QSOs with $\log P(W/Hz) \geq 26.4$ in two intervals of M_B

luminosities ($-26<M_B$) the detection rate decreases from about 3% to less than 0.5%. For $M_B<-26$ it changes from 25% to about 2.5%. The cosmological evolution (Fig.4) cannot explain these differences; there must be an intrinsic dependence on both optical luminosity and redshift. In fact, the dependence on M_B is proved in Table 1. It is also clearly seen in Fig.3 which shows N(<B) vs. z relations for optical and radio QSOs with two different M_Bs. Since some samples, used here, are not complete in z, mean redshifts have been computed from B magnitudes assuming constant M_B in Fig.2. The sky density of radio-loud QSOs with $\log P(W/Hz) \geq 26.4$, but with different M_B, are almost identical within statistical errors (bars in Fig. 3), though sky density of optical QSOs with the same optical luminosities differ significantly. Thus, the dependence of radio emission on M_B is unquestionable.

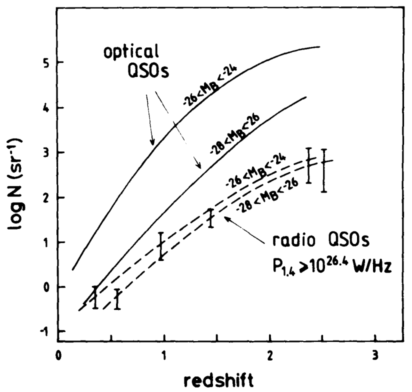

Fig. 3. Sky density of QSOs vs. redshift

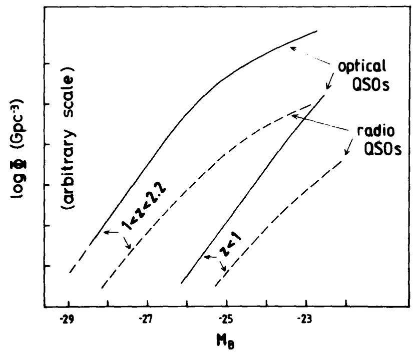

Fig. 4. Luminosity functions for two ranges of redshift

A dependence on z can be interpreted (Peacock et al. 1986) either by different probability distribution of the radio emission of QSOs at high redshift, or, having postulated two distinct populations of quasars, by different proportion of radio-loud to radio-quiet QSOs at high z. A paucity of data on faint radio QSOs, especially uncompleteness of redshifts, does not allow now to solve this ambiguity.

CONCLUSIONS

1. Probability of being radio-loud (const L_{radio}, const z) is strongly dependent on M_B; the detection rate at const R only slightly decreases with decreasing M_B, implying some $L_{radio}-L_{opt}$ correlation

2. Probability of radio emission (at const M_B) decreases with increasing redshift.

3. Evolution functions of radio-quiet and radio-loud QSOs in the optical domain are almost identical, suggesting some luminosity evolution also in the radio domain.

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