PAIRING, CLUSTERING, OPTICAL VARIABILITY AND GRAVITATIONAL LENSING IN A SAMPLE OF ABOUT 150 FLAT-SPECTRUM RADIO-SELECTED QSOs

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Some years ago, Bolton, Peterson, Wills and Wills (1976, BPWW) reported a statistically-significant excess of QSOs within 2' arc of flat spectrum radio-selected QSOs (specifically, they found 5 such objects while only 1 was expected by chance). None of the QSO pairs had the same redshifts so the result could be regarded as evidence for non-cosmological redshifts, non-uniform QSO distributions, or a statistical fluctuation. Because of the potential importance of BPWW's result, we later used the same technique to examine an independent sample of about 150 QSOs with flat radio spectra and found results that are consistent with the known surface density of QSOs. If we assume a surface density of 3.3 QSOs per square degree brighter than B = 19 (e.g. Marshall et al. 1983), the 150 fields each of 2' arc radius should contain 1.7 random QSOs above this limit and we found 2 (e.g. Wills 1978). A third object is very close to B = 19, and another field contains an object that is extremely blue, with B < 19, on the Palomar Sky Survey, but below our plate limit (i.e. B > 21); we have so far been unable to obtain a spectrum for it. One of the 3 confirmed QSOs is 119" arc from the radio-emitting one, so rather small changes in the magnitude limit, search radius and choice of epoch at which the magnitudes are measured can result in there being anywhere between 1 and 4 secondary QSOs (or 1-3 if the variable object is not a QSO), compared with 2 expected by chance, and perhaps 10 that would be predicted by BPWW's results.

This initial search was limited to B = 19 for comparison with BPWW's, but most of our two-colour image-tube plates reach B > 21, and we later obtained spectra of some of the fainter UV-excess objects at McDonald Observatory. All but one of the objects are within 2' arc of the radio source positions on which the plates were centred. The detailed results will be reported elsewhere, but in summary we now have redshifts for 15 of the secondary objects; 3 are low-luminosity galaxies (z < 0.1) and the remainder are typical QSOs (0.5 < z < 2.2). There are a few more objects that have not yet been observed and some whose spectra have so far given inconclusive results. Restricting the sample to B = 20, we have confirmed 8 UV-excess QSOs within 2 arcmin of the radio positions and there are about 6 more objects to be observed. Adopting a surface

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density of 27 per square degree at this magnitude (from Marshall et al. 1983), the expected number of random QSOs on our plates to B = 20 is 14 and our results are therefore quite consistent with these fainter QSOs all being random ones, unrelated to the radio-detected QSOs.

In no case are the redshifts of the members of a pair (or triplet) the same, so no spatial clustering has been found; this does not contradict Shaver's (1984) results, since fewer than 1% of the QSOs in his homogeneous sample of QSOs are clustered in redshift.

Because of the recent interest in discovering new cases of gravitationally-lensed QSOs, we have carefully examined all the QSO images on our plates (7.9 arcsec per mm) for signs of noncircularity or multiplicity. The seeing was typically 1-2" arc and on most of the plates an object 2 arcsec away with B < 21 would easily have been noticed. Only one such case was found, and we are investigating it further.

Finally, we note that 13% of the flat-spectrum radio QSOs show changes of at least 1 mag between the epochs of the Palomar Sky Survey and our image-tube plates (20-25 yr timescale); this is higher than the incidence of variables among steep-spectrum radio QSOs (e.g. Uomoto, Wills and Wills 1976). There is a statistically-significant negative correlation between variability and redshift in our sample, in the same sense as that noted by Uomoto et al. This could be a luminosity effect, but it could also be due, at least in part, to time dilation if the timescale of the variability is comparable to the 20-25 yr baseline of the observations.

In summary, our recent spectra of the fainter UV-excess objects in the fields of flat-spectrum radio QSOs show that their numbers are consistent with expectations based on the known surface densities of QSOs at B = 20, and the new search does not support earlier evidence for excess pairs of QSOs with different redshifts. The recent claim by Burbidge, Narlikar and Hewitt (1985) that the significance of QSO pairing has increased with the addition of more data has been effectively refuted by Shaver elsewhere in these proceedings.

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