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3C 68.1: A VERY RED QSO WITH AN INTERMEDIATE REDSHIFT

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ABSTRACT

Spectroscopic observations of the red stellar object identified with 3C 68.1 show it to be a QSO with redshift 1.238. The spectral index of the optical continuum is found to be about 6, a value considerably steeper than that previously found for QSOs.

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

I. INTRODUCTION AND OBSERVATION

The object 3C 68.1 is a highly asymmetric double radio source with separation 58″ and component intensities in the ratio 9:1 (McKay 1969). The radio spectrum is a power law with spectral index 0.85 (Véron, Véron, and Witzel 1972), with no strong evidence for variability. Longair and Gunn (1975) have identified this source with a 19th magnitude red stellar object lying between the two radio components.

Spectroscopic observations of 3C 68.1 were made in 1973 November in conditions of good (<2″) seeing using the University College London Image Photon Counting System (IPCS) (Boksenberg 1972; Boksenberg and Burgess 1973) mounted on the Oke-Gunn Cassegrain spectrograph at the Hale 5 m telescope. Object and sky spectra were recorded simultaneously through two 2″ diameter apertures over 512 channels each, at a dispersion at the camera focus of 240 Å mm^{-1}. Useful coverage was from about 3300 Å to over 7000 Å, at 12 Å per channel, with some noisy signal outside this range. The total integration time was 70 minutes.

Details of the observational and sky subtraction procedures as applied to the IPCS have already been described (Boksenberg and Sargent 1975; Boksenberg *et al.* 1975), and the same basic methods were employed in this case. The spectrum of 3C 68.1, after calibration using Oke's (1966) spectrophotometry of 3C 48, is shown in Figure 1. It is clearly non-stellar and the continuum rises very steeply in the red. Two emission lines are present, and these may be identified with C IV λ1549 and C III] λ1909, with a mean redshift of 1.238. The identified lines are marked in Figure 1, and the details of wavelength and individual redshifts are given in Table 1. The line identified with C III] λ1909 is the weaker of the two, but it is statistically significant (>4 σ) and seen in a region free from large-scale structure in the sky or in detector response. Its presence is confirmed from independent observations by Spinrad and Smith and by Burbidge and Smith (private communication). The equivalent widths of both features are comparable with those normally found in QSOs, though only approximate values could be determined, especially for C IV λ1549 where the continuum is poorly known. These lines show up more clearly in Figure 2, where the spectrum has been divided by a best-fit power law. At the redshift of 1.238 we should normally expect Mg II λ2798 to be visible at 6262 Å, but we find only weak evidence for an emission feature there. In this region the photocathode response is lower than at shorter wavelengths, hence the signal-to-noise ratio is lower and a line such as that identified with C IV, for example, would be more difficult to detect, especially against the higher continuum level.

TABLE 1

EMISSION LINES

Observed Wavelength (Å)	Equivalent Width (Å)	Identification	Redshift
3461...........	∼100	C IV λ1549	1.235
4278...........	∼ 50	C III] λ1909	1.241

Over the wavelength range observed we find that a power law with spectral index $\alpha \sim 6.1$, where α is defined by $f_\nu \propto \nu^{-\alpha}$, fits the observed continuum very well. Estimates of continuum slope based on data obtained through a narrow aperture and over a restricted wavelength range should be treated with some caution, but the error in α is unlikely to be greater than 0.5. With the same qualifications, we find $m_v \approx 19$, consistent with Longair and Gunn's (1975) estimate, and $B - V \approx 1.7$. Galactic extinction is unlikely to affect these quantities by very much, since at $b^{II} = -24°$ the correction to $B - V$ should not exceed 0.15 mag.

II. DISCUSSION

The radio source 3C 68.1, despite its extremely red color, is almost certainly a QSO. The object looks stellar on the deep plates taken by Longair and Gunn (1975), has a high redshift, and is far too luminous to be a normal galaxy. Hitherto neutral or red stellar identifications

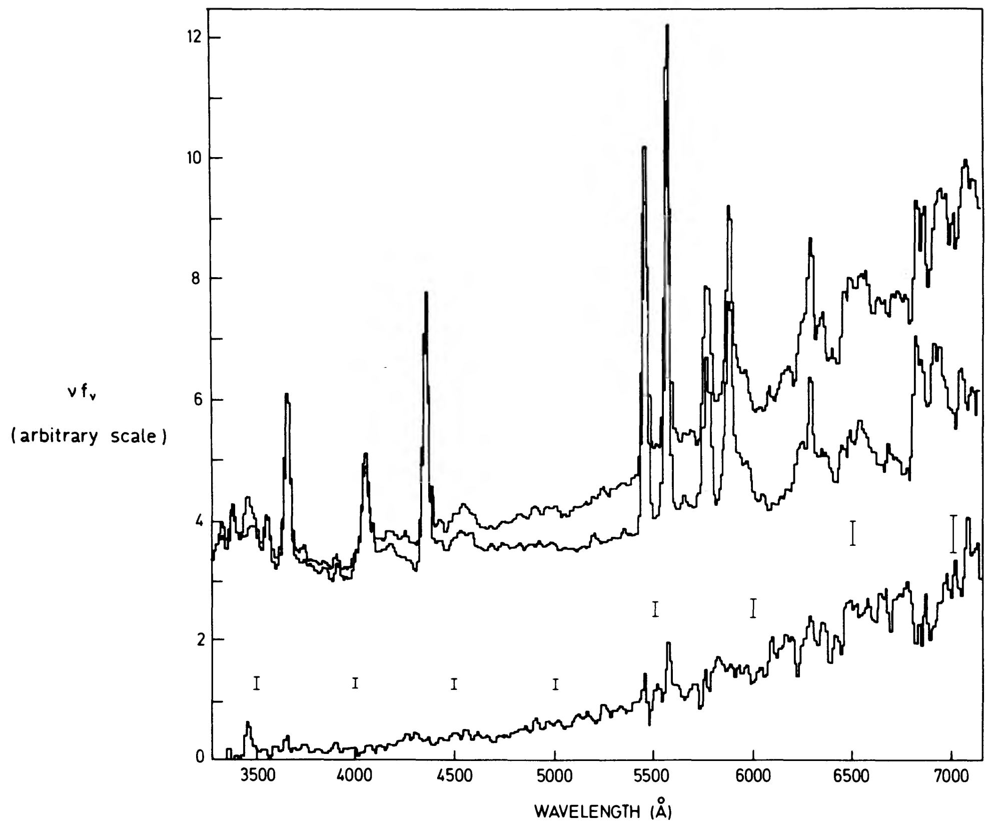

FIG. 1.—The observed spectrum of 3C 68.1 after renormalization. The top two spectra show the object with sky and the simultaneously recorded sky signals (biased up by 2 units) and the lowest curve shows the result of sky subtraction. A renormalization that gives the object spectrum in counts per angstrom (or νf_ν) in arbitrary units was applied to all three spectra, and the horizontal scale is in angstroms. Error bars shown above the subtracted spectrum give, at various points, the probable error in each channel at the $\pm$ 1σ level.

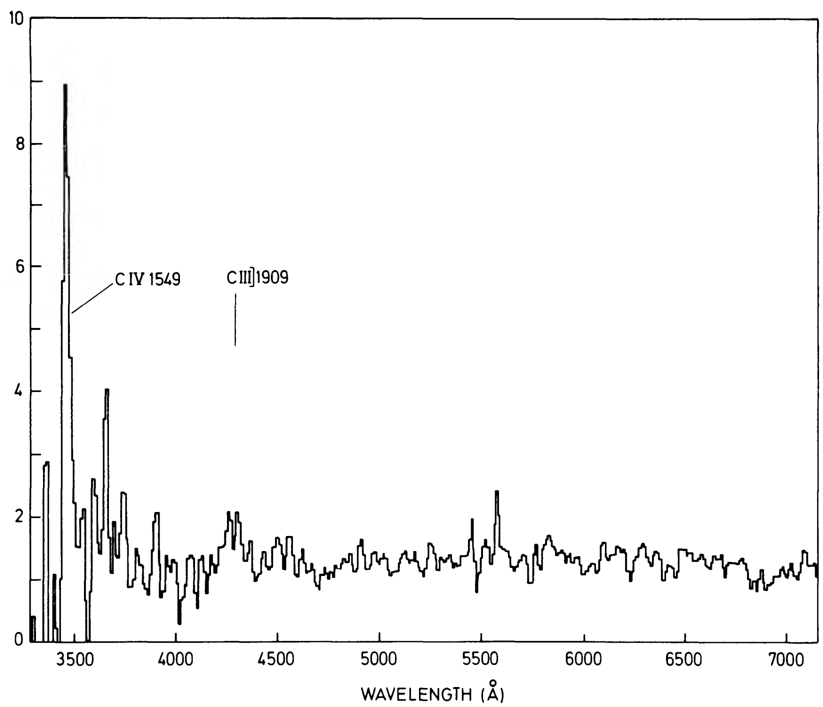

FIG. 2.—The spectrum after division by a power-law spectrum with $f_\nu \propto \nu^{-6.1}$. Lines used in determining the redshift are marked. The residual night sky lines may be identified in Fig. 1; these varied substantially during the exposure and then did not fully subtract out.

of radio sources have turned out to be either BL Lacertae objects (Strittmatter *et al.* 1972; Strittmatter *et al.* 1975) with optical spectral index <3.8 (Spinrad and Smith 1975) or in some cases high-redshift QSOs with normal underlying continuum ($0.2 < \alpha < 1.5$) which has been severely absorbed in the ultraviolet by intervening material (Carswell and Strittmatter 1973; Beaver *et al.* 1976). The 3C 68.1 source falls into neither of these two classes, though the extreme continuum slope does invite a comparison with BL Lacertae objects. The main difference lies in the presence of emission lines in 3C 68.1, and the observations reported here appear to rule out any hypothesis requiring that steep spectrum objects have no emission lines. Attempts to explain the absence of lines in BL Lacertae objects based on the lack of ultraviolet photons to ionize a surrounding gas, rather than, for example, the absence of any such gas, should be reexamined. The presence of C III and C IV in an object with such a low flux of ionizing photons (assuming the power law to hold in the far-ultraviolet) also raises the possibility that some other ionization mechanism might be required. Another possibility that we cannot rule out is that 3C 68.1 is a normal QSO and there is an intervening dust cloud causing an exceptionally large amount of reddening, though there is no sign of a strong absorption feature at a rest wavelength near 2200 Å, which is an extinction characteristic observed in our Galaxy.

Unlike BL Lacertae objects and violently variable QSOs, 3C 68.1 does not appear to have a compact variable radio component coincident with the optical object. There are insufficient data to determine whether or not the optical flux is variable; all we can say is that our 19 mag estimate is consistent with that of Longair and Gunn (1975) from plates obtained a year earlier.

The existence of very red QSOs such as this also reinforces the view that, to obtain a complete sample of such objects, all possible candidates of all colors should be examined spectroscopically. Very red objects near the Palomar Sky Survey plate limit may be classed as galaxies since it is difficult to determine whether an object is compact or extended at that level. If the radio structure of 3C 68.1 is at all typical, then there is an added complication. As Longair and Gunn (1975) have pointed out, if the weaker component of the asymmetric double source had been only a little fainter, then it could well have been missed entirely, leaving what would apparently be a single fairly compact radio source. The true optical identification would then be $\sim 23''$ from the radio position, which places it well outside the error box normally used when reasonably accurate radio positions are available, and so 3C 68.1 would be then classified as a blank field. It is important to observe further red candidates near radio sources to ascertain whether or not such very-steep-spectrum QSOs are indeed rare, or if they have been missed through not being identified as QSO candidates because of their color and radio properties.

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