THE "GRAVITATIONAL LENS" 3C 321: A REMARKABLE IMPOSTOR

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ABSTRACT. Recent observations of the radio galaxy 3C 321 are presented. The optical nucleus consists of two components (A, B), separated by $\sim 4''$ (~ 6 kpc), whose low-resolution spectra strongly resemble those of high-ionization type 2 Seyfert nuclei. The relative intensities of the emission lines differ in A and B by less than 1%, and their profiles are almost identical. 3C 321 appears to be a convincing example of a gravitationally lensed object.

Careful analysis of high-quality radio and optical data, however, reveals that the system is almost certainly *not* a lens. The equivalent widths of the emission lines are roughly twice as high in B than in A, and there are significant spatial offsets between regions of bright continuum and line emission. A slight, but fundamental, difference is visible in the two Hα emission profiles. The radial velocities of A and B are discrepant by 31 ± 10 km s^{-1}. Finally, component A is nearly coincident with a flat-spectrum radio core, whereas B is next to an extended, steep-spectrum knot of radio emission.

This object should serve as a warning to lens hunters: beware of impostors, whose true properties may be difficult to ascertain without extensive optical and radio observations.

1. INTRODUCTION

Detailed studies of extended, optical emission-line regions associated with radio galaxies can provide valuable information on the ways in which jets interact with ambient gas. "Minkowski's object," for example, consists of a dwarf galaxy in which a violent burst of star formation was recently triggered by a radio jet from an adjacent elliptical galaxy in the cluster Abell 194 (van Breugel *et al.* 1985). The interstellar medium is ionized by ultraviolet light from the hot, massive stars, as in the similar case of Cen A (Graham and Price 1981). Other objects show that jets may be deflected and disrupted when they collide with dense extranuclear material, and that synchrotron radiation from internal shocks can photoionize the surrounding gas (see van Breugel 1986 for a recent review).

In this paper I briefly describe observations of 3C 321 ($z = 0.096$), and show that the galaxy at first sight appears to be gravitationally lensed. Careful analysis of the data, however, casts serious doubt on this interpretation. A complete discussion is given by van Breugel *et al.* (1987).

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2. OBSERVATIONS

Visually, 3C 321 is a sixteenth magnitude galaxy with two fairly compact nuclei (A, B) separated by $\sim 4''$, or ~ 6 kpc ($H_0 = 75$ km s^{-1} Mpc^{-1}, $q_0 = 0.5$). Component A is roughly twice as bright as B, and a common envelope is present in deep photographs. Low-resolution optical spectra (FWHM ≈ 10 Å) obtained with the 3-m Shane reflector at Lick Observatory show that A and B have strong emission lines spanning a wide range of ionization levels. The spectra resemble those of high-ionization type 2 Seyfert galaxies, as indicated by the intensity ratios [O III] λ5007/H$\beta \approx 11$ and He II λ4686/H$\beta \approx 0.5$. Lines such as [Ne V] λ3426 are strong, but [O I] λ6300 is also prominent.

Most remarkable, however, is that the emission-line intensity ratios in components A and B are *nearly identical* — they differ by less than 1%! Although such emission-line characteristics are often found in different H II regions within a given galaxy, and in the high-excitation spectra of extragalactic H II regions, they have rarely (if ever) been seen in any two distinct Seyfert nuclei or QSOs. It seems, therefore, that 3C 321 should be added to the growing list of known gravitational lenses (see Canizares 1987 for a current review).

To explore this possibility, extensive new observations of 3C 321 were made at radio and optical wavelengths. In particular, spectra having excellent signal-to-noise ratios and moderate resolution (FWHM $\approx 1.5 - 2.5$ Å) were obtained on 29 March 1986 UT with the 5-m Hale telescope at Palomar Observatory; the long slit of width $1''$ was oriented at a position angle of 131° to include both components. Also, high-quality radio maps were made with the Very Large Array. These could be compared with the corresponding optical images obtained with the Shane reflector.

Figure 1 illustrates the spectrum of component A over the observed wavelength range $\sim \lambda\lambda 4700 - 5600$. An effective entrance aperture of size $1'' \times 2''$, centered on A, was synthesized from the original two-dimensional (2-D) CCD data. A spectrum of component B was obtained in a similar manner, and subtracted from that of A. The difference is shown in the bottom part of the figure, with the same ordinate scale. The degree to which the emission lines are absent is astounding. Only a slight "oscillation" in the continuum level is visible at the wavelength of the strongest line, [O III] λ5007, but the *integrated* strength of this line is almost exactly zero. This confirms that the relative intensities of emission lines in the centers of A and B are nearly identical. Furthermore, the *absolute* intensities and widths must also be comparable in the central regions. The 2-D spectra show that the relative intensities are similar in the more extended regions of A and B, and in several faint, detached wisps of emission as well.

3. 3C 321: A GRAVITATIONAL LENS?

Do these observations really imply that 3C 321 is a gravitational lens? The answer, unfortunately (or fortunately, depending upon one's point of view), is no. A major obstacle to the lens interpretation is that the *equivalent widths* of the emission lines in component B are roughly twice those in A (Fig. 1). If the true nucleus of 3C 321 were lensed, the underlying continuum would be nearly the same in both images, as are the emission lines. Models involving microlensing (e.g., Kayser, Refsdal, and Stabell 1986) can produce the observed discrepancy, but this is considered unlikely here in view of the extended nature of the components, whose emission-line intensity ratios are everywhere very similar.

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There are several other arguments against the lens scenario. Careful inspection of the red spectra ($\sim \lambda\lambda 6850 - 7500$), for example, reveals a very weak, broad component of Hα emission (FWZI $\gtrsim 6000$ km s^{-1}) in A, but not in B. This Hα line is reminiscent of, but much weaker than, those seen in type 1 Seyferts; it has been detected in the spectra of many bright, nearby galaxies by Filippenko and Sargent (1985). In addition, the narrow emission lines in the spectra of A and B exhibit a systematic offset of 31 ± 10 km s^{-1}. Finally, the 2-D spectra show that the region in component A having the most intense emission lines is offset by $\sim 1.1''$ from the region of brightest continuum emission, and that a displacement of $\sim 0.4''$ in the opposite spatial direction is present in component B. This has been confirmed with the narrow-band images of 3C 321.

One of the most striking discrepancies between A and B is found in the radio data. Maps at $\lambda = 6.2$, 18.3, and 21.6 cm show that optical component A is almost coincident with a flat-spectrum, compact "core" of radio emission. Component B, on the other hand, is next to a steep-spectrum, somewhat extended, radio

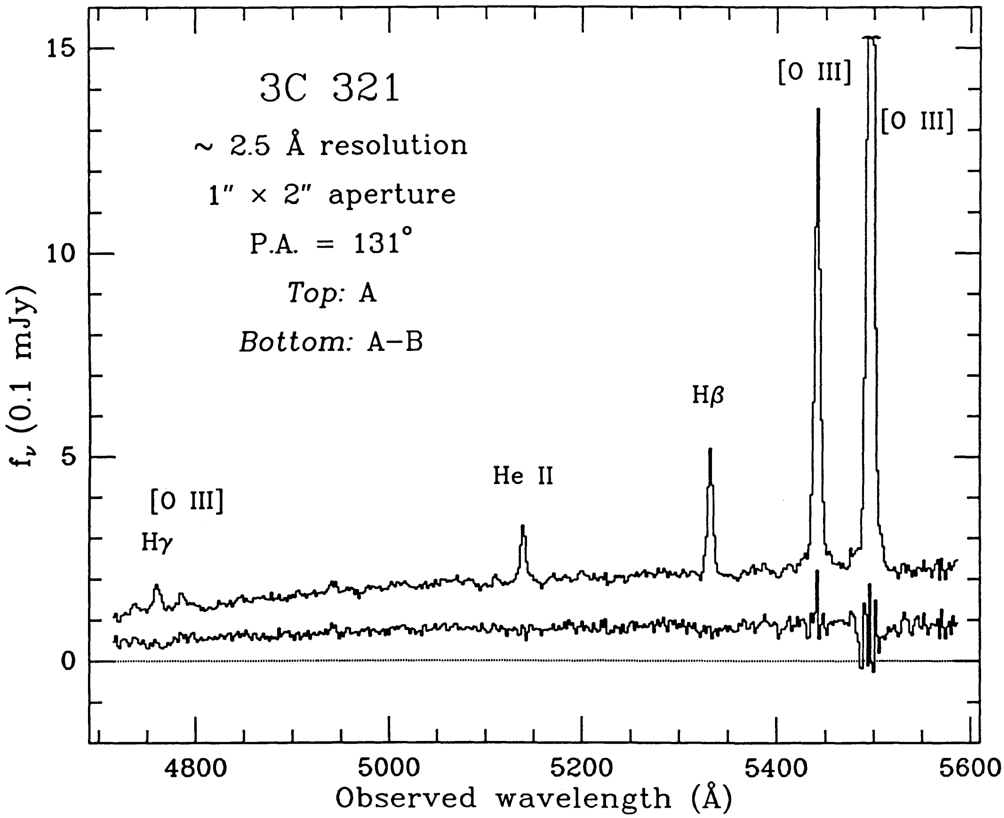

Figure 1: Blue spectrum of 3C 321 A (*top*), showing some of the high-excitation emission lines. The spectrum of 3C 321 B has been subtracted from that of A in the bottom portion of the figure, after removal of a slight velocity difference (31 km s^{-1}). A continuum devoid of emission lines remains. The equivalent widths of the lines are therefore much greater in B than in A, although their intensities are almost indistinguishable.

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"knot." This knot itself lies along the path of a one-sided jet of length $\sim 20''$ which originates in the radio core. The optical images of 3C 321 show complex emission-line regions within the galaxy, aligned roughly along the jet. These characteristics are undoubtedly inconsistent with gravitational lensing. Instead, the jet and ambient medium seem to be interacting in a complicated manner, especially in the vicinity of component B.

Note that if a lens were indeed responsible for the optical appearance of 3C 321, it would probably have to be very massive ($M \approx 10^{12}$ $M_\odot$, but this is model dependent). Since 3C 321 is so nearby, the lensing object should be easily visible, unless it is a black hole or some other form of dark matter. Galactic objects such as neutron stars could produce the observed separation if the impact parameter were small, but the lens would last only a short time. Moreover, it would be difficult to account for extended emission of the type actually observed.

4. CONCLUSIONS

Although at first sight 3C 321 resembles a gravitationally lensed object, under closer scrutiny there are many arguments against this interpretation. The possibility of being fooled into thinking that two adjacent, extragalactic *H II regions* having similar spectra are lensed images of a single galaxy has already been stressed by Halpern, Marshall, and Oke (1984), in a detailed study of 1300 + 361 A, B. Other examples of such galaxies are discussed by Chen and Shaver (1982) and by He (1987). 3C 321, however, is the first case in which separate "nuclei" with nearly identical *Seyfert 2* spectra have been identified. Despite their highly unusual spectral properties, components A and B are physically distinct entities, albeit very puzzling ones. Their origin, relationship to each other, and ionization mechanisms are not yet understood.

3C 321 should therefore serve as a warning to observers attempting to identify gravitational lenses with low-resolution optical spectra alone. Extensive optical and radio observations may be necessary to determine the true nature of lens candidates. One must beware of impostors, whose superficial characteristics may be strikingly similar to those of lenses. This, together with the intrinsic differences which can exist in the spectra of *genuinely* lensed objects (see, e.g., Kayser *et al.* 1987, and references therein), may render the search for gravitational lenses very difficult indeed.

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DISCUSSION

Maccacaro: What do you think is responsible for the observed properties of 3C 321, if it is not a gravitational lens?

Filippenko: Ah, the question I was hoping for! There are many possibilities, none of which is convincing at this time. Let me explain them very briefly; full details can be found in van Breugel *et al.* (1987).

One idea is that component A is the nucleus, as suggested by the radio data, and that it emits nonstellar radiation which ionizes the surrounding gas, including that in the off-nuclear knot, B. The great similarity of the emission-line spectra of A and B, however, can only be explained if the ionization parameter is independent of location in 3C 321, and this is improbable because the gas does not exhibit large spatial density gradients. Moreover, the absorption lines in *both* A and B seem to be diluted by featureless continua, suggesting that a source of ionizing radiation is present in both.

Similar ionization parameters in A and B can be produced if the true nucleus is midway between the two components. In this case, it must be obscured by a dense cloud of dust, or by some other object for which there is no independent evidence. Furthermore, this model does not explain why the radio core is close to A, nor does it account for the nonstellar continua noted above.

Perhaps components A and B are like "cosmic mirrors" which reflect the spectrum of a hidden nucleus between them. But again, there is no evidence for thick dust or an obscuring disk in 3C 321. In addition, light scattered from A and B should be strongly polarized, whereas actually it is not.

Components A and B could both harbor sources of ionizing radiation if they are the nuclei of two merging galaxies. Although the general idea of a merger is not unlikely, the small separation between the extended radio knot and optical component B must then be a coincidence in 3C 321. Also, it is difficult to imagine why the ionization parameters should be nearly identical in A and B.

A diffuse source of ionizing photons, such as in a "thermal bath" of constant temperature, might account for the similar emission-line spectra in A, B, and surrounding regions. If so, 3C 321 is a unique object, and severe problems are encountered in attempts to explain the origin of the diffuse bath. The radio data also seem inconsistent with this hypothesis.

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