OPTICAL IDENTIFICATIONS OF RADIO SOURCES WITH ACCURATE POSITIONS USING THE UKST IIIa-J PLATES

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SUMMARY

Three radio identification programmes are described which are drawn from radio samples with accurate radio positions (< 2" arc rms). Optical identifications are being made on the basis of radio-optical positional coincidence alone, without regard to colour or morphology, using the UKST IIIa-J sky survey to a limiting magnitude of 22.5. Some preliminary results are presented.

I. INTRODUCTION

Preliminary optical identification work using the UKST IIIa-J sky survey plate material as it became available and the Parkes 2.7 GHz radio positions (at best accurate to ∿ 10") (Savage et al. 1976 and references therein) highlighted the need for accurate radio positions (∿ 2") to minimise the spurious identifications resulting from the high surface density of optical objects on the UKST IIIa-J plates (∿ 10^{-3} per arcsec^2).

This high surface density results from the finer grain of the IIIa-J emulsion and the hypersensitising techniques developed successfully by the UKST team (see Corben et al. 1974 and Sim et al. 1976) which enables these normally slow plates to be useful astronomically, reaching $2^{m}_{\cdot}5$ fainter than the POSS Whiteoak extension. Additionally the achromat corrector on the UKST means that the image size is well matched over all wavelengths to the emulsion grain size, giving improved resolution and allowing improved morphological classifications (see Savage 1983).

M. Capaccioli (ed.), Astronomy with Schmidt-Type Telescopes, 481–487.

Three major identification programmes are now in progress using the UKST IIIa-J plate material and accurate radio positions. These are described in the following section together with some preliminary results which each programme has produced.

II THE OPTICAL IDENTIFICATION PROGRAMMES

(a) The Parkes 5.0 GHz deep survey to 30 mJy.

The 5° by 5° region centered $22^{h}-18^{\circ}$ has been surveyed with the Parkes 64 m radiotelescope at 5.0 GHz by Wall et al. (1982). This survey complete to 32 mJy yielded a catalogue of 75 sources, of which 57 had fluxes greater than 30 mJy. These 57 sources have been positioned using the Tidbinbilla Interferometer at a frequency of 2.3 GHz (see Batty et al. 1982 for a description of the performance of the Tidbinbilla Interferometer). A preliminary comparison between the Tidbinbilla and Parkes positions showed a scatter much larger than expected based on the quoted Parkes error. The 6cm position errors appear to be a factor 1.5-2 larger than quoted so that the target diagram appears as in Figure 1.

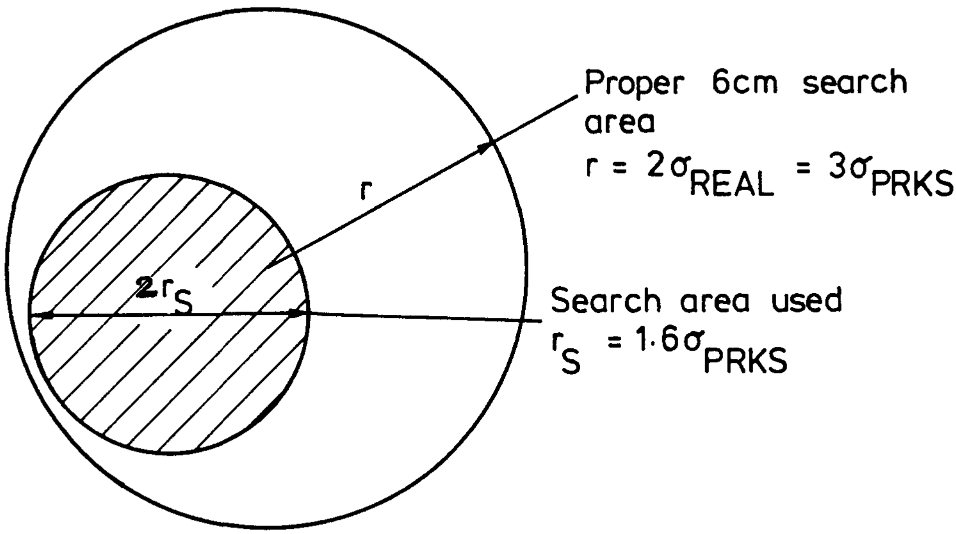

Figure 1. Clear circle, the error circle that should have been searched. Hatched circle, area searched for optical identification using underestimated radio positional errors. This latter area ended up being only one quarter of the area that should have been searched. Thus some 12 misidentifications were made and 24 identifications missed in the work of Savage et al. (1982).

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The region searched ends up being only one quarter of the area that should have been searched. Consequently it was expected that few of the published optical identifications would be confirmed and that many of the correct identifications would have been missed.

The identifications using the accurate Tidbinbilla positions have now been completed using UKST IIIa-J, IIIa-F, IV-N and objective prism plates. The original premise is found to be correct; just over 50% (12) of the original identifications claimed by Savage et al. (1982) have been found to be incorrect, and the identification rate has increased from just under 50% (including the spurious identifications) to just over 63%; in all some 24 identifications were wrongly made or excluded by Savage et al.

(b) The Tidbinbilla-UKST Radio Quasar Idenfication Programme

The Tidbinbilla Interferometer is also being used to position all the Parkes 2.7 GHz compact and/or flat spectrum sources south of declination -30°. First results (Jauncey et al. 1982) showed that the Tidbinbilla positions and the UKST survey plates are well matched for the identification of such sources. Anglo-Australian Telescope spectroscopy has confirmed most of the identifications and revealed a redshift of 3.78 for the QSO PKS 2000-330 (Peterson et al. 1982), the highest redshift known so far. For compact sources, the ability to identify such radio sources on the basis of positional coincidence alone, without recourse to colour or morphology, is an important feature of radio identification programmes. Identification criteria such as ultraviolet excess and morphology have in the past provided serious bias in the resulting redshift distributions. Figure 2 demonstrates the bias due to identification procedures based on colour. It shows the error circle due to the Parkes radio position and the original identification with a UVX object, A, although the error circle just touches PKS 2000-330. The small error circle is that from the Tidbinbilla position and it is centered on PKS 2000-330 and excludes object A.

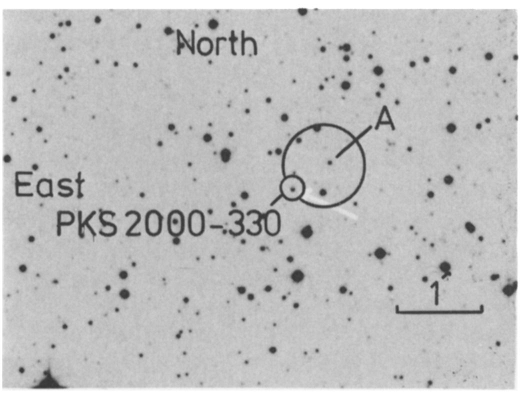

Figure 2. Using UVX criteria as an aid to identification procedures in conjunction with radio source positions with large positional errors, Object A was originally identified as the counterpart of PKS 2000-330. Subsequent acurate radio positioning work uniquely identified the radio source without recourse to colour or morphology criteria.

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Additionally, high redshift quasars appear red and have a galaxy type morphology on POSS plates (Savage 1983) because the presence or absence of the strong emission lines, Lyman-α in particular, has a significant effect on the quasar colours and image structure. This effect is compounded by the presence of the Ly-α absorption forest and also of any Lyman limit absorption (see Fig. 3). The density of absorption lines increases with increasing redshift (Peterson 1983) with the result that the integrated continuum magnitudes on either side of the Ly-α emission line differ significantly. For PKS 2000-330 these broad band colours show a $1^{m}.7$ difference. Thus the most luminous quasar appears as a $17^{m}.3$ object in the red but drops to $19^{m}.5$ on the "blue" UKST IIIa-J plates, and we might expect quasars with z > 3.5 to appear at $\sim 20^{m}.0$ rather than $18^{m}.0$ on those plates. Interestingly at radio wavelengths the z > 3.0 quasars have been found to have spectra with distinct peaks (see Figure 4).

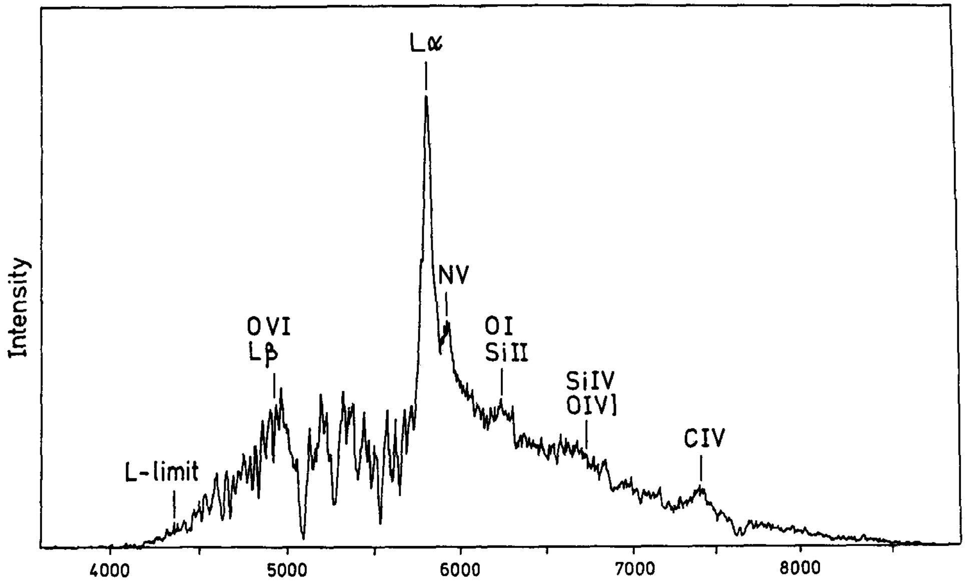

Figure 3. Spectrum of Pks 2000-330, the highest redshift quasars at z = 3.78. The continuum emission drops by about 1.5 magnitudes between the long wavelength side of Ly α and the short wavelength side.

The observed radio flux densities and optical magnitudes of the known z > 3.0 radio quasars show clearly that if similar objects exist at z > 3.5 then they should be well above the existing radio (Parkes 2.7 GHz) and optical (UKST IIIa-J) survey limits. The Tidbinbilla - UKST programme offers a proven method for finding and identifying z > 3.5 quasars with which to test the various cosmological models of differential evolution and galaxy formation.

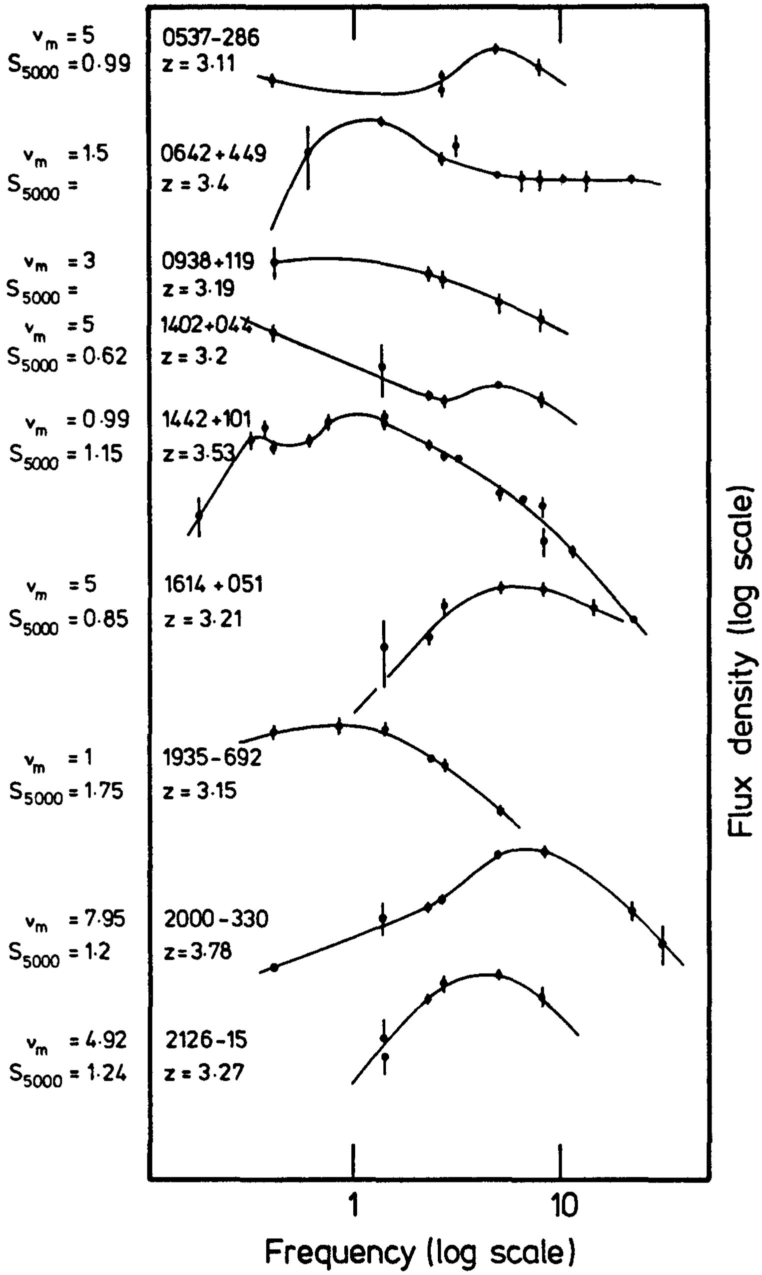

Figure 4. Radio spectra of all the known radio quasars with redshifts greater than 3.0. All show "humps" in their radio spectra, the observed frequency of these humps is given as ν_m on the LHS of the figure.

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(c) Optical Identifications of Radio Sources with VLBI Positions.

Very few radio identifications with quasars or bright optically selected quasars are known south of declination -35° and even fewer south of -45°. This VLBI programme of positioning all compact sources with 5.0GHz fluxes > 0.5 Jy (Morabito et al. 1983) has produced some candidates which are brighter than $17^{m}.0$. These can be used to contribute to the Hipparcos Satellite and Space Telescope complementary astrometry programmes (Duncombe et al. 1982). The NASA/ESA Space Telescope will have the capability of measuring relative positions of 9-17 magnitude stars within its 18 arcmin field of view with an accuracy of 0.002 arcsec rms. The HIPPARCOS instrumental system of bright ($\sim 11^{m}.0$) stars will produce a solid body reference frame with an overall unknown rotation. Two separate problems with common solutions must be distinguished. One, to determine the rotation of the Hipparcos instrumental system, and two, to tie in the actual coordinates of the Hipparcos system. Using its capability to measure precise angular distances between objects of disparate magnitudes, the ST can be used to tie the Hipparcos system to (in particular) (a) an absolute coordinate system derived from radio interferometric observations using radio sources which have discrete optical counterparts and (b) very distant, and, hence relatively motionless objects such as the QSOs. This VLBI programme will be contributing bright radio QSOs.

The need for such an improved astrometric grid is highlighted by this programme. Residuals from the reference star positions in the solutions for the optical positions were found to increase dramatically with increasing southern declination (i.e. 0.85 at 0° to 2.0 at -80°) and also to increase with epoch: 0.68 (24 fields) for POSS plates epoch 1950.0 to 0.85 (10 fields) for SERC IIIa-J plates epoch 1980.0. Thus in this programme it is now the optical position errors which are dominating and defining the search error circle.

These accurate radio positions have increased the identification rate from 56% to 88%, enabling some identifications to be made in very crowded stellar fields, some subsequently confirmed by AAT spectroscopy. 11% (8 of the 92) of the original identifications have been found to be incorrect.

III CONCLUSIONS

The three accurate radio positioning programmes here and the subsequent optical identification programme undertaken on the UKST IIIa-J plates have demonstrated:

(1) The improvement in the identification rate afforded by the deeper, finer resolution plate material provided by the UKST.

(2) The biasses introduced with identification procedures based on morphology and colour.

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(3) The spurious and missed indentifications resulting from identifications using radio positions with large positional errors and high quality deep plate material.

(4) The need for accurate fundamental optical astrometry particularly in the Southern Hemisphere so that identification work based on VLBI positions with an accuracy of 0."004 are not limited by the optical position errors of ~ 2."0.

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