THE APM QSO SURVEY: DESCRIPTION AND STATUS REPORT

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ABSTRACT. The APM QSO survey is a quantitative survey aimed at finding a large sample ($\sim$ 1000) of QSOs using broadly-based selection criteria applied to machine-scanned UK Schmidt Telescope direct and objective-prism plates. The survey is currently entering its third year and, as of August 1988, the sample consists of $\sim$ 700 QSOs with $m_J \geq 18.75$ in the range $0.2 \leq z \leq 3.3$. Preliminary analysis suggests that the sample is relatively free of the selection effects endemic to most QSO surveys based on slitless spectroscopy.

1. PRIMARY SCIENTIFIC OBJECTIVES

We will find a large sample of QSOs in a wide range of redshift ($0.2 \leq z \leq 3.3$) and QSO types using *well-defined and consistently-applied* broadly-based selection criteria. This sample will be used in the following investigations:

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 25–30.

- To determine the emission line strengths and widths of a large sample of optically-selected QSOs as a function of, for example, luminosity and redshift.
- To investigate the frequency of occurrence of 'rare' QSO types, e.g. broad absorption line QSOs or QSOs with extremely narrow or weak emission lines.
- To search for QSO pairs with separations less than 1 arcminute to serve as probes of the sizes of intervening absorbing clouds.
- To provide a list of bright QSOs displaying damped Lyman α or other interesting absorption lines for further investigation at high resolution.
- To provide an additional constraint on the space density of bright QSOs in the range $2.2 \leq z \leq 3.3$.

2. SURVEY CHARACTERISTICS

Our goal is to identify ~ 1000 QSOs brighter than $m_J = 18.75$ in the redshift range $0.2 \leq z \leq 3.3$ using machine-scanned direct and objective-prism plates from the UK Schmidt telescope. Plates are scanned at the Institute of Astronomy's Automated Plate Measuring (APM) facility.

Among the ~ 20000 objects per field with $16.0 \leq m_J \leq 18.75$, approximately 80 are selected by computer algorithms (Hewett *et al.* 1985) as possible QSOs if they meet one or more of the following criteria: (a) their colors are extremely blue relative to common galactic stars, (b) their spectra show evidence for strong emission or absorption features, (c) their spectra show evidence for strong continuum breaks.

CCD frames in two colors obtained at the McGraw-Hill 1.3 m telescope or Las Campanas 1 m are used to provide magnitude calibrations for each field in the survey to a precision of ~ 0.1 magnitudes.

A spectrum of each candidate is obtained with the MMT or DuPont 2.5 m telescope at 6-10 Å resolution (FWHM) and S/N of ~ 15 in the continuum window closest to 4500 Å. 65 to 70% of the candidates are spectroscopically confirmed to be QSOs. Follow-up observations at higher resolution and S/N and at red wavelengths are carried out using the MMT, the McGraw Hill 2.5 m and the Hale 5 m telescopes.

Since the very best UKST plates allow the detection of QSOs as faint as $m_J \simeq 20.5$, we are well above the plate limit for such plates. Adopting a relatively bright cutoff has the considerable advantage that plates of only intermediate quality can be used. In practice, we find that after accounting for small plate-to-plate differences in our magnitude limit, the derived surface densities from different plates are consistent with one another.

3. CURRENT SURVEY STATUS

The first installment of the survey (Foltz *et al.* 1987) includes 192 QSOs found in 102 square degrees centered on the Virgo cluster. Correcting for overlapping spectra, the surface density for this subsample is 2.1 degree^{-2}. There is no tendency for the QSOs to cluster near the plate or cluster centers.

As of August 1, 1988, 686 QSOs have been identified in 15 fields, of which 526 come from fields with nearly completed identification spectroscopy. With the exception of the four Virgo fields, and three southern fields, the fields are distributed along the celestial equator.

4. PRELIMINARY ASSESSMENT OF SELECTION EFFECTS

When we compare our confirmed lists of QSOs with existing catalogs, we find that except for those objects whose objective-prism spectra are contaminated by overlapping images, we recover essentially all of the previously-known QSOs. In the Virgo fields, for example, one non-overlapping previously-known QSO (of 22) was missed: 1210+127, a BL Lac object of unknown redshift which appears red on the objective prism plate.

Figure 1a compares the redshift distribution of the 526 QSOs from fields with nearly completed identification spectroscopy with that for ocularly-scanned objective prism surveys as published in the most recent Hewitt and Burbidge QSO Catalog (1987). The bias that results from the appearance of Lyman α in the visible window toward detecting QSOs near $z = 2.2$ that is evident in previous surveys is absent in our sample. Figure 1b compares our redshift distribution with Parkes flat-spectrum radio QSOs (from Savage 1988) where emission-line-related biases are presumably absent. The agreement is striking and suggests that our sample is relatively free of the type of bias that has effected past objective prism surveys. Furthermore, unless our selection effects are conspiring to make our redshift distribution similar to that of the radio-loud QSOs, the agreement of the distributions in panel b suggests that *the ratio of the number of optically-selected to radio QSOs might not be a strong function of redshift.* However, a detailed comparison must account for the difference in the apparent magnitude distributions of the two samples.

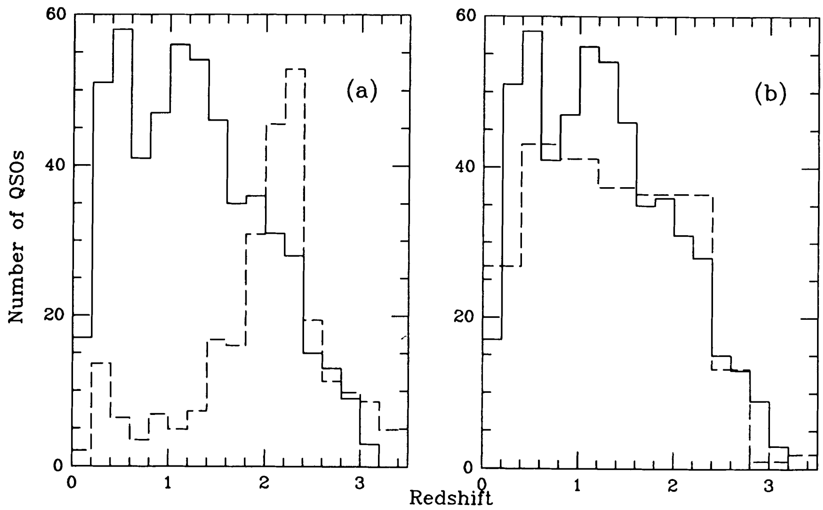

Figure 1. Redshift distribution of 526 APM QSOs (solid line) compared to that for previous ocularly-scanned objective prism surveys (panel a) and flat-spectrum radio sources (panel b). The samples are normalized to have equal numbers of QSOs in the redshift range $1.4 \leq z \leq 3.2$. Note the gap in the APM QSO distribution at $0.6 \leq z \leq 0.8$ where the observed wavelengths of the C III] $\lambda 1909$ and Mg II $\lambda 2798$ emission lines make the candidates difficult to distinguish from galactic stars.

In order to further demonstrate that our criteria do *not* preferentially select strong-lined objects, we have measured the rest equivalent widths of the Lyman α+ N V and C IV emission lines for the QSOs selected from the four Virgo fields. The Lyman α measurements are compared to those of QSOs selected in surveys using other selection criteria Table I (derived from Peterson, 1988). There appears to be no tendency for APM QSOs to have systematically stronger lines than those in QSOs chosen by means other than slitless spectroscopy and, in fact, the APM QSOs do tend to have weaker lines on average than QSOs chosen by ocular scanning of grens plates.

TABLE I. Lyman α Rest Frame Equivalent Width

Sample	$\overline{W}$	σ_W	n
Radio	56	37	37
Variable	61	41	19
APM	68	29	67
Grens	85	46	59

Finally we note that if we were systematically selecting QSOs with strong emission lines, the C IV emission line observed equivalent widths for QSOs with $z < 1.7$ (where C IV is typically the strongest emission line in the optical window) might be *larger* than that for $z > 1.7$ (where Lyman α becomes visible from the ground). In fact, in the case of the Virgo QSOs, the lower redshift objects have a mean observed equivalent width of 65 Å with a standard deviation of 44 Å while the higher redshift objects have a mean of 85 Å with a standard deviation of 39 Å. That is, the low redshift sample has systematically weaker *observed* C IV lines than the high redshift sample. The *rest* equivalent width distributions are nearly identical with mean rest equivalent widths and standard deviations of 26.5 ± 17.4 and 26.6 ± 12.2 Å for the low and high redshift samples, respectively.

5. QSO SPECTRAL CHARACTERISTICS

As noted above, the identification spectroscopy is carried out at high enough signal-to-noise ratio that the spectra are useful for more than just confirmation and redshift determination. We have carried out a preliminary set of measurements of the Virgo database, primarily to investigate questions of selection effects, but the measurements do bear on other issues and are summarized here.

5.1 LYMAN ALPHA AND C IV EQUIVALENT WIDTHS AND FWHM

Figure 2 presents histograms of the rest equivalent widths and FWHM of the Lyman α + NV and C IV emission lines for the Virgo QSOs. No effort was made to deblend the N V emission from Lyman α since we were interested in the object selection and the two lines are inexorably blended on the objective prism spectra.

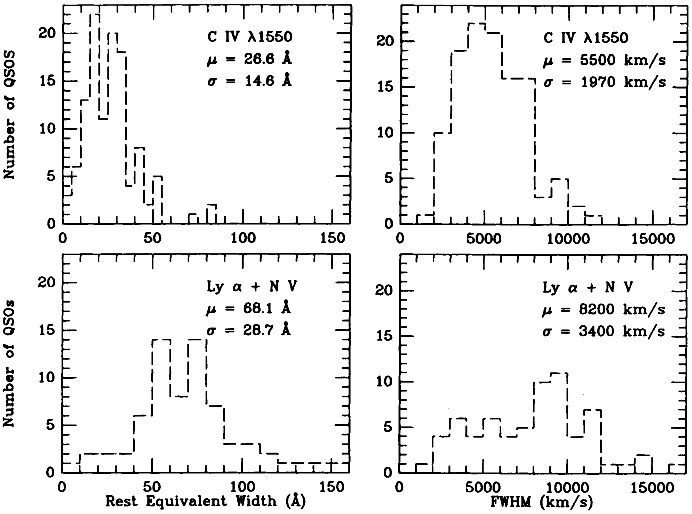

Figure 2. Emission-line properties of C IV λ1550 and Lyman α + N V λ1240 emission for the QSOs in the Virgo fields.

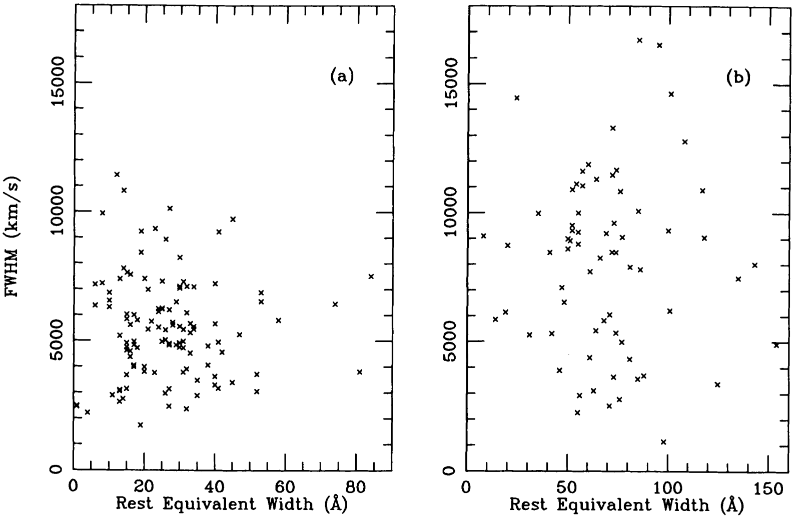

Figure 3. Scattergrams of the emission line width versus rest equivalent width for C IV (panel a) and Lyman α + N V (panel b). No strong correlation is evident.

Figure 3 presents scattergrams of the FWHM versus rest equivalent width for C IV and Lyman α + N V. The larger mean FWHM seen in panel a is due to the blending of Lyman α and N V which are separated by nearly 6000 km/s. No strong correlation is evident in either data set.

5.2 FRACTION OF QSOS WITH BROAD ABSORPTION LINES

Weymann *et al.* (1988) have inspected the spectra of APM QSOs with $z > 1.4$ looking for evidence of broad absorption lines (BALs) of C IV and, when accessible, Si IV , N V and O VI. Assigning them the weights of 1 for *certain* BALQSOs, 2/3 for *probable* BALQSOs, 1/3 for *possible* BALQSOs, and 0 for *certain non*-BALQSOs, they derive the fraction of high redshift optically-selected QSOs with BALs of $\sim 9 \pm 3\%$. This means that:

- BAL QSOs are not 'rare'. In fact, in a sample of optically-selected QSOs, *nearly as many objects will be BALQSOs as will be strong radio sources.*
- Given that only one of the 150 or so radio-loud QSOs whose spectra are available to us could be classified as a BALQSO (a marginal classification at that), *the probability that radio-loud and optically-selected QSOs are drawn from the same parent population (as regards the presence of BAL gas) is less than* $\sim 10^{-4}$. The evidence is mounting that BALs occur preferentially in the spectrum of *radio-quiet* QSOs.

6. ACKNOWLEDGEMENTS

The APM QSO survey is supported by NSF grants AST 86-15485, AST 86-20427, and AST 87-00741, for which we are very grateful. We also acknowledge with thanks the cooperation of the UK Schmidt Telescope Unit and the APM group at Cambridge which is supported by the SERC as a national facility.

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