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SURVEY INCOMPLETENESS AND THE EVOLUTION OF THE QSO LUMINOSITY FUNCTION

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It is a commonly held notion that there is a significant amount of evolution in the QSO luminosity function at relatively low redshifts ($z <\sim 2$). However, analyses of the QSO luminosity function often make use of data gathered heterogenously at different redshifts. Surveys are usually optimized for finding either low redshift ($z <\sim 2$) QSOs (e.g. Boyle *et al.* 1990; Schmidt & Green 1983) or high redshift ($z >\sim 2$) QSOs (e.g. Warren *et al.* 1991; Schmidt, Schneider & Gunn 1986), so that the redshift where the strong evolution is thought to begin is suspiciously coincident with the point at which survey strategies change. Before claims of rapid evolution at low redshifts can be made reliably, one must be confident that the apparent deficint in low redshift quasars compared to expectations from mildly evolving the high redshift population is not simply an artifact of sample incompleteness.

Are QSO surveys missing a significant fraction of low redshift QSOs? Recently Goldschmidt *et al.* (1992) have shown the Palomar-Green survey has a factor of 3.4 fewer quasars in one field in common between these two UV-excess surveys (which are most sensitive to QSOs with $z <\sim 2.2$). Hazard (1991) points out that the low redshift ($z = 2$) counterparts to the brightest $z \geq 4$ QSOs have apparent magnitudes of $16 < B < 17.5$ and therefore have spectra which are saturated (and therefore neglected) in typical objective prism surveys. Here we concentrate on a third type of survey which depends on selecting QSO candidates based on combinations of colors. Since QSOs have emission lines and power-law continua, they are expected to yield broadband colors unlike those of stellar photospheres. Previously, the fraction of QSOs expected to be hiding (unselected) within the locus of stellar ($U - J, J - F$) colors was estimated at about 15% (Koo & Kron 1988, KK88 hereafter; Marano *et al.* 1988). We have now verified that the KK88 survey is at least 11% incomplete, but have determined that it may be as much as 34% incomplete. The "missing" QSOs are expected to be predominantly at $z \leq 2.2$.

We have studied the proper motion and variability properties of all stellar objects with $J \leq 22.5$ or $F \leq 21.5$ in the SA 57 field (0.3 degrees^2) which has previously been surveyed with a multicolor QSO search by KK88. The high precision proper motions (Majewski 1992) have the potential of identifying ALL extragalactic, compact objects since most stars will have measureable, telltale proper motions. We find 223 candidate objects with proper motions less than 4σ (including *all* of the 31 previously found QSOs), of which a majority are still contaminating stars. In order to improve our efficiency at isolating QSOs, we make a further requirement of variability within the candidate sample. We have (Majewski 1992) high precision, profile-fitted photometry (random errors less than 0.02 over most of the magntude range surveyed) of all stellar objects in SA 57 at 16 epochs over 16 years which allows us to check for variability on timescales of years to decades. Of the 31 spectroscopically-confirmed SA 57 QSOs previously found by KK88, we find 30 to be variable; it appears that all QSOs are variable over a 16 year baseline. The total number of variable objects with proper motions less than 4σ is 81, including: (a) the 30 known QSOs from KK88, (b) 3 compact, narrow-emission line galaxies (NELGs) found in KK88, (c) 1 confirmed star, (d) 27 objects identified by KK88 as QSO candidates but still lacking spectroscopic confirmation, but also (e) 20 new candidates which were not previously identifed by KK88. Seventeen of these fall within the blue end of the stellar locus in the $(U-J, J-F)$ color diagram. By modelling the change in colors through redshifting typical QSO spectra we find that this region of color space is most likely to be inhabited by QSOs with $z < 2.3$.

We have obtained spectra for 4 candidates in the stellar locus: 3 are QSOs - with redshifts 0.71, 0.74 and 1.61 - and one is an NELG (redshift 0.16). An additional new QSO which is not in the stellar locus was also found at a redshift of 3.54. Thus, based on the 35 known SA 57 QSOs, the KK88 survey is 4/35 = 11% incomplete. We might project that of the total new 20 candidates, 16 will be QSOs. Then at worst, KK88 will be 16/(31+16) = 34% incomplete. However, there are candidates selected by both KK88 and the proper motion + variability survey which still lack spectroscopic confirmation. Presently, the QSO:NELG:star breakdown is 35:4:1, so that we might project that in the entire sample of 81 proper motion + variability objects we might have 70 QSOs, or a density of 233 degree^{-1} to $J = 22.5$. In this case, the incompleteness of the multicolor survey is 16/70 = 23%. Based on their colors, a majority of these new QSOs will be at $z < 2.3$. However, based on their apparent magnitudes and under the assumption that they are at $z < 2.3$, a majority of these new QSOs would lie on the fainter ($M_B > -25$), flatter part of the luminosity function. Thus, while it does appear that the multicolor surveys are missing QSOs in the redshift range of interest, at present it does not appear that these QSOs will significantly alter the perception of a significant amount of evolution at low redshifts in the currently-fashionable pure luminosity evolution models.

Boyle, B. J., Fong, R., Shanks, T., and Peterson, B. A. 1990, MNRAS 243, 1.
Goldschmidt, P., Miller, L., La Franca, F., & Cristiani, S. 1992, *preprint*
Hazard, C. 1991, in *The Space Distribution of Quasars*, David Crampton (ed.), (Provo:ASP), 170.
Koo, D. C., and Kron, R. G. 1988, *Ap. J.*, 325, 92 (KK88).
Majewski, S. R. 1991, *Ap. J. Suppl.*, , 78, 87.
Marano, B., Zamorani, G., and Zitelli, V. 1988, MNRAS 232, 111.
Schmidt, M. & Green, R. F. 1983, *Ap. J.*, 269, 352.
Schmidt, M., Schneider, D. P. & Gunn, J. E. 1986, *Ap. J.*, 310, 518.
Warren, S. J., Hewett, P. C., Irwin, M. J., and Osmer, P. S. 1991, *Ap. J. Suppl.*, 76, 1.