THE ASTROPHYSICAL JOURNAL, 296:399–401, 1985 September 15

NARROW-BAND [O III] IMAGING OF THE QSO 4C 18.68: A TIDAL TAIL REVEALED?

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Received 1984 December 4; accepted 1985 March 13

ABSTRACT

We have imaged the $z = 0.313$ quasar 4C 18.68 and its surroundings in the light of redshifted [O III]. The QSO appears much more extended than in broad-band images, with a large halo and possibly a faint tidal tail discerned. A broad-band *I* CCD image taken in 1″–1″.2 seeing resolves the QSO from a companion galaxy 3″.6 distant, similar to many others seen in the field. We suggest that the elongated and asymmetric shapes of some QSOs may be due to not-quite-resolved companion galaxies, and that caution be exercised in interpreting luminosity and color profiles as evidence for underlying spiral or elliptical structure.

Subject headings: galaxies: clustering — quasars

I. INTRODUCTION

Efforts to detect and study underlying resolved structure associated with QSOs have largely been concentrated in three areas to date.

First, direct *broadband imaging* with photographic plates (Kristian 1973; Hutchings *et al.* 1981; Wyckoff, Wehinger, and Gehren 1981; Hutchings, Crampton and Campbell 1984) and CCDs (Gehren *et al.* 1984) has succeeded in resolving ~100 quasars. Lower redshift objects generally show larger isophotal diameters, and many quasars exhibit bisymmetrical extensions. This has been interpreted in terms of underlying spiral galaxy structure.

Second, many QSOs has been found on direct images to have *companion galaxies.* These galaxies often appear to be interacting with their associated QSOs (Wyckoff *et al.* 1980*b*; Stockton 1982; Hutchings, Campbell, and Crampton 1982; Bothun *et al.* 1982; Hutchings and Campbell 1983).

Third, *spectroscopy of the resolved "fuzz"* around QSOs (Wampler *et al.* 1975; Stockton 1976; Morton, Williams, and Green 1978; Wyckoff 1980*a*; Boroson, Oke, and Green 1982) has in some cases revealed strong, narrow, nebular emission lines, and in other cases hints of underlying galaxies.

Direct broad-band imaging with a large telescope at prime focus reaches faint limiting magnitudes quickly, but with sensitivity only to continuum radiation. This is the method of choice for initial study of many quasars, and for detecting their companions.

Spectroscopy is more time-consuming; ultimately desirable is the spectrum at each resolved point in a two-dimensional image. The only detailed study to date is that of Bergeron *et al.* (1983), who studied the giant H II envelope around the nearby QSO MR 2251-178.

A fourth, and as yet largely untried, approach should be exploited: *narrow-band imaging* to isolate emission line features, particularly for spiral or tidal arms or both of galaxies underlying QSOs. Initial tests we and Stockton and MacKenty (1983) have carried out on several quasars have been successful, and we report here results on the quasar 4C 18.68, including discovery of a probable tidal tail and an extended [O III] envelope around the QSO.

II. METHOD AND OBSERVATIONS

The most extensive spectroscopic study of QSO fuzz is that of Boroson, Oke, and Green (1982). [O III] λ5007 is strong or very strong in eight of their 12 objects; Hβ is generally much weaker or undetected, while Hα falls too far to the red to be easily detected. We therefore decided to image QSOs in the light of redshifted [O III].

A 50 Å FWHM Hα filter was available for our use at the Canada-France-Hawaii 3.6 m telescope. A QSO with $0.309 < z < 0.313$ has [O III] λ5007 redshifted to the Hα passband ($6554 < \lambda < 6574$ Å). With $z = 0.313$, and showing hints of resolution (Hutchings *et al.* 1981; Hutchings *et al.* 1984), 4C 18.68 was chosen as our first target. Figure 1 shows an uncalibrated spectrum of the core of 4C 18.68 displaying the great strength of [O III] λ5007. It was obtained using beam switching apertures of size 2″ × 3″ at the 4.5 m Multiple Mirror Telescope, just before a major breakdown of the blue-sensitive intensified Reticon spectrograph. The resolution has FWHM ≈ 8 Å.

A 2 hr [O III] plate taken in 1″ seeing with the ITT 90 mm single-stage image tube at the CFHT prime focus was obtained on the night of 1982 July 24–25 and is shown in Figure 2 (Plate 1). An *R* plate with the same instrument and comparable seeing was obtained on 1983 January 15–16 and is shown in Figure 3 (Plate 2).

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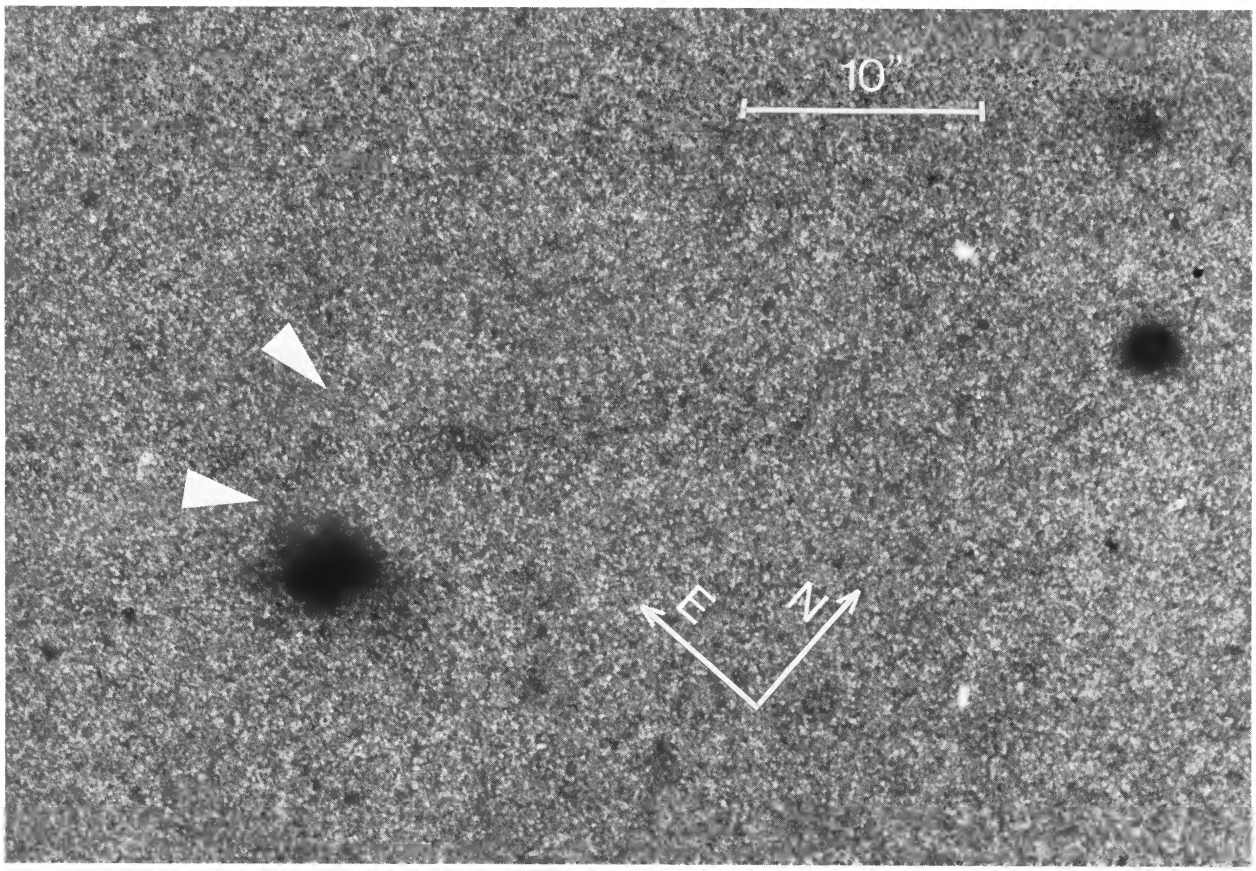

FIG. 2.—The field of the QSO 4C 18.68, from a 2 hr exposure taken with the Canada-France-Hawaii 3.6 m + ITT image tube through a 50 Å FWHM Hα filter. The QSO's $z = 0.313$ redshifts [O III] λ5007 into the bandpass of the Hα filter. A faint arc which may be a tidal tail extends (toward the north) from the QSO and is indicated with two arrows in the figure. A halo of [O III] emission surrounds the QSO.

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PLATE 2

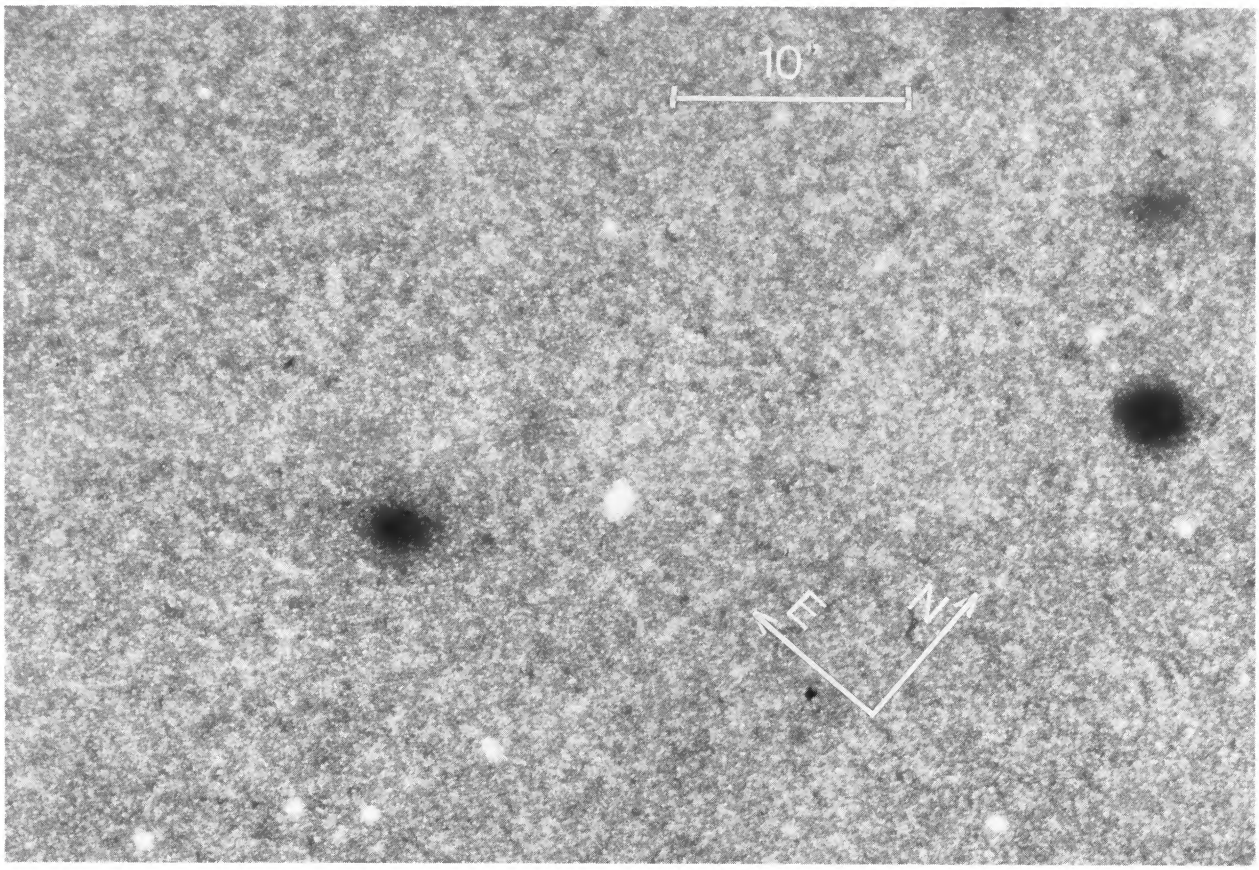

FIG. 3.—A five minute *R* plate of 4C 18.68 taken with the same instrument as Fig. 2. The halo and tidal tail in Fig. 2 are not seen in this broadband image.

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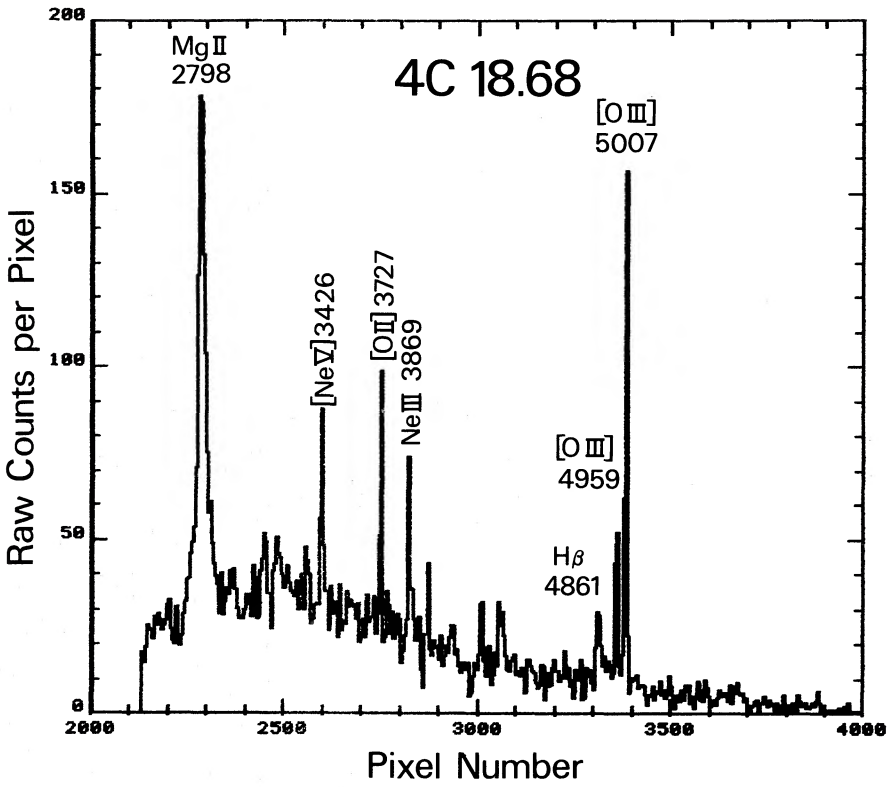

FIG. 1.—Uncalibrated Multiple Mirror Telescope spectrum of the central core of the $z = 0.313$ QSO 4C 18.68. The spectral range is ~4000–7000 Å, with a resolution of FWHM ≈ 8 Å. Strongest emission lines are identified.

The QSO is much more extended in the [O III] image than in the *R* image, relative to the star 30″ to the northwest. In particular, the QSO is seen to have a faint [O III] halo extending 6″ in the northwest-southeast direction, a bulge 3.″6 to the northeast, *and a very faint, curved feature beginning at the southeast side of the QSO and extending at least 6″ to the north.*

The northwest-southeast extension and northeast bulge are also seen in the red isophotal map of 4C 18.68 by Hutchings *et al.* (1984). The curved feature in Figure 2 is not seen in either the red or blue isophotal maps of Hutchings *et al.* (1984), even though they reach fainter *continuum* magnitudes than our [O III] or *R* images.

On 1984 July 7–8, we imaged 4C 18.68 with the University of Hawaii 2.2 m telescope + TI CCD at the Cassegrain focus. Three 5 minute exposures through an *I* filter in 1″–1.″2 (FWHM) seeing have been summed to produce Figure 4 (Plate 3). This image clearly resolves the northeast extension of 4C 18.68 as a companion galaxy, distinct and separate from the QSO.

III. DISCUSSION

In this section we assume $H_0 = 75$ km s^{-1} Mpc^{-1}, $q_0 = \frac{1}{2}$, and hence 1″ = 3.75 kpc at $z = 0.313$.

We consider the curved feature in Figure 1 to be a candidate for a tidally induced tail extending at least 22 kpc from the QSO. (Double tails in the QSOs 3CR 249.1 and Ton 202 have been detected by Stockton and MacKenty 1983.) We consider it unlikely that the feature is a jet of the M87 or 3C 273 variety, because it is neither straight nor directed radially from the QSO, though a possible alternative is a precessing jet (Gower and Hutchings 1982).

Tidal tails and extended halos are the natural consequences of a close passage of two galaxies (Toomre and Toomre 1972). There is no obvious candidate for the tidally interacting galaxy in Figure 1, but the image is not a very deep one.

The much deeper image of Figures 4 and 5 reveals several possible candidates. The most obvious are the galaxies (3.″6 northeast and 7.″3 north) of the QSO; the latter, however, is a foreground galaxy at $z = 0.2427$ (Stockton 1978). Another, much fainter object 13″ (49 kpc) north-northeast of the QSO lies in the path of the extension of the [O III] emitting arc in Figure 2. Figure 17 in Toomre and Toomre (1972) is similar to the configuration of Figure 2 and suggests that the galaxy 9″ west and slightly north of the QSO is producing the tidal tail. The suggestion that any of these galaxies is responsible for the tail is, of course, speculative and can only be tested with much deeper narrow-band images and spectroscopy of the galaxies in the field of 4C 18.68.

We conclude by noting that the newly detected galaxy 3.″6 northeast of, and ~3 mag fainter than, the QSO was distinctly resolved only because of excellent seeing and instrumentation at the University of Hawaii 2.2 m telescope. Furthermore, with 4C 18.68 as a relatively close example, other galaxies may easily be unresolved (at $r \lesssim 1''$–$2''$) within many of the ~100 "resolved" QSOs imaged under less ideal conditions. If this is the case, then using brightness and color profiles to deduce morphological types of QSOs' underlying galaxies may yield spurious results. It is stating the obvious that an unambiguous determination of the nature of QSOs' host galaxies will only be

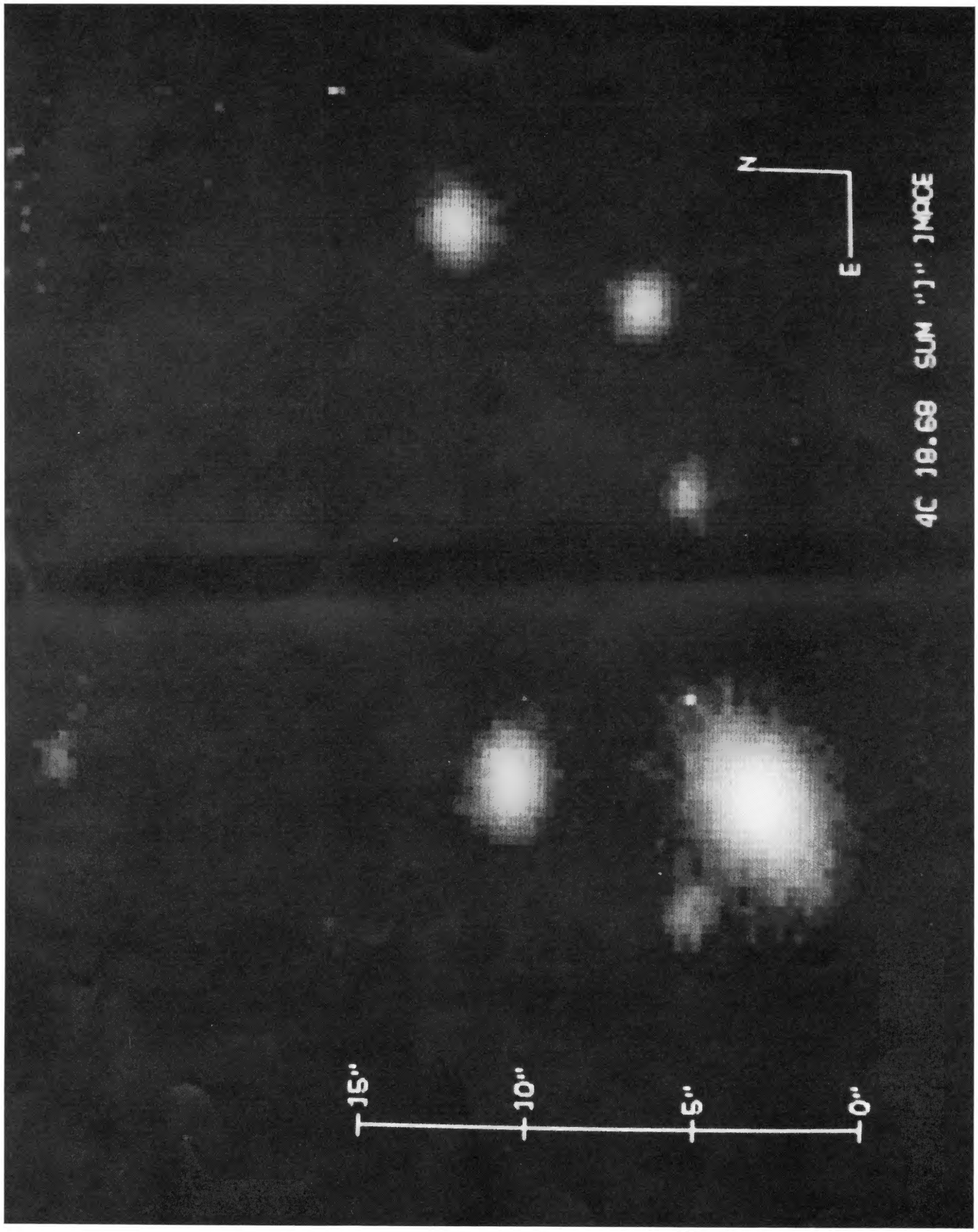

FIG. 4.—Sum of three 5 minute CCD frames of 4C 18.68 taken through an *I* filter with the University of Hawaii 2.2 m + TI CCD. The northeast extension of the QSO seen in Fig. 2 is clearly resolved as a galaxy 3".6 from the QSO.

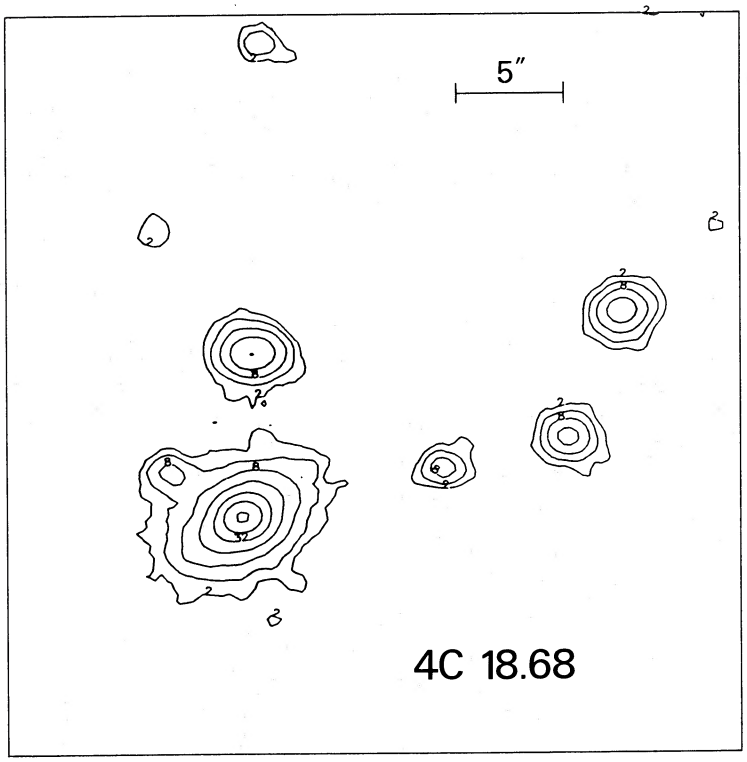

FIG. 5.—An *I*-band isointensity contour map of 4C 18.68 derived from Fig. 4.

obtainable with Space Telescope or with significant advances in ground-based seeing enhancement techniques.

IV. SUMMARY

We have imaged the $z = 0.313$ QSO 4C 18.68 and its surroundings in the light of redshifted [O III] λ5007. The QSO is considerably more extended than in broad-band images, and a faint extension suggestive of a tidal tail is seen. A deep *I* image in very good seeing resolves the QSO from a companion 3″.6 away and cautions that many "resolved" QSOs may contain unresolved galaxies. Deducing the morphological types of QSOs' underlying galaxies may thus be impossible without the ~0″.1 resolution of Space Telescope.

M. M. S. and A. F. J. M. are grateful for excellent support and disaster prevention at CFHT from Rick Salmon and Ken Barton, and image processing support from Dan Klinglesmith at GSFC and Mike Potter at ST ScI. Ray Weymann did everything possible to make a balky MMT spectrograph work for us, and we appreciate his hard work. M. M. S. thanks Pat Henry for support at the University of Hawaii 2.2 m telescope. Observing time on CFHT, the UH 2.2 m and the MMT are gratefully acknowledged.

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