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PKS 2000−330: A QUASI-STELLAR RADIO SOURCE WITH A REDSHIFT OF 3.78

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ABSTRACT

Observations with the Image-Tube Dissector Scanner on the Anglo-Australian Telescope of the 19th magnitude quasi-stellar object identified with the radio source PKS 2000−330 show it to have an emission redshift of 3.78.

Subject headings: galaxies: redshifts — quasars — radio sources: spectra

I. INTRODUCTION

As part of a program to determine the true space distribution of QSOs, spectroscopic observations have been undertaken of samples of radio and optically selected QSOs (see Savage *et al.* 1978; Peterson *et al.* 1979, and references therein). Observations of the 19th magnitude QSO identified with PKS 2000−330 were made as part of the program exploring the redshift distribution of optically faint radio sources with peaked radio spectra.

The radio source PKS 2000−330 was found during the third part of the Parkes 2.7 GHz survey (Shimmins 1971). The identification of the radio source with the optical counterpart is based on an accurate radio position measured with the Tidbinbilla Interferometer,

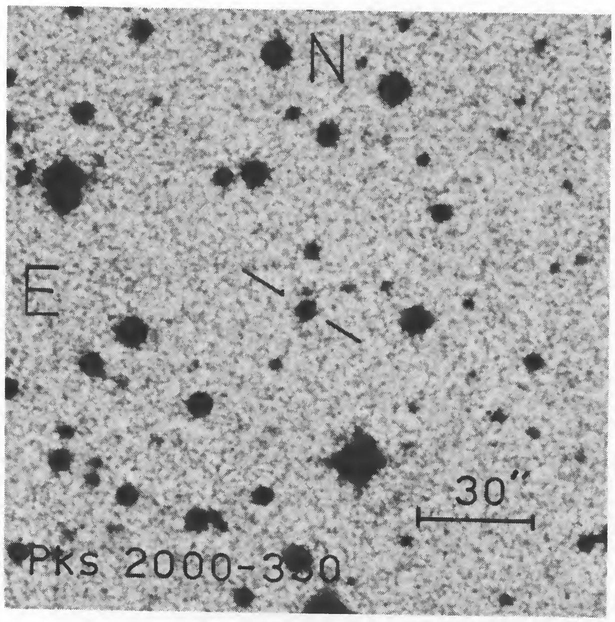

FIG. 1.—The optical counterpart of PKS 2000−330. The 19th magnitude QSO is in the center of the figure, indicated by the two bars. Note the faint, diffuse images 5″ to the north and south of the QSO. The figure is reproduced from the SERC J Sky Survey film.

TABLE 1
EMISSION LINES IN PKS 2000−330

Observed Wavelength (1)	Identification (2)	Redshift (3)
4935	Lyβ λ1025.7	3.811
	O VI λ1033.8	3.774[a]
5825	Lyα λ1215.7	3.791[b]
5920	N V λ1240.1	3.774
6250	O I λ1303.5	3.795
	Si II λ1307.6	3.780[a]
6735	S IV λ1396.7	3.822[c]
	O IV] λ1406	3.790[c]
7400	C IV λ1549.1	3.777

[a]The emission feature is a blend of two lines. The noted redshift gives best agreement.
[b]The Lyα emission line is self-absorbed in the short-wavelength wing, shifting the line centroid to a higher redshift.
[c]The redshift agreement is poor.

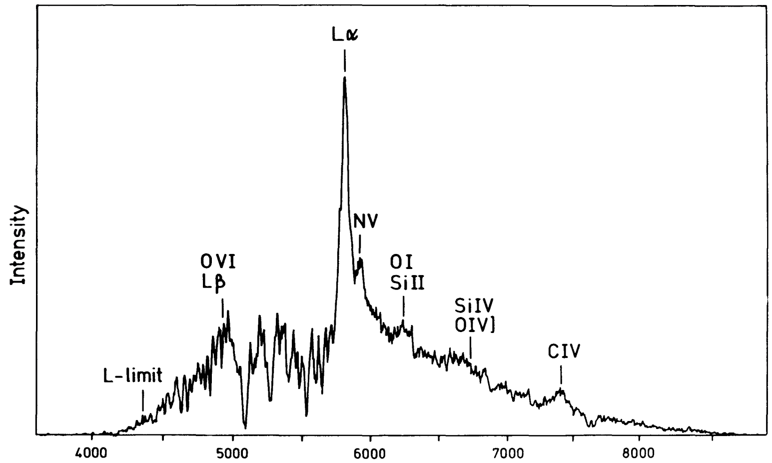

FIG. 2.—The optical spectrum of PKS 2000−330 obtained 1982 March 26 with the Image-Tube Dissector Scanner at the f/15 focus of the Anglo-Australian Telescope. Relative intensity is shown as a function of observed wavelength in Å. The spectrum has a resolution of ~ 10 Å. Identifications of the principal emission features and the position of the Lyman limit are shown. Many blended absorption features are seen on the short-wavelength side of the Lyα emission line. The absorption features are attributed to Lyα absorption in clouds along the line of sight to the QSO.

located near Canberra, Australia. The optical identification was made on the basis of positional coincidence alone, without regard to the color or morphology of the optical object on U.K. Schmidt Telescope deep IIIa-J Sky Survey plates, by Jauncey *et al.* (1982). The positions (equinox 1950.0) are: radio, R.A. $20^{h}00^{m}13^{s}.20$, decl. $-33°00'12''.3$; optical, R.A. $20^{h}00^{m}12^{s}.94$, decl. $-33°00'14''.6$. A finding chart is given in Figure 1. As noted by Shimmins and Bolton (1974) when the survey radio position was improved, the earlier identification of the source with an object with an ultraviolet excess by Shimmins *et al.* (1971) is incorrect.

II. THE OPTICAL AND RADIO SPECTRA

The optical spectrum of PKS 2000−330 was obtained by us on the night of 1982 March 25–26 with the Image-Tube Dissector Scanner (Robinson and Wampler 1972) at the f/15 Cassegrain focus of the Anglo-Australian Telescope. The observations were made through a 1″ × 1″ aperture, at a spectral resolution of ~ 10 Å, and cover the wavelength range from 4200 Å to 8200 Å. The optical spectrum of PKS 2000−330 is shown in Figure 2. The wavelengths of the emission features and their identifications are given in Table 1. The line identifications are similar to those for other

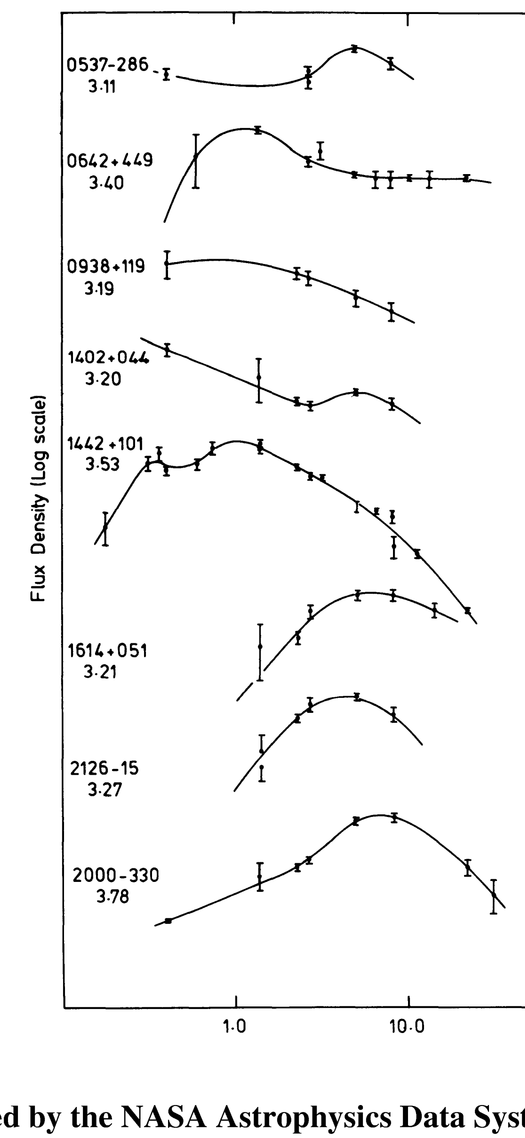

FIG. 3.—The radio spectra of high-redshift QSOs. Flux density is shown as a function of observed frequency in GHz on log-log scales. The redshift of each QSO is given below the coordinate designation which labels the radio spectrum of the QSO. All the radio spectra are peaked, indicative of a compact component that is synchrotron self-absorbed at low frequencies and optically thin at high frequencies.

QSOs with redshifts greater than 3. We note in particular the similarity to PKS 1402+044 (Peterson *et al.* 1978) and 0938+119 (Beaver *et al.* 1976). The Lyα line is the strongest line in the spectrum, with C IV, N V, and O VI also prominent. The mean emission redshift based upon the lines of O IV, N V, Si II, and C IV is 3.78 ± 0.01. The short-wavelength wing of the Lyα emission line is self-absorbed biasing the line centroid to longer wavelengths and a higher redshift.

The continuum on the short-wavelength side of the Lyα emission line is broken up by many unresolved absorption lines, typical of high-redshift QSOs (see Peterson 1978). The strongest absorption features are at λ5095, λ5280, and λ5405. The continuum of PKS 2000−330 extends to wavelengths shorter than λ4360, the Lyman limit in the emission redshift system. The continuum in the spectra of 1442+101 (OQ 172), 0938+119, and 0805+046 (4C 05.34) also extends to wavelengths shorter than the Lyman limit of the emission lines.

Figure 3 shows the radio spectrum of PKS 2000−330 together with the radio spectra of the other radio QSOs with redshifts greater than 3. These spectra are based on published flux densities, together with our own measurements at 2.3 and 22.3 GHz, and on unpublished measurements communicated to us. As a group, all the spectra in Figure 3 show distinct peaks and steepen beyond 8 GHz.

III. DISCUSSION

All surveys for QSOs are beset with selection effects. Many of these selection effects, in both optical and radio surveys, can limit the redshift range of the QSOs in the survey (Peterson and Savage 1982). For example, the surface density of radio QSOs is only ~ 8% of the surface density of optical QSOs (Savage and Bolton 1979), but the number of radio QSOs and optical QSOs with redshifts greater than 3 is comparable. Furthermore, the two QSOs with the highest redshifts are both radio QSOs.

The QSO identified with the radio source PKS 2000−330 was identified by position. Attempts to identify the radio source by color were unsuccessful. The object appears as a 19th magnitude star on the blue-sensitive IIIa-J plates. Comparison of the flux measured in the $\lambda\lambda$4200–8200 band for the object with standard stars gives a magnitude of 17.3. Similar high-redshift objects should be found on objective prism surveys that cover comparable wavelength bands. However, the bandpass available to such surveys is much narrower. The narrower bandpass and emulsion sensitivity variations will make it more difficult to recognize the nature of the high-redshift objects and may account for the lack of identified QSOs with redshifts greater than 3.3 in these searches.

The QSO identified with PKS 2000−330 has a redshift of 3.78 and is the most distant and most luminous object known.

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