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DO THE BROAD EMISSION LINES IN ARP 102B ARISE IN A RELATIVISTIC DISK?

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ABSTRACT

It is been proposed by Chen, Halpern, and Fillippenko that the asymmetric, double-peaked, emission-line profiles observed in Arp 102B arise in a relativistic disk. We present new data showing that at least at some epochs the long-wavelength side of the line profile is higher than the short-wavelength side, contrary to what is expected from a relativistic disk in which the approaching side of the disk is brighter because of Doppler boosting. Moreover, the two peaks do not vary together in flux as expected if the emission-line variability is attributable to changes in the flux from the central continuum source. We conclude that an axisymmetric relativistic disk cannot explain the salient features of the line profiles in Arp 102B.

Subject headings: galaxies: individual (Arp 102B) — galaxies: nuclei — galaxies: Seyfert — line profiles

I. INTRODUCTION

The broad-line profiles observed in the spectra of active galactic nuclei (AGNs) are sometimes double peaked. In some cases, this double-peaked structure is clearly seen only in the difference spectrum produced by subtracting "low-state" from "high-state" spectra of variable objects, which indicates that the variable part of the emission line is double peaked. In other objects, the double structure is more pronounced and can be seen in individual spectra. Double-peaked, broad emission lines obviously provide an important clue to the physical structure and kinematics of the broad-line region (BLR). Double-peaked emission lines have been variously ascribed to rotating disk structures (e.g., Stirpe, de Bruyn, and van Groningen 1988; Alloin, Boisson, and Pelat 1988; Pérez *et al.* 1988) or binary BLRs (e.g., Gaskell 1983; Peterson, Korista, and Cota 1987). No consensus has emerged, although rotating disks, which may or may not be related to the purported accretion disks which fuel the central engine, currently seem to enjoy popularity.

The emission-line profiles observed in the spectrum of Arp 102B are of particular interest. The Hα profile has been modeled as arising in a relativistic disk by Chen, Halpern, and Fillippenko (1989) and Chen and Halpern (1989) in an attempt to explain the asymmetric double-peaked profiles; the short-wavelength (blueshifted) side of the profile is brighter than the long-wavelength (redshifted) side on account of Doppler boosting. In this contribution, we present new spectra of Arp 102B which show that at least at some epochs the sense of the profile asymmetry is reversed, with the red peak higher than the blue peak. This argues against interpretation of these line profiles as the signature of a relativistic disk.

II. OBSERVATION AND RESULTS

The spectrum of Arp 102B was recorded with the Lick Observatory Image-Dissector Scanner (Robinson and Wampler 1972; Miller, Robinson, and Wampler 1976) at the Cassegrain focus of the 3 m Shane telescope on UT 1982 July 24. These data, shown in Figure 1, cover the wavelength range 3700–7700 Å at a resolution of ~16 Å. A second scan covering the wavelength range 3300–6400 Å at resolution ~10 Å, shown in Figure 2, was obtained with the grism spectrograph (Miller, Robinson, and Goodrich 1988) and a TI 800 × 800 CCD on the Shane telescope on UT 1988 October 9. The data were reduced using standard procedures as described by Miller, Robinson, and Goodrich (1988).

In low-luminosity AGNs such as Arp 102B, a significant fraction of the observed optical continuum is due to starlight from the host galaxy. The stellar absorption lines can introduce artificial structure into the emission-line profiles, so it is important to try to remove the contaminating stellar component from the observed spectrum (e.g., Filippenko 1985; Crenshaw and Peterson 1985). We attempted to remove the contaminating stellar features in these spectra by subtracting a suitably scaled spectrum of M32; the spectrum was scaled in such a way as to minimize the strength of the residual absorption lines. Figures 1 and 2 also show the observed spectrum after correction for the stellar component.

Figure 1 clearly shows that the broad Hα profile is asymmetric and that the red peak is the stronger of the two even after allowing for contamination by the narrow [S II] λλ6716, 6731 lines. The Hα profile is shown in more detail in Figure 3. In order to determine whether or not the red peak is intrinsically the higher of the two, we considered the following questions:

1. Is the red side of Hα enhanced by noise or a flat-field effect? The IDS a dual-beam instrument and the spectrum of Arp 102B was recorded through each of the two apertures, which yields two completely independent spectra. The red side of Hα and Hβ appears higher in each of these spectra, which makes it extremely unlikely that an instrumental effect has altered the line profile.

2. Could the red wing of Hα be affected by the atmospheric B band? To test this, we used an empirical model of the atmospheric A and B bands which specifies their profiles and relative strengths, which leaves only the total strength of the A band as a free parameter. We scaled this model to adequately remove the A band from the spectrum, as shown in Figure 3.

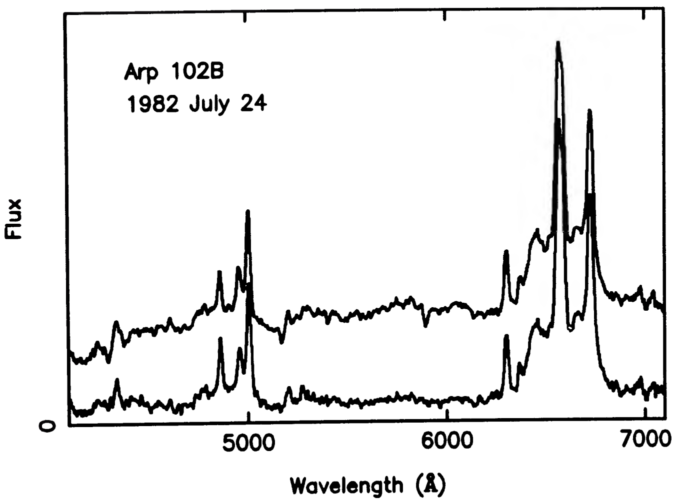

FIG. 1.—Spectrum of Arp 102B as recorded with the Lick Observatory IDS on 1982 July 24. The data have been scaled abitrarily in energy s^{-1} cm^{-2} $Å^{-1}$ in the rest frame of Arp 102B ($z = 0.02438$). At this time, the redward peak in the Balmer lines is higher than the blue peak. A scaled spectrum of M32 has been subtracted from the observed spectrum to remove absorption features due to starlight from the host galaxy.

This figure shows that the B band lies far enough to the red that it affects only about one-half of the red peak of Hα, and that regardless of whether or not an attempt is made to account for B band contamination the red wing of Hα is higher than the blue peak.

Additional evidence that the red peak is higher than the blue peak is found by careful examination of the Hβ profile, as shown in Figure 4. The Hβ profile is similar to the Hα profile, although the red peak in Hβ is not clearly seen because of the contamination by the narrow [O III] λλ4959, 5007 lines. Indeed, the apparent partial blending of these two lines is in part due to the underlying red peak in Hβ. To verify that this is true, we have attempted to model the [O III] λλ4959, 5007 contribution. This was accomplished by adopting the *narrow*

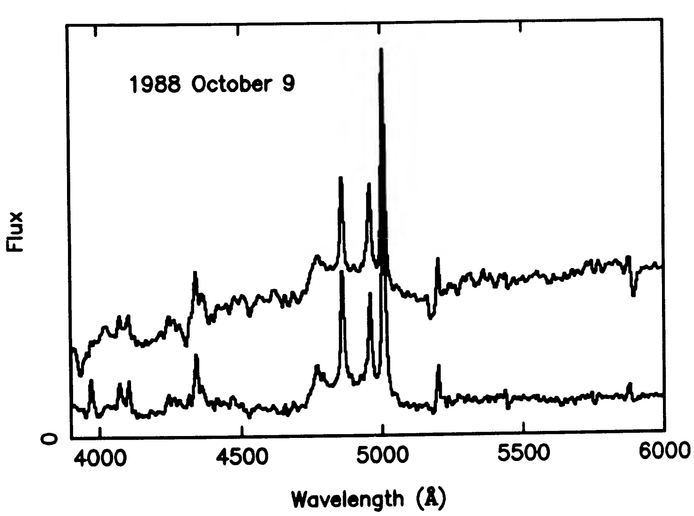

FIG. 2.—Spectrum of Arp 102B observed with the grism spectrograph with the TI CCD on 1988 October 9, and plotted as in Fig. 1. Here the blue peak is higher than the red peak in the Balmer lines, as in the spectra shown by Chen, Halpern, and Filippenko (1989) and Halpern and Filippenko (1988). As in Fig. 1, the spectrum is shown both as observed and with the starlight component subtracted off.

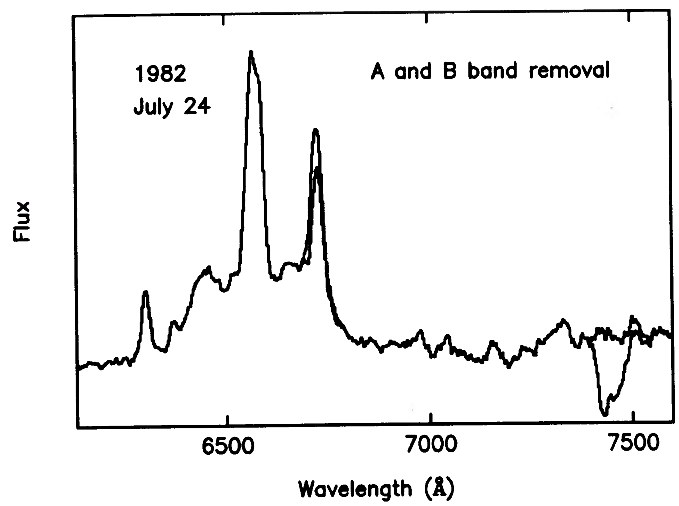

FIG. 3.—Here we have attempted to remove the effects of the atmospheric A and B bands from the Hα region of the spectrum shown in Fig. 1. It is clearly seen that the prominence of the red peak in the broad Hα feature is not attributable to uncertainty in removal of the B band.

Hβ profile as a template and using it to model the profiles of each of the [O III] lines. For each of the [O III] doublet lines, the narrow-line template was scaled in flux, shifted in wavelength to the position of the line to be modeled, and subtracted from the observed spectrum. The higher resolution scan shown in Figure 2 was used to obtain the flux scale factors (F([O III] λ5007)/F(Hβ) = 2.25), and to ascertain that, at the resolution

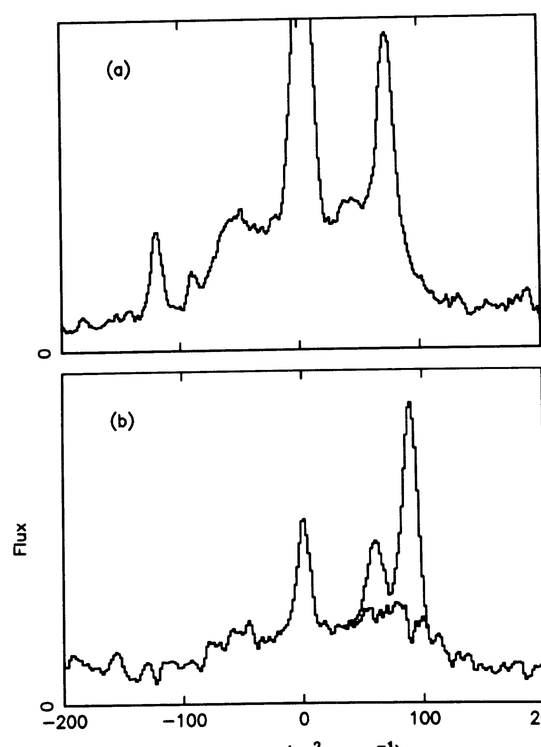

FIG. 4.—In the upper panel. The Hα profile shown in Fig. 1 is expanded and plotted as a function of velocity relative to the narrow lines. The corresponding Hβ profile is shown in the lower panel. Also shown in the lower panel is the result of removing the narrow [O III] λλ4959, 5007 lines; this clearly shows the underlying red peak in the broad Hβ lines.

employed here, the profiles of the [O III] lines and the narrow component of Hβ are indistinguishable. The result of subtracting the modeled [O III] lines from the data is shown in Figure 4, along with the corresponding Hα profile on the same velocity scale. It is seen that after proper removal of the [O III] lines, the red peak in the broad Hβ component is stronger than the blue peak.

III. DISCUSSION

The relativistic disk model of Chen, Halpern, and Filippenko (1989) and Chen and Halpern (1989) has two important, observable consequences:

1. If the emission lines are powered by radiation from the central source, the emission-line fluxes should vary in response to continuum variations, as indeed is observed in other AGNs (see Peterson 1988 for a review). As seen by an external observer, different parts of the BLR will respond to continuum variations at different times, depending on the differences in light-travel time to the observer. For an axisymmetric rotating disk, no time delay should be observed between the red and blue emission line peaks, and an external observer should see the peaks vary together. Comparison of the data presented here with the data shown by Chen, Halpern, and Filippenko (1989) shows that the red and blue peaks do not vary in concert. A series of Hα profiles shown by Halpern and Filippenko (1988) also shows that the red and blue sides of the line profile do not seem to vary together in Arp 102B.

2. The blue side of the line should be stronger than the red side if the asymmetry is due to Doppler boosting in a relativistic disk. Figure 4 shows that this is not always the case.

The observations presented here argue strongly that the line profiles of Arp 102B cannot be explained in terms of an axisymmetric relativistic disk. While a contribution by such a structure cannot be ruled out, an additional broad emission-line component would have to be invoked to explain the strength of the red side of the profile during some epochs.

Chen, Halpern, and Filippenko (1989) also cite the case of 3C 390.3, a more luminous broad-line radio galaxy, as another possible case where the asymmetric double-peaked line profiles might arise in a relativistic disk. However, in this case as well, the two peaks do not vary together and quite often the red side of the profile is brighter than the blue side (Veilleux 1990).

On the other hand, the fact that the wavelength of the blueward peak in Arp 102B has been stationary for five years argues against the binary BLR hypothesis (Halpern and Filippenko 1988). The very fact that more than two discrete components are observed in some cases, such as NGC 5548 (Peterson *et al.* 1990), demonstrates that the binary hypothesis is also incapable of explaining all of the structure observed in broad-line profiles; more complicated scenarios are almost certainly required.

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