THE RADIO EMISSION FROM OPTICALLY SELECTED QUASARS

J.A. Peacock and L. Miller
Royal Observatory, Edinburgh.

A.R.G. Mead
Department of Astronomy, University of Edinburgh.

ABSTRACT. We describe models which try to account for the incidence of quasar radio emission in terms of two populations. One is effectively radio quiet, with radio powers $P_{2.7} \leqslant 10^{22}$ WHz^{-1} sr^{-1} characteristic of type I Seyferts. These are presumed to lie in spiral host galaxies. The other population is the classical radio-loud quasars with $P_{2.7} \geqslant 10^{24}$ WHz^{-1} sr^{-1}. Apparent correlation of radio and optical powers can arise without any real effect being present because the two populations in general have separately-evolving luminosity functions.

1. A DUAL-POPULATION MODEL FOR QUASAR RADIO EMISSION

Most quasars are not radio sources. One of the outstanding problems of quasar research for more than a decade has been to account for this simple fact. The general picture which has emerged is not a simple division into radio-loud and -quiet classes, but of a single population with a very broad distribution of radio-to-optical spectral indices (e.g. Condon et al 1981). The origins of this viewpoint are to be found in a seminal paper by Schmidt (1970) in which an apparent correlation between radio and optical properties of quasars was found. The argument was based on the fact that the redshift distribution of 18 mag quasars selected optically by ultraviolet excess (UVX) was statistically identical to that of 3CR quasars of the same apparent magnitude. If we suppose that quasars of all optical luminosities have a universal distribution function of radio luminosity, then a radio-selected subset of the quasar population should be strongly biased to low redshifts, contrary to observation. Schmidt therefore proposed that there was instead a universal distribution of the radio-to-optical flux ratio R (effectively the spectral index between these wavebands. Astrophysically, this was a very important conclusion since it indicated that the radio properties were primarily determined by the optical properties of the active nucleus.

The applicability of Schmidt's correlation to the most recent quasar data has been re-examined by Peacock, Miller & Longair (1986; PML) and

G. Swarup and V. K. Kapahi (eds.), Quasars, 103–107.

we summarise some of their arguments here. PML made a comparison between UVX quasar data from three samples (the Palomar Green survey and the two Braccesi samples) and Parkes radio quasars selected according to the same optical criteria. The Hubble plot of these data is reproduced in Figure 1.

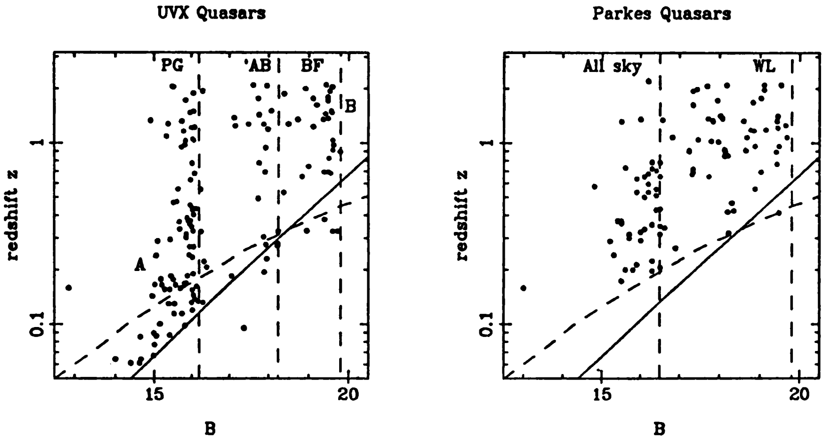


Fig. 1

The solid line marks an absolute magnitude of $M_B = -23$ calculated as specified by Schmidt and Green (1983) ($H_o = 50$ kms^{-1} Mpc^{-1}; $q_o = 0.5$; $F_\nu \propto \nu^{-0.5}$). The dashed line represents the track expected for an evolving elliptical galaxy (scaled arbitrarily in the horizontal direction). The main different in the two plots is the lack of radio-selected quasars at faint M_B. No Parkes quasar at the PG optical level has $M_B > -24$, whereas the PG survey found many objects with $M_B > -23$. These were rejected by Schmidt & Green via an arbitrary criterion at $M_B = -23$; weaker objects, although predominantly stellar in appearance, turned out to be Seyfert galaxies. The quasar host galaxies (spiral in the case of Seyferts) are the clue to explaining this behaviour. If we assume that radio-selected quasars reside in giant ellipticals (which, for radio galaxies, have $M_B \simeq -22$), it is reasonable that nuclear quasar luminosities of $M_B \leqslant -24$ will be needed to outshine the galaxy completely. At high redshift, the galaxy K-correction causes appreciable dimming, and hence the lower limit on quasar optical luminosity falls. The Broad-Line Radio Galaxies (e.g. 3C109), which are found at $z \leqslant 0.3$, would be classified as quasars at $z \sim 1$. In short, the lack of optically weak radio quasars may be understood as an effect of image classification.

If we assume that quasars with $M_B \geqslant -24$ have radio emission characteristic of Seyferts, then with $P_{2.7}$ rarely exceeding 10^{22} WHz^{-1} sr^{-1} (Meurs & Wilson 1984), sensitivities of $\leqslant$ 1mJy are required for detection even at $z = 0.1$. In this interpretation, with 'radio-loud' quasars having $P_{2.7} \geqslant 10^{24}$ WHz^{-1} sr^{-1} and 'radio-quiet' $P_{2.7} \leqslant 10^{22}$ WHz^{-1} sr^{-1}, classification simply according to detection will usually yield a consistent separation of the two classes.

2. VLA OBSERVATIONS OF FAINT QUASARS

It has long been known that faint quasars are harder to detect in the radio than bright , even at constant redshift, which has been interpreted as evidence for a radio-optical power correlation (e.g. Wills & Lynds 1978). However, in PML's model, the two classes of quasar can in principle have different optical luminosity functions: detectability of two different sets of quasars will then be governed by the relative proportions of the radio-loud and -quiet classes. PML considered this problem by comparing the detection rates of quasars with $M_B \simeq -25$ at low and high redshift. Even considering radio limits which corresponded to the same radio power threshold, the high-redshift (i.e. apparently faint) quasars were detected less often than their low-redshift counterparts. This is clear evidence for cosmological evolution, but the existing radio data could not discriminate between the alternatives of changing proportions of radio loud/quiet quasars or simply some evolution in the mean level of radio output. To sort this out requires radio observations deep enough to detect Seyfert-like emission or, more realistically, to set upper limits well into the transitional luminosity range around $P_{2.7} \sim 10^{24}$ WHz^{-1} sr^{-1}. We shall briefly describe two sets of observations.

The first (Miller & Hawkins in preparation) consists of 5-GHz VLA snapshots with rms noise ∿ 200μJy of 154 quasar candidates (selected via variability) with $B < 21$; only 3 were detected. If we assume (via other smaller samples) a typical $z \sim 1$, this corresponds to a 3σ luminosity limit of $\sim 10^{23.5}$ WHz^{-1} sr^{-1} - close to the point at which we would begin to detect Seyferts. This drastic drop in detectability supports our above hypothesis: optically faint quasars are hard to detect in the radio, not because of a radio-optical correlation, but because the vast majority ($\gtrsim$ 98 percent) of quasars with $B \simeq 20$ are radio-quiet analogues of Seyferts. Thus, the steeply-rising number counts of optically-selected quasars down to $B \simeq 20$ are telling us about strong evolution of the radio-quiet optical LF only. The task of making models for the quasar LF (e.g. Marshall 1985) may now be severely complicated by the need to account for two separately-evolving populations.

To escape some of the complications caused by an unknown degree of Cosmological evolution, we have taken another set of VLA snapshots of 107 quasars over the (small) redshift range $1.7 < z < 2.5$. These objects were selected by emission lines (Osmer & Smith 1980; Osmer 1980). This allows us to look directly at the variation of radio properties over 3-4 mag of optical luminosity. In all, 10 quasars were detected (including 6 bright detections seen by Smith & Wright 1980); these data are plotted in two ways in Figure 2. First, a histogram of optical luminosity with the positions of the detections marked: the detection rate varies from ∿ 50 percent at the bright end to ∿ 5 percent at the faint. This corresponds to a difference in slope of 0.8 ± 0.1 for the luminosity functions for the two classes. Second, we plot radio power versus optical. Note that, for the radio-loud objects, there is no evidence for any correlation. The distribution of radio powers is consistent with the form found by PML at low redshift: F(>P) α P^{-1} for $P > 10^{25}$ WHz^{-1} sr^{-1}. The radio luminosity distribution flattens for lower powers; we need deeper data to see if there is in fact a lack of quasars with $P \sim 10^{23}$ -10^{24} WHz^{-1} sr^{-1}.

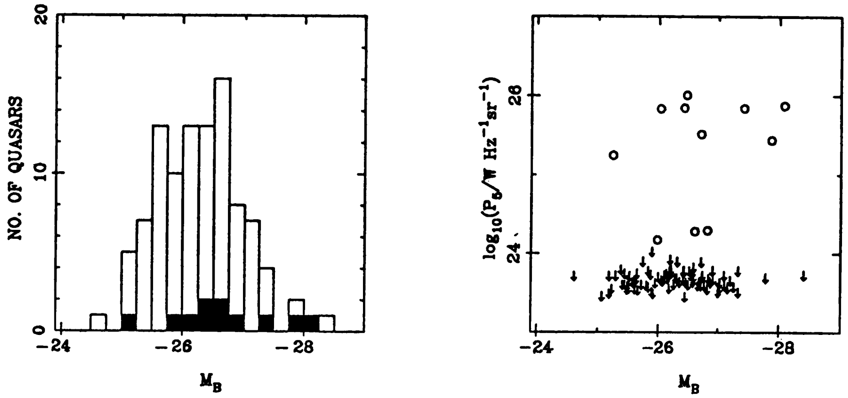


Fig. 2

3. CONCLUSIONS

We have described observations which go some way towards verifying the PML explanation for the radio properties of quasars. In particular, it does seem necessary to account for two radically different populations. Also, radio and optical powers seem essentially uncorrelated: we recommend that use of the parameter radio-optical spectral index be avoided. There remains the possibility of some weak correlation, especially for compact flat-spectrum quasars: this should be looked into. Observationally, the next step is long integrations with many quasars in one VLA beam, to reach the predicted emission at Seyfert levels.

REFERENCES

Condon, J.J., O'Dell, S.L., Puschell, J.J. & Stein, W.A., 1981. Astrophys. J., 246, 624.
Marshall, H.L., 1985. Astrophys. J., in press.
Meurs, E.J. & Wilson, A.S., 1984. Astron. Astrophys. 136, 206.
Osmer, P.S., 1980. Astrophys, J. Supply., 42, 523.
Osmer, P.S. & Smith, M.G., 1980. Astrophys. J. Suppl., 42, 333.
Peacock, J.A., Miller, L. & Longair, M.S., 1986. Mon. Not. R. astr. Soc., in press.
Schmidt, M., 1970. Astrophys. J., 162 371.
Schmidt, M. & Green, R., 1983. Astrophys. J., 269, 352.
Smith, M.G. & Wright, A.E., 1980. Mon. Not. R. astr. Soc., 181, 871.
Wills, D. & Lynds, R., 1978. Astropnys, J. Suppl. Ser. 36, 317.

DISCUSSION

Petrosian : Your results (and those presented by Kellermann) about two classes are very similar to the conclusion I drew from analysis of the very first optically selected sample. In that paper I suggested that perhaps the class with lower luminosity does not undergo the strong evolution observed at higher luminosities. Is this interpretation consistent with the new and more extensive data ?

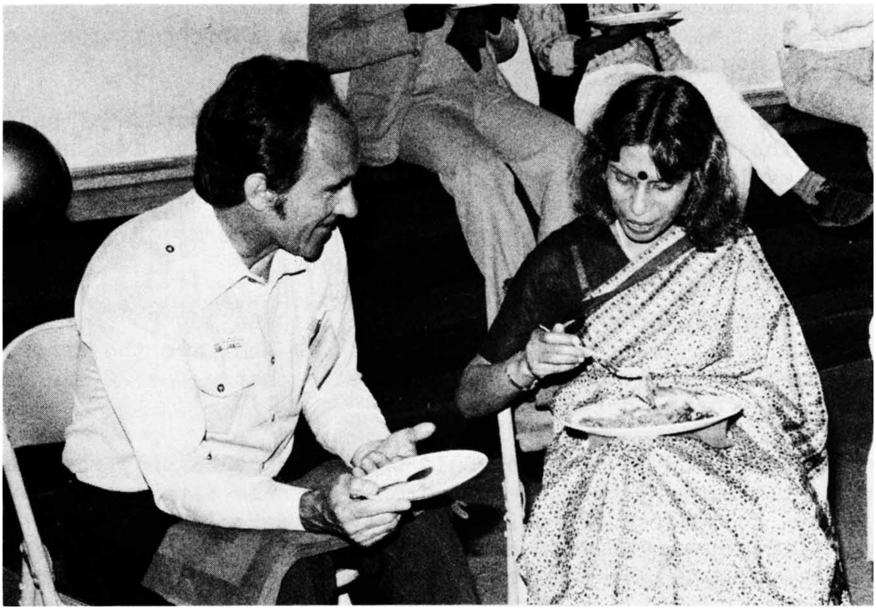
Peacock : Your suggestion, I believe, was that the absence of radio-loud quasars at the lowest redshifts ($z < 0.4$ in the samples available then) was due to evolution of their LF. In the PG sample we see a drop in numbers of radio-loud quasars at $z \simeq 0.1$ which is very abrupt. These two facts make a non-evolutionary explanation in terms of simply stellar/ non-stellar image classification more attractve.

Elvis : In comparing the 16 mag and 20 mag samples you go from an 8% to 3% detection rate, scaling appropriately : (1) What are the errors on these number ? (2) How much would you have to change the 20 mag radio limit by to get an 8% detection rate ?

Peacock : The 8% and 3% numbers could be argued to be only marginally inconsistent; however, they are based on published data only. If we use our VLA data to lower both radio limits by a factor 10, the detection rate at 16 mag rises to ~ 20%, whereas that at 20 mag remains about 3%. Our model implies that this will only improve if 20 mag quasars can be observed with sensitivities of ~ 10 μJy.

Burbidge : Is not the radio morphology for giant ellipticals different from that of QSOs ?

Peacock : At a given radio power, the only difference I am aware of is nuclear : radio quasars have relatively brighter central components and more frequently one-sided jets. The outer structurers in extended sources are similar.



Jerzy Machalski and Bina Swarup