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THE ULTRAVIOLET SPECTRUM OF THE SEYFERT GALAXIES NGC 3516 AND NGC 5548[1]

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ABSTRACT

The two Seyfert 1 galaxies NGC 3516 and NGC 5548 have been observed with the *International Ultraviolet Explorer* (*IUE*). In both galaxies the ultraviolet continuum becomes harder when it brightens. Analysis of the emission lines permits one to partially unravel the structure of the broad line region. In contrast to most quasar spectra, the C IV λ1550, Mg II λ2800 and C III λ1909 line have different profiles, with C IV being broader than Mg II which is broader than C III. The differences between the profiles provide evidence for the existence of at least three types of clouds with different physical conditions and different velocities; the physical conditions correlate with the velocities of the clouds.

This difference found here between the structure of the broad line regions of Seyfert galaxies and of quasars is likely to be related to the fact that Seyfert galaxies do not seem to follow the Baldwin relation for quasars, between absolute luminosity and equivalent width of C IV.

In NGC 3516 there is a slightly blueshifted absorption line in C IV λ1550 and N V λ1240. The red edge of the absorption is at 1550 ± 1.5 Å and 1242 ± 2 Å with respect to the galaxy for these two lines respectively. The apparent variations of the width and equivalent width of these absorption lines are interpreted as actual variations of the number of absorbers and not to variations of the underlying emission profile. The equivalent widths of the absorption lines lie in the range 1–4 Å, corresponding to $\sim 10^{19}$ cm^{-2} for the column density of hydrogen.

Subject headings: galaxies: individual — galaxies: Seyfert — quasars — ultraviolet: spectra

I. INTRODUCTION

Given the fact that the ultraviolet spectrum of intrinsically bright, high-redshift quasars is already known from ground-based observations, the observations of the UV spectrum of Seyfert nuclei, especially faint ones, allow making a comparison of the UV spectra of active nuclei over a wide range of absolute luminosities.

The two Seyfert galaxies NGC 3516 and NGC 5548 have been selected for a program of UV observations of variable Seyfert nuclei with the *IUE* satellite (Boggess *et al.* 1978). In the course of this study, remarkable variations of the continuum and of the profiles and intensities of the lines have occurred in the UV spectrum of NGC 3516. For this reason, most of the observing time in this program has been devoted to this galaxy.

The electromagnetic spectrum of NGC 3516 and NGC 5548 is shown in Figures 1a and 1b. The data come from measurements made at different epochs; however, the continuum variations in the optical and UV ranges are less than a factor 4, and therefore the general shape of the spectrum in Figures 1a and 1b is very probably representative of the actual spectrum, at least up to X-ray energies.

The nucleus of NGC 3516 is surrounded by a highly ionized nebulosity extending several kiloparsecs from the nucleus. The high degree of ionization in this nebulosity is consistent with photoionization by the central ultraviolet source observed with *IUE* (Ulrich and Péquignot 1980).

II. DATA BASE AND REDUCTION

We observed the nucleus of NGC 3516 and NGC 5548 with *IUE* in the low-dispersion mode at a resolution of 8 Å and with the large aperture to ensure photometric accuracy. The images which we obtained are listed in Table 1.

All the short-wavelength spectra of NGC 3516 were reduced in a homogeneous way with the reduction program installed at Vilspa in 1981 June, giving a pixel size of 1.15 and 1.87 Å in the SWP and LWR ranges, respectively. All the other spectra were reduced with the standard reduction package available at the date they were taken. Those affected by the ITF error were corrected following the procedure outlined by Cassatella and Ponz (1979). In addition we extracted some of the spectra from the last two-dimensional images produced by the standard reduction packages and were able to

[1]Based on observations by the *International Ultraviolet Explorer* collected at the Villafranca Satellite Tracking Station of the European Space Agency.

TABLE 1
JOURNAL OF UV OBSERVATIONS

Image Number	Date	Time (Minutes)
	NGC 3516	
SWP 1821	1978 June 20	300
LWR 1703	1978 June 20	50
SWP 1840	1978 June 22	390
SWP 8633	1980 April 2	240
LWR 7378	1980 April 2	140
SWP 13425	1981 March 7	240
LWR 10089	1981 March 7	135
SWP 14241	1981 June 11	280
LWR 10834	1981 June 11	105
SWP 14243	1981 June 12	280
LWR 10839	1981 June 12	122
	NGC 5548	
LWR 8131	1980 June 26	60
SWP 9379	1980 June 26	180
SWP 9380	1980 June 26	32

extend the wavelength range of the short-wavelength camera by 50 Å toward the long wavelengths. The standard wavelength scale has been used throughout, and, when necessary, a small shift has been made to ensure that the peak of C III λ1908.7 and N IV] λ1486 fall at the appropriately redshifted wavelength ($V_{\odot}$ = 2838 km s^{-1} and 4980 km s^{-1} for NGC 3516 and NGC 5548, respectively [Sandage and Tammann 1981]). The setting of the zero point of the wavelength scale is important for establishing whether in NGC 3516 the absorption lines observed in N V λ1242 and C IV λ1550 are blueshifted (§ V). The effective wavelength of the C III doublet is less than 1908.7 if there is a significant contribution from the component λ1906.7 which mostly comes from the narrow-line region (Ferland 1981). NGC 3516 has a relatively weak narrow-line region (Boksenberg and Netzer 1977), and therefore the effect of the component λ1906.7 is probably small. In any case the end effect of a contribution of λ1906.7 to the doublet will be to yield an underestimate of the blueshift of the absorption lines. Similarly, if the N IV] λ1486 line is blueshifted as seems to be the case for lines of highly ionized elements observed in the optical spectrum of Seyfert galaxies (Pelat, Alloin, and Fosbury 1981), the use of this line to set the zero point of the wavelength scale will lead to an underestimate of the blueshift of the absorption lines.

The UV spectrum of NGC 3516 (1981 June) and NGC 5548 (1980 June) is shown in Figures 2 and 3.

The signal-to-noise ratio (S/N) of our data in Table 1 is evidently uneven and depends on the brightness of the object and the exposure time. The best spectra are those of NGC 3516 of 1981 June, and the noisiest is the long-wavelength spectrum of NGC 3516 of 1978.

III. THE ULTRAVIOLET CONTINUUM ENERGY DISTRIBUTION

The analysis is based on the values of the continuum measured in the wavelength intervals identified as free of emission or absorption lines in the spectrum of NGC 4151 (Penston *et al.* 1981). The windows used here are centered at 1450, 1700, 2220, 2410, 2700, 2915, and 3010 Å in the rest frame of the galaxies.

The minimum value of the reddening is due to absorption by the Galaxy and is determined from the column density of neutral hydrogen in the direction of the galaxies (Heiles 1975). Assuming $N_{\rm H}/E_{B-V} = 6 \times 10^{21}$ atoms per cm^2 per magnitude (Gorenstein and Tucker 1976), this reddening corresponds to E_{B-V} = 0.05 and 0.01 for NGC 3516 and NGC 5548, respectively.

The additional reddening has been evaluated by plotting the values of the continuum measured in the "continuum windows" after applying different reddening corrections (Figs. 4 and 5). We take for the maximum value of the reddening the largest value which, after correction, produces a bump at 2200 Å (Perola *et al.* 1982). The reddening is assumed to be constant with time and to be represented by the law of Seaton (1979). Following these precepts, we find that the maximum value of the reddening is $E_{B-V} = 0.25$ and 0.075 for NGC 3516 and NGC 5548, respectively.

The values of the reddening obtained from the $I(\mathrm{H}\alpha)/I(\mathrm{H}\beta)$ ratio in the extended nebulosity surrounding the nucleus of NGC 3516 (Ulrich and Péquignot 1980) and from the $I(\mathrm{H}\alpha)/I(\mathrm{H}\beta)$ ratio of the narrow components of the lines emitted by the nucleus (Boksenberg and Netzer 1977) are $E_{B-V} = 0.18$ and 0.30, respectively, and are not likely to be appropriate to the continuum. The value of the reddening obtained from the S II line intensity ratio I(4071 Å)/I(1.03 μm) in the nucleus of NGC 5548 is E_{B-V} = 0.9 (Wampler 1968), very different from the value obtained above for the continuum. This is consistent with the widespread view that in Seyfert nuclei the continuum source is seen through a hole in the narrow-line region.

There are two sources of uncertainty in the determination of the reddening and of the shape of the continuum energy distribution: one is the large measurement errors in the range 2000–2200 Å, and the other one is the presence of Fe II blends in the continuum windows in range 2200–2600 Å. In spite of this uncertainty it is possible to reach several conclusions.

a) *The Continuum of NGC 3516*

The continuum has brightened from 1978 to 1981 June (Fig. 4). Regardless of the value of the reddening, the continuum has a harder spectrum when it is bright (1981 June) than when it is weak (1978). This behavior

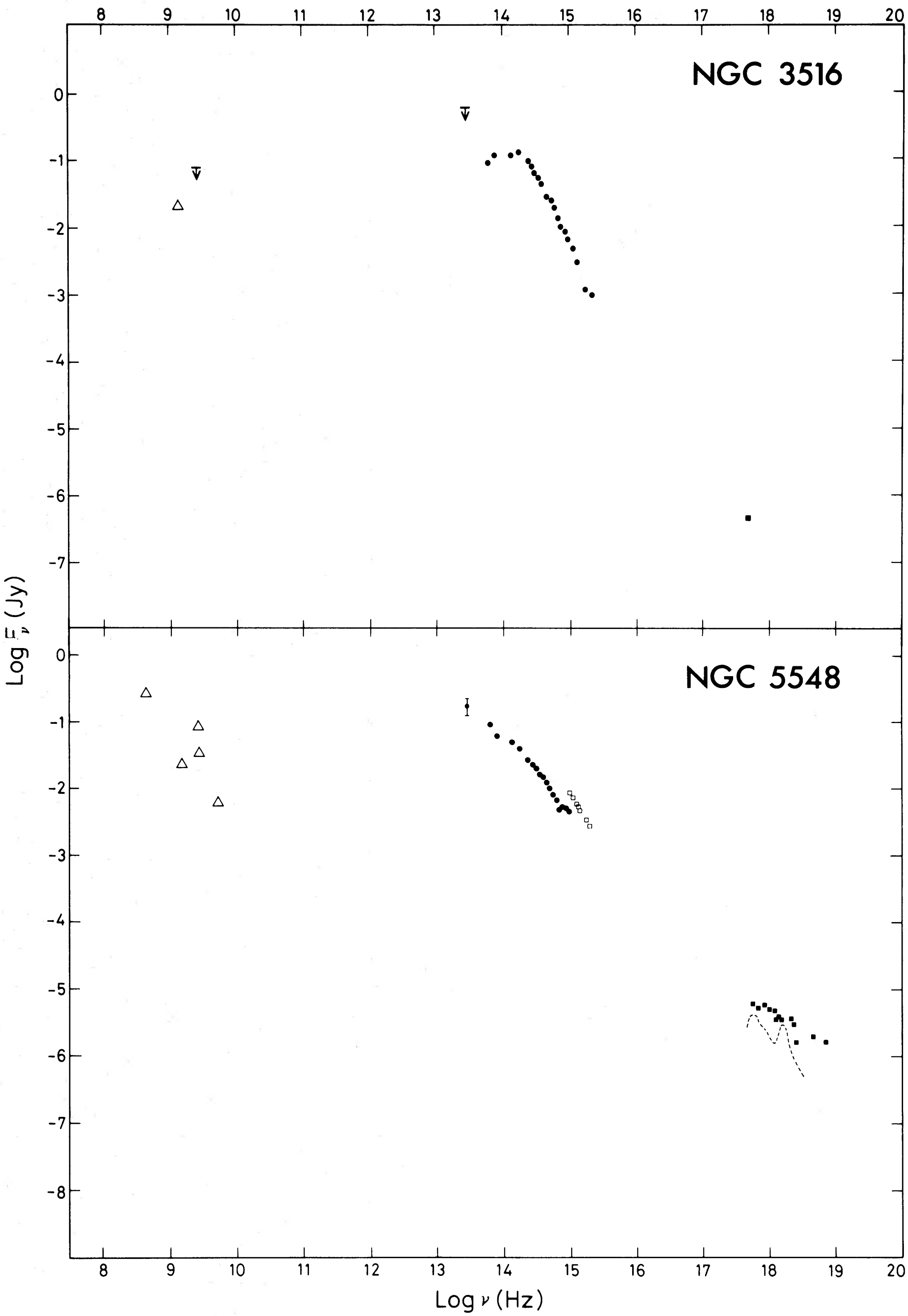

FIG. 1.—Electromagnetic spectrum of NGC 3516 and NGC 5548. For NGC 3516: radio data from Hummel (1981), Wade (1968); infrared data from Rieke and Low (1972), McAlary *et al.* (1979); optical data from de Bruyn and Sargent (1978); X-ray data from Ku (1980). For NGC 5548: radio data from Haynes *et al.* (1975), Heckman *et al.* (1978), Wilson and Willis (1980); infrared data from Rieke and Low (1972), McAlary *et al.* (1979); optical data from de Bruyn and Sargent (1978); UV data from this paper; the X-ray spectrum shows the observation with *Ariel* 5 from 1977 January 15 to 1977 January 18 (Hayes *et al.* 1980) and with *HEAO A* from 1978 January 9 to January 15 (Mushotzky *et al.* 1980).

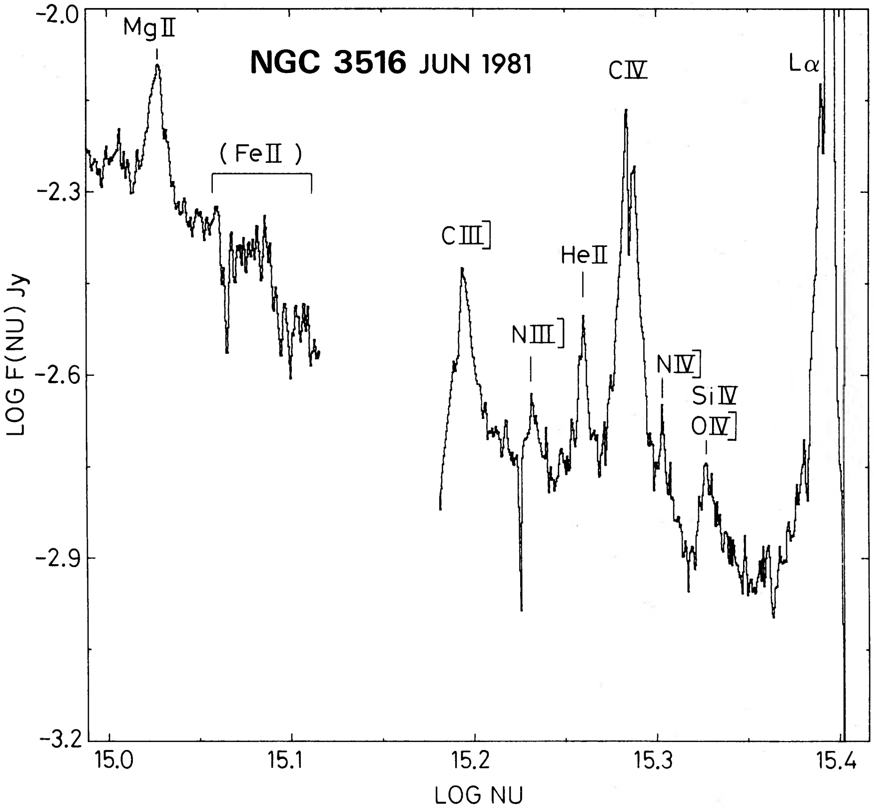

FIG. 2.—The UV spectrum of NGC 3516, 1981 June

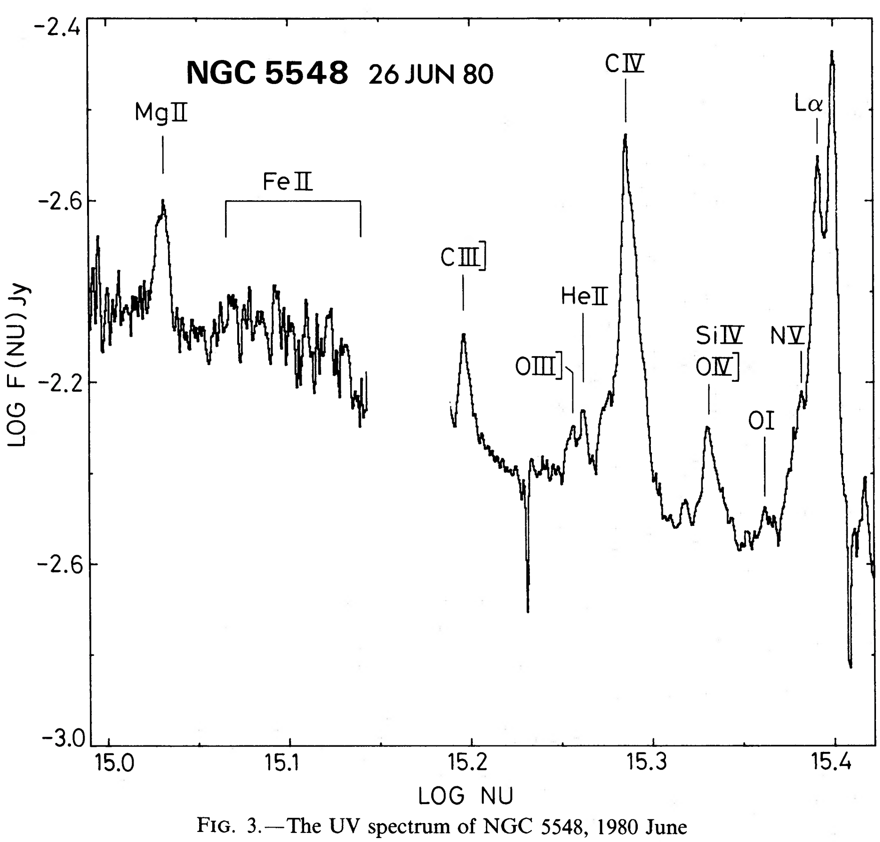

FIG. 3.—The UV spectrum of NGC 5548, 1980 June

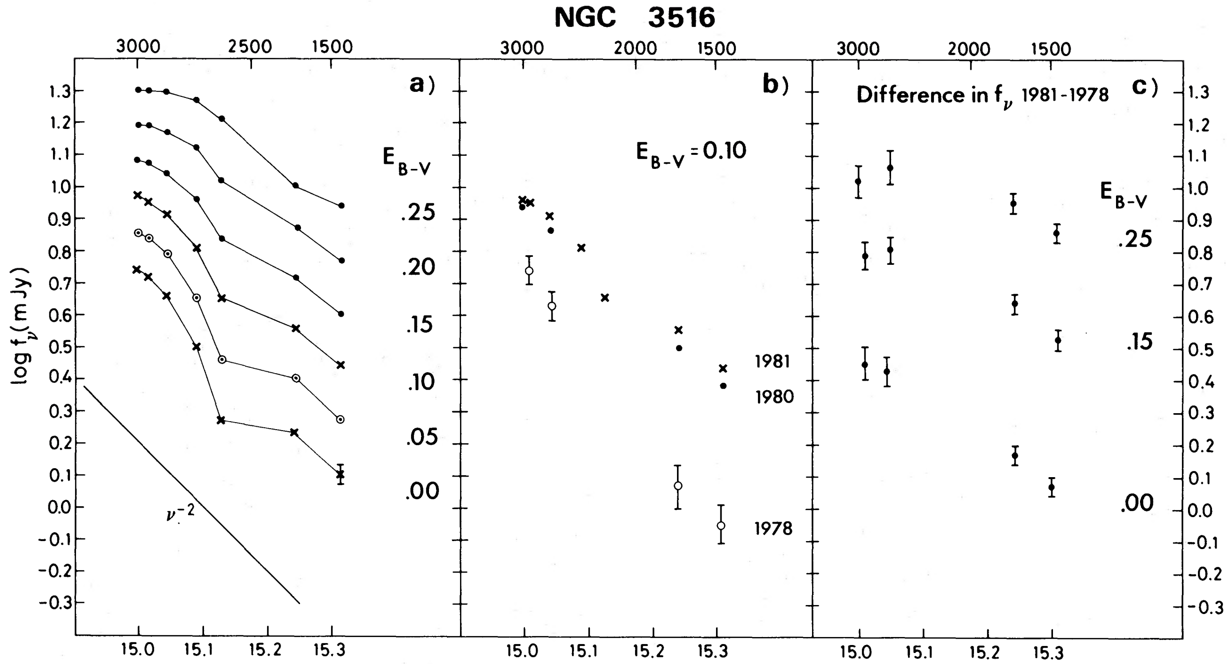

FIG. 4.—The UV continuum of NGC 3516. (*a*) The UV continuum in 1981 after correction for different values of E_{B-V}. The original data are labeled $E_{B-V} = 0.00$. (*b*) The UV continuum at three epochs corrected for $E_{B-V} = 0.10$. (*c*) The difference spectrum between the maximum and minimum for different values of E_{B-V}.

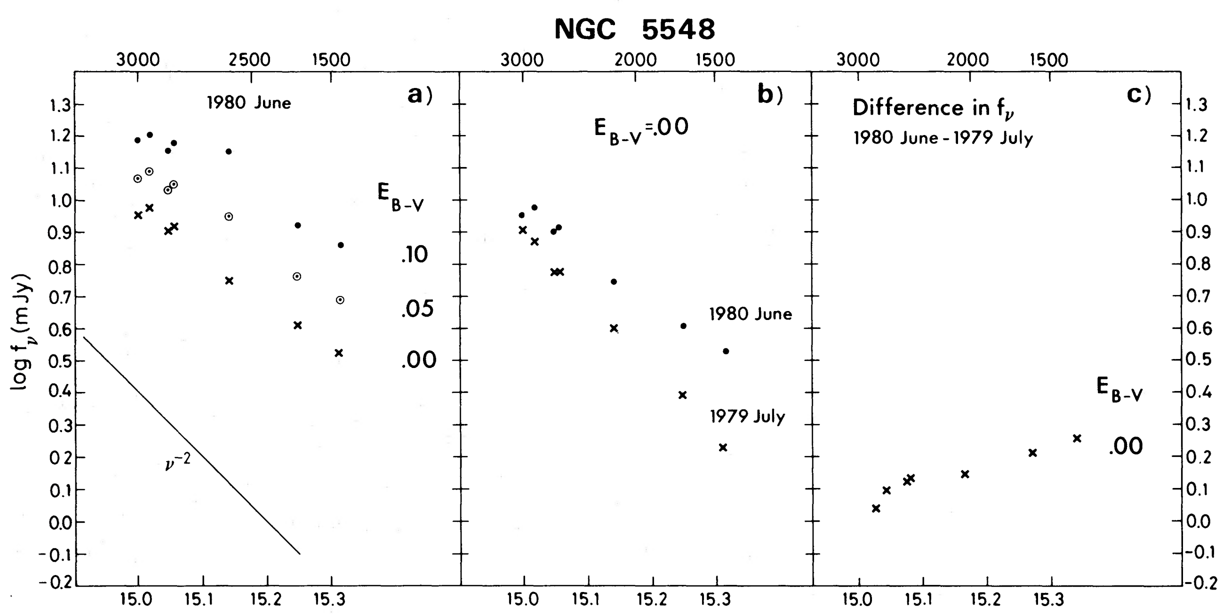

FIG. 5.—The UV continuum of NGC 5548. (*a*) The UV continuum on 1980 June 26 for different values of E_{B-V}. (*b*) The UV continuum in 1979 July and 1980 June. (*c*) The difference spectrum between 1980 June and 1979 July.

is also followed by the continuum in 1980 June and 1981 March. The intensity variations observed between 1978 and 1981 are by a factor 3 at 1700 Å and a factor 1.6 at 2100 Å (Table 5 below).

The shape of the continuum depends on the value attributed to the reddening: In 1981, for $0.05 < E_{B-V} < 0.20$, there is a change of slope near 2200 Å, the spectrum being harder at short wavelengths than at long wavelengths. For $0.20 < E_{B-V} < 0.25$, the spectrum can be fitted by a single power law between 1450 and 2700 but flattens at $\lambda > 2700$ Å.

b) The Continuum of NGC 5548

A similar analysis applied to the spectra of NGC 5548 taken in 1979 July (Barr *et al.* 1980) and in 1980 June (this paper) leads to the following results: (i) the spectrum is harder when the continuum is brighter (Fig. 5), and (ii) the reddening is less than $E_{B-V} = 0.075$, in agreement with the determination of the reddening by Barr *et al.* (1980). In 1979 when the object is fainter, the UV continuum can be fitted with a single power law, but in 1980 there is evidence for two components, the one dominating at short wavelength having a harder spectrum.

In NGC 4151, as in NGC 3516 and NGC 5548, it has been found that the UV spectrum is harder when the object is bright (Perola *et al.* 1982). Extension of this analysis of the variations of the UV continuum to other Seyfert galaxies indicates that this behavior is likely to be a general characteristic of Seyfert galaxies. No exception to this rule has yet been found among the eight Seyfert galaxies so far analyzed (Boisson and Ulrich 1982).

IV. THE EMISSION LINES

a) Intensities

Tables 2A and 3 give the line intensities measured on the 1981 June spectra of NGC 3516 and the 1980 June spectra of NGC 5548; Δλ is the wavelength interval in which the line is measured. The intensities are not corrected for reddening, blends with weaker lines, or absorption features. The errors in *I* primarily come from the uncertainty in defining the local continuum.

TABLE 2A

LINE INTENSITIES IN NGC 3516 IN 1981 JUNE
(in 10^{-14} ergs cm^{-2} s^{-1})

Line	Δλ	*I*
Lyα red side	1220–1260	150
N V λ1240	...	< 10
Si IV λ1398 } O IV] λ1402 }	1357–1443	32
N IV] λ1485	1484–1507	6
C IV λ1549	1450–1620	280[a]
He II λ1640	1632–1668	32
O III] λ1663	1668–1681	4:
N III] λ1750	1755–1770	4:
C III] λ1909 } Si III] λ1892 }	1880–1945	37
Mg II λ2798	2750–2900	76
O III λ3133......	3147–3173	14

[a] Not corrected for the absorption line.

TABLE 2B

VARIATIONS OF THE LINE INTENSITIES IN NGC 3516
(in 10^{-14} ergs cm^{-2} s^{-1})

Line	Δλ	1978	1980	1981 March	1981 June
Lyα red side	1220–1260	80	124	120	150
C IV	1450–1620	140	210	210	280
C IV red side..........	1559–1620	70	117	123	127
C IV component B3 ...	1559–1586	33	33	...	...
C III]+Si III]..........	1880–1945	30	33	34	37
Mg II	2750–2900	50:	70	70:	76

TABLE 3

LINE INTENSITIES IN NGC 5548 IN 1980 JUNE (in 10^{-14} ergs cm^{-2} s^{-1})

Line	Δλ	I
Lyα (red side) ...	1237–1302	486[a]
N V λ1240	1261–1276	> 19
O I λ1302	1306–1338	18
C II λ1335	1348–1364	6
Si IV λ1396 } O IV] λ1402 }	1373–1454	117
C IV λ1550	1512–1642	767[b]
C IV (red side) ...	1578–1642	304[b]
He II λ1640	1642–1680	42
O III] λ1663	1681–1713	28
C III] λ1909 } Si III] λ1892 }	1901–1972	88
[Ne IV] λ2422	2454–2480	19
Mg II λ2800......	2807–2890	158
Fe II	2280–2690	316

[a] Includes N V λ1240.

[b] Includes unidentified feature at λ_{rest} = 1591 Å.

All the lines found in the spectrum of NGC 3516 and NGC 5548 are present in the spectrum of NGC 4151 (Boksenberg *et al.* 1978; Penston *et al.* 1981), and are the lines most commonly found in quasar spectra. The line intensity ratios in NGC 3516 and NGC 5548 are rather similar to those in quasar spectra, with several interesting differences: the ratio I(C IV λ1550)/I(C III] λ1909) is 10 and 7 in NGC 3516 and NGC 5548, respectively. In fact, since C III] λ1909 is narrower than C IV λ1550 (see § IV*b* below), this ratio is, in the region emitting the broadest component of the lines, even larger than the values quoted above. In quasars the range of this ratio I(C IV)/I(C III) is 1.2 to 7 (see, for example, Kwan and Krolik 1981), but in most quasars this ratio is ~ 3 which is also the value often used in modeling quasar spectra (Davidson and Netzer 1979; Kwan and Krolik 1981; Grandi 1982). (An example of a quasar with weak C III] λ1909 is 0407−199 [White, Murdoch, and Hunstead 1980]).

Another difference between the intensity ratios of Seyferts and quasars is relative to the ratio I(Lyα)/I(C IV λ1550). In quasars this ratio is usually greater than 2 (Baldwin 1979). Oke and Zimmerman (1979) found that in 3C 120 and Markarian 79 this ratio is 0.6 and 1.2, respectively, and 1.3 and 1.6 after reddening correction. The redshift of NGC 3516 and NGC 5548 is such that only the red half of Lyα can be measured. Using the parts of the lines longward of the emission peak, one finds that I(Lyα)/I(C IV λ1550) is 1.2 and 1.6, respectively for these two Seyfert galaxies.

The broad bump in the range 2200–2600 Å especially prominent in NGC 5548 is qualitatively similar to the blend of Fe II multiplets present in the spectra of a number of quasars of intermediate redshifts (Wills *et al.* 1980) and in several Seyfert galaxies (Snijders, Boksenberg, and Haskell 1980). No attempt is made here to measure the intensity of the Fe II blend in view of the difficulty in defining the continuum.

b) *Comparison of the Emission Line Profiles*

The analyses of the profiles are based on the spectra of 1981 June of NGC 3516 which have the best S/N and on the spectra of 1980 June of NGC 5548. The main UV emission lines of NGC 3516 and NGC 5548 are plotted in Figures 6 and 7, with the same velocity scale. A number of weak lines can possibly contribute to the main lines:

Si III] λ1892 is definitely present in NGC 3516 and causes the apparent asymmetry of C III] λ1909: the subtraction of the red profile of C III] λ1909 from its blue profile produces a line peaking at 1891 ± 1.5 Å. The same operation on the C III] λ1909 line profile in NGC 5548 also produces a peak coinciding with the wavelength of Si III] λ1892, but there remains a residual asymmetry of the C III line, with the blue side being the stronger.

Among Fe II multiplets, only UV 60, 61 is identified with some certainty in NGC 3516, where it is the very probable origin of the emission feature at 2890–3000 Å (line 2 in Fig. 6). Other lines whose presence has been noted previously in quasars or Seyfert spectra or which have been mentioned as likely contributors to the wings of stronger lines (Wills *et al.* 1980; Snijders *et al.* 1981; Penston *et al.* 1981) could be present but are not seen as distinct features. They are Fe II UV 62, 63 at ~ 2748 Å near Mg II (line 1 in Fig. 6), Fe II UV 65, 97, 96 near C III] λ1909 (lines 1, 2, 3 in Fig. 6), He I λ2733 (line 3 in Fig. 6), He I λ2945, [Ne V] λ1575.

In NGC 5548, there is a broad weak line in the red wing of C IV at 1590 Å. This feature is present in the spectra of NGC 4151 and is still unidentified (Penston *et al.* 1981).

Let us compare the profiles of the C IV, Mg II, and C III] lines in NGC 3516. Regardless of the presence of the weak lines mentioned above, the emission profiles of the three main lines differ by their full width at half-maximum (FWHM) and their full width at zero intensity (FWZI). The values of these parameters are given in Table 4.

The difference in the emission profiles is taken as evidence that the gas is present in different types of clouds with different physical conditions and velocities. (The term *velocity* refers here to the velocity of the systematic motions and to the velocity dispersion. The two types of motions are not readily distinguishable from the profiles.)

The broad wings of C IV, especially the blue wing, have no counterpart in the Mg II and C III] lines. The ratio I(C IV)/I(Mg II) varies with the velocity of the

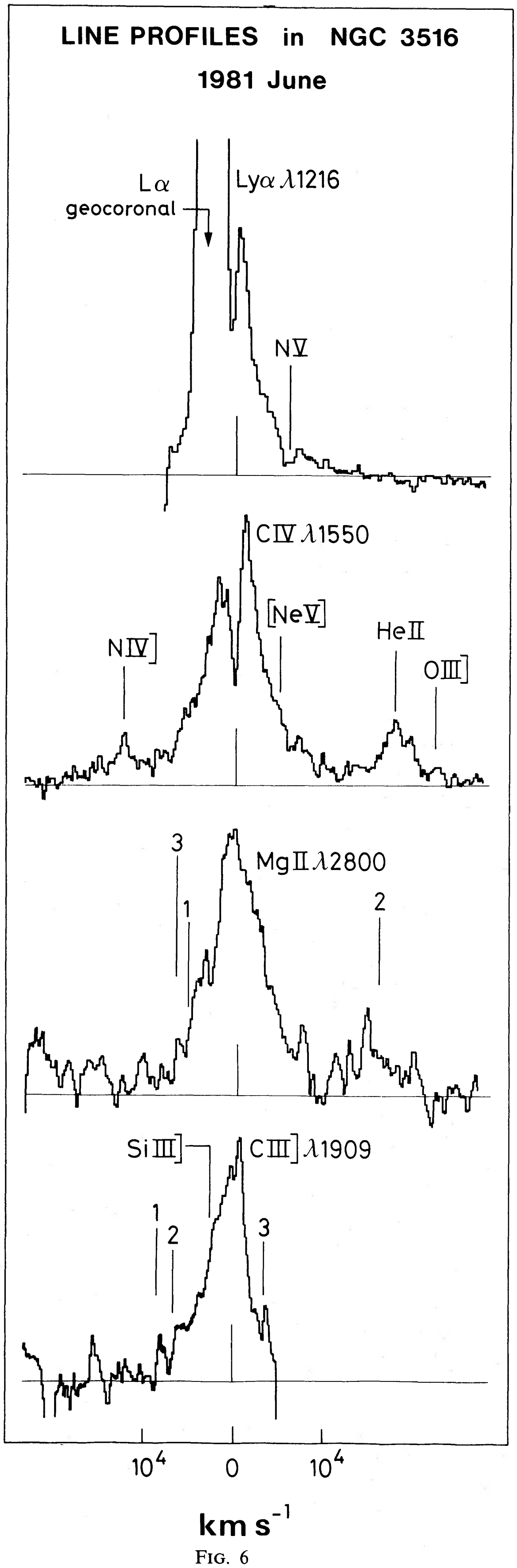
LINE PROFILES in NGC 3516
1981 June
Lα
geocoronal
Lyα λ1216
NV
CIV λ1550
[NeV]
NIV]
HeII
OIII]
3
1
MgII λ2800
2
SiIII]
CIII] λ1909
1
2
3
10^4
0
10^4
km s^-1

FIG. 6

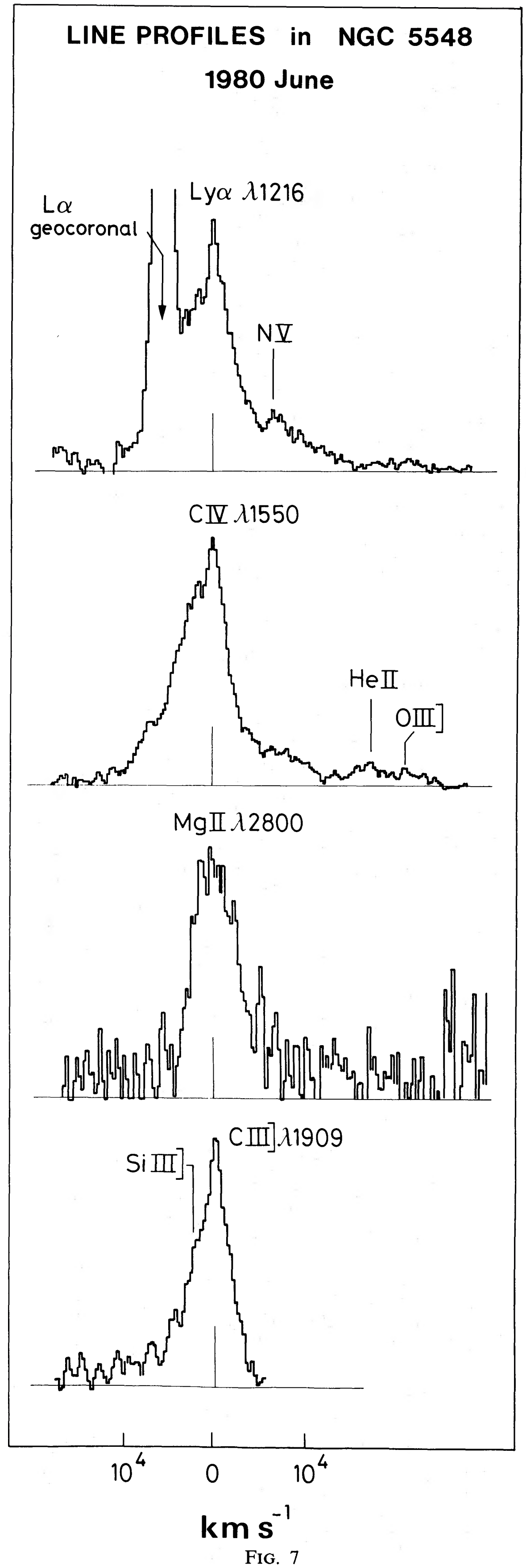
LINE PROFILES in NGC 5548
1980 June
Lα
geocoronal
Lyα λ1216
NV
CIV λ1550
HeII
OIII]
MgII λ2800
SiIII]
CIII] λ1909
10^4
0
10^4
km s^-1

FIG. 7

TABLE 4

FULL WIDTH AT ZERO INTENSITY (FWZI) AND FULL WIDTH AT HALF-MAXIMUM (FWHM) OF THE MAIN EMISSION LINES IN NGC 3516[a]

Line	C IV λ1550	Mg II λ2800	C III λ1909
FWZI (km s^{-1})	28000	21000	...
Short wavelength side ...	17000	12000	8500
Long wavelength side ...	11000	9000	...
FWHM (km s^{-1})		6000	4000

[a]Not corrected for instrumental resolution.

emitting material and is larger at high absolute velocities (i.e. in the wings) than at small or zero velocities. As indicated in Table 4, the Mg II emission goes below the limit of detection for $V > 11{,}000$ km s^{-1} and $V > 9000$ km s^{-1} to the blue side and to the red side of the line center, respectively. Taking into account that the signal-to-noise ratio of the spectra is smaller in the wings than near the line center, the intensity ratio I(C IV)/I(Mg II) appears to increase by a factor greater than 2 from the value at center to the value for $V > 10{,}000$ km s^{-1}. Either the phase emitting the wings of C IV is totally ionized and optically thin, or it is optically thick but somehow Mg II is depressed by a factor greater than 2 as compared to the gaseous phase emitting the rest of the line (smaller optical depth).

Following the notation used in the analysis of the lines in NGC 4151 (Ulrich *et al.*, in preparation) we call the clouds emitting the C IV wings BLR1. Two other types of clouds, BLR2 and BLR3, are evidenced by the difference in FWHM and FWZI given in Table 4. The use of the FWHM to characterize BLR2 and BLR3 is justified since the Mg II and C III profiles are not strongly affected by absorption. The characteristics of the different phases can be summarized as follows:

BLR1: emits C IV with FWZI = 25,000 km s^{-1}. Mg II and C III not detected.

BLR2: emits Mg II (and probably also C IV) with FWHM = 6000 km s^{-1}. C III not detected.

BLR3: emits C III] (and probably also C IV and Mg II) with FWHM = 4000 km s^{-1}.

The three different types of clouds in the broad-line region differ by their value of the velocity and by their physical conditions. The physical conditions correlate with the velocity.

Similar differences in the line profiles indicating inhomogeneities in the broad-line region (BLR) as found here in NGC 3516 are present in NGC 5548 (Fig. 7) and have also been found in NGC 4151 (Boksenberg *et al.* 1978; Penston *et al.* 1979; Penston *et al.* 1981; Ulrich *et al.*, in preparation). In most quasars the main emission lines are found to have identical profiles (Baldwin 1979). In the interpretation of quasar spectra it is customary to use the ionization parameter U which is proportional to the ratio of the flux of incident photons to the particle density: $U = L_c r^{-2} N^{-1}$, with L_c the luminosity of the continuum, r the distance from center, and N the particle density (Davidson and Netzer 1979; Kwan and Krolik 1983). The similarity of the line profiles in quasar spectra means that the lines are emitted by clouds all having identical values of U. This happens if all the clouds are at the same distance from the center and have the same density or if N is proportional to r^{-2}. Clearly, in the broad-line region of Seyfert galaxies, matter is distributed differently than in quasars. This difference is probably related to the fact that Seyfert galaxies do not fall in the extrapolation toward faint luminosity of the relation EW(C IV) versus continuum luminosity found for quasars (Baldwin 1977).

V. VARIATIONS OF THE EMISSION-ABSORPTION PROFILE OF C IV λ1550 IN NGC 3516

a) The Emission Profile

Figure 8 shows the short wavelength spectrum of NGC 3516 at the four epochs of observations.

The C IV line can be decomposed into several components:

(i) B1 is the broad component which extends from 1485 to 1620 Å in the 1978 spectrum. B1 is asymmetric, with its short-wavelength side being the stronger.

(ii) B2 is the prominent component which appeared between 1978 and 1980 in the range 1525–1600 Å.

(iii) B3 is the relatively narrow component ~ 12 Å wide at half-maximum (uncorrected for instrumental profile) and redshifted by 6 Å with respect to the galaxy. This component is best seen in 1978 and 1980.

(iv) An absorption line with its red edge at approximately zero redshift.

The intensity of the C IV line increased between 1980 and 1981, with the additional energy appearing in the central part of the line. This could be due to a decrease of the absorption line or to a real increase of the emission near the line center. The component B3 is present on the spectra of 1978 and 1980 (Table 2). This,

FIG. 6.—The profiles of the main emission lines in NGC 3516, 1981 June. The vertical lines near Mg II λ2800 are at the position of possible contributors to the wings. Lines 1 and 2: Fe II multiplets of UV 62, 63 at 2748 Å and UV 60, 61 at 2950 Å, respectively. Line 3: He I λ2733. Vertical lines near C III] λ1909 are at the position of the Fe II multiplets UV 65, 97, and 96 (for details see text).

FIG. 7.—The profiles of the main UV emission lines in NGC 5548, 1980 June. Note the broad weak component in the long wavelength wing of C IV. This line is also present in NGC 4151.

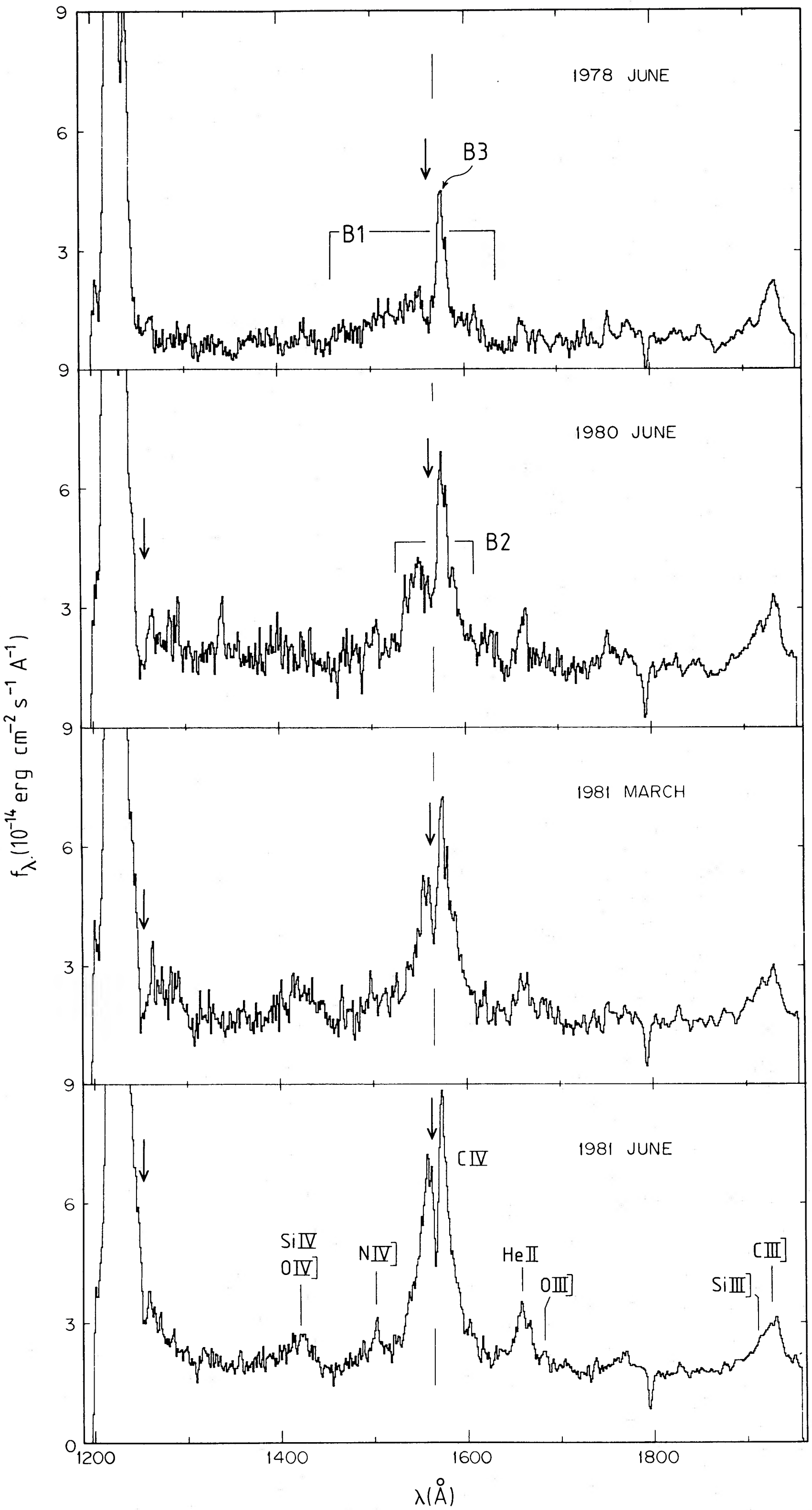

FIG. 8.—The spectrum of NGC 3516 between 1200 and 1980 Å at four epochs. The vertical line represents the wavelength 1550 Å in the rest frame of the galaxy. Approximate positions of N V and C IV absorption lines are shown with vertical arrows. Components B1, B2, B3 are identified in 1978 and 1979 spectra. Main emission lines are marked.

together with its small width, suggests that it has not varied in 2 years.

Figure 8 shows that the very broad component B1 is not stronger in 1980 June than in 1978 June. This suggests that in the region emitting B1, ε(C IV) is near a maximum when the continuum is at the level of 1978 June. This corresponds to $U = 10^{8.5}$ cm s^{-1} if the gas is optically thin (e.g., Davidson and Netzer 1979) and is consistent with the fact that the broadest component of the C IV line has no counterpart in the C III and Mg II lines (§ IV). Component B1 could be emitted by small, optically thin filaments which continuously form at the surface of an accretion disk and undergo radial acceleration away from the continuum source as proposed by Shields (1977). If the disk is tilted with respect to the line of sight to the observer, the line emitted by the filaments would appear asymmetric, with the short wavelength side being the stronger, as is in fact observed for component B1.

The region emitting B1 is qualitatively similar to BLR 1. There is also a qualitative similarity between BLR 3 and the region emitting B3 in the sense that both emit lines which are narrow and constant in intensity. The fact that I(C III)/I(C IV) is larger in BLR 3 than in other regions indicates a smaller value of U in BLR 3. A possible explanation is that in first approximation the density decreases with r more slowly than r^{-2}.

b) *The Absorption Lines*

There are two absorption lines in the UV spectrum of NGC 3516: the unresolved doublets N V λλ1238.8, 1242.8 and C IV λλ1548.2, 1550.7. Both lines are blueshifted with respect to [Ne IV] λ1486 and C III] λ1908.7. The long-wavelength edge of C IV is at 1550 ± 1.5 Å. The N V absorption-line red edge is at 1242 ± 2 Å. The N V emission line is weak, and thus the absorption line is mostly absorbing the Lyα wing and/or the continuum. There is no evidence for an absorption in the Mg II λ2798 line. The absence of this line and the strength of N V λ1240 indicates that the absorbing material is highly ionized and in that respect similar to the one producing the broad absorption lines in QSO spectra. The width of the broad absorption lines in quasars, however, is somewhat larger than in NGC 3516 (Weymann, Carswell, and Smith 1981). The two absorption-like features possibly present longward of the Hβ line center in 1975 (Boksenberg and Netzer 1977) do not appear in the emission profiles.

The *formal* values of the EW listed in Table 5 are obtained as follows: the equivalent width of the N V line is measured by adopting a continuum which is a horizontal line in the f_λ versus λ plot (Fig. 8) at the level of the small emission feature at 1260 Å. (This feature either is a weak emission of N V λ1240 or is produced by the absorption in the steep Lyα wing.) The equivalent width of C IV is measured by adopting a continuum which is a straight line joining the two peaks in emission. The width of N V is measured at the level of the local continuum, and the width of C IV is measured at the level of the lower (blue) emission peak.

TABLE 5

CHARACTERISTICS OF THE ABSORPTION LINES IN NGC 3516[a]

	N V λ1240		C IV λ1550	
Date	Width (Å)	EW (Å)	Width (Å)	EW (Å)
1978 June	...	...	...	...
1980 June	14	3.6 ± 1	15	5.5 ± 0.5
1981 March...	15	3.2 ± 0.8	9	3 ± 0.3
1981 June	7	0.75 ± 0.25	8	2.5 ± 0.3

[a] These are formal values; for procedure of measurements, see text.

The column density of N^{+4} ions, calculated with EW(N V) = 4 Å, is 2×10^{15} cm^{-2}; and if all N atoms are assumed to be in the N^{+4} stages, then the total column density is $N_H \sim 10^{19}$ cm^{-2}. Similarly, the column density of C^{+3} ions assuming EW(C IV) = 4 Å is 1.3×10^{15} cm^{-2}, corresponding to $N(H) = 4 \times 10^{19}$ cm^{-2} assuming all C is C^{+3} and normal abundances (Allen 1973). In both cases the optical depth calculated with a velocity dispersion of 1000 km s^{-1} is less than 1, consistent with the gas being optically thin and with the absence of Mg II λ2800 in absorption.

From the values in Table 5 and from the examination of the spectra it appears that the absorption lines are variable in width and equivalent width. Specifically, the N V and C IV absorption lines appear weaker and narrower in 1981 June than in 1981 March and 1980 June.

The reproducibility between the two spectra taken in 1981 June is excellent: the rms of the difference between one spectrum and the mean of the two spectra is 0.08×10^{-14} and 0.34×10^{-14} ergs cm^{-2} s^{-1} Å^{-1} in the intervals 1240–1260 Å and 1550–1565 Å, respectively.

The variations of the absorption lines are confirmed by new material. Four *IUE* spectra of NGC 3516, two in each wavelength range, were taken in 1982 May. Their reproducibility is again very good, with the difference between one spectrum and the mean of the two spectra in the short-wavelength range being 0.27×10^{-14} and 0.21×10^{-14} ergs cm^{-2} s^{-1} Å^{-1} in the intervals 1240–1260 Å and 1540–1590 Å. These spectra will be discussed elsewhere. It is useful to say here that the continuum is about two times stronger in 1982 May than in 1981 June and the equivalent widths of the absorption lines are approximately 4 times stronger in 1982 May than in 1981 June. When spectra at all epochs are considered, it appears unlikely that the variations of the absorption lines are caused solely by the variations of the emission profiles. We think that the variations of the absorption lines are caused at least in part by variations in the number of absorbers along the line of sight, but evidently only qualitative estimates of the variations can be made because of the uncertainty in the underlying emission profiles (Table 5). Part or all of the variations in width can be caused by saturation effects.

From the depth of the absorption line, one can evaluate an effective covering factor of the BLR by the absorbing material. The real covering factor is not necessarily the same for the different emitting zones in the broad line region, and in particular the covering factor for B3 can be much larger than for the innermost zones if the latter are seen through a hole in the absorbing material. In the spectra taken in 1981 June, the depth of the C IV absorption line, measured from the top of the red peak of the emission, is 0.65 the height of the emission line and is larger than the continuum level. This is a minimum value of the absorption line depth, first because the absorption could lower the height of the emission peak and second because the absorption line itself could be narrower and deeper than that recorded with this wavelength resolution. If none of the continuum is absorbed, then 0.67 of the emission line is absorbed; and if all the continuum is absorbed, then 0.33 of the emission line is absorbed (in the wavelength range of the absorption line).

One possible interpretation of the narrow and redshifted emission component B3, so conspicuous in 1978 June, is that this component is the red half of an emission component 20 Å wide centered at zero redshift with respect to the galaxy and whose blue half is totally absorbed in 1978. This interpretation gives a simple explanation to the fact that B3 is redshifted and that its short-wavelength side is sharp. On the other hand, there is the following difficulty in this interpretation: since B3 is narrow and appears to have been constant between 1978 and 1980, it is likely that it is emitted in a region which is at least at 2 lt-yr from the center. It is therefore difficult to find a simple model of an absorption region producing variable absorption lines on a time scale of 3 months (1981 March–June) and located farther out than B3. The location of the absorbing region is thus an unsettled point at present. It is an important point, however, because it bears directly on the evaluation of the rate of mass loss.

The mass outflow, in first approximation, is

$$\dot{M} = 2.0\times 10^{-50}\pi R^2 N V l^{-1} f \left(M_\odot \text{ yr}^{-1}\right),$$

where R is the radius of the absorbed region (in cm), l the thickness of the absorbing region (in cm), N the column density ($\sim 10^{19}$ cm^{-2}), V the outflow velocity ($V \sim 10^8$ cm s^{-1}), and f the covering factor ($f \sim 0.5$). With these numerical values and taking $R \sim l$, the rate of mass loss is $\dot{M} \sim 3\times 10^{-23} R$ ($M_\odot$ yr^{-1}).

Only a small fraction (perhaps 1/15) of Seyfert galaxies appear to have absorption lines similar to NGC 3516 and NGC 4151. That prominent absorption lines are known to be present only in these intrinsically faint Seyfert nuclei could mean that the corresponding absorption region is a feature whose presence depends on the absolute luminosity and is more common in faint nuclei. Alternatively, the absorption region could be a general feature of Seyfert nuclei which is detectable only when the line of sight to the observer has a special position with respect to the nucleus (see, for example, the model of Gordon, Collin-Souffrin, and Dultin-Hacyan 1981). Statistics on the occurrence of these lines in all absolute luminosity classes in Seyfert galaxies and quasars are needed to settle this point.

VI. SUMMARY

The observations of the UV spectra of NGC 3516 and NGC 5548 with *IUE* have led to the following results:

In both galaxies the UV continuum becomes harder when it brightens. In NGC 5548, for which the reddening is very small, the continuum variations suggest that the continuum is the sum of two components with different slopes. In NGC 3516 the limits which can be set on the reddening are far apart, $0.05 < E_{B-V} < 0.25$, and no conclusion can be reached as to whether a two-component model would be appropriate.

The line intensities in NGC 3516 and NGC 5548 are generally similar to those in quasar spectra with some interesting differences: the ratio I(C IV λ1550)/I(C III] λ1909) is larger than 7; in quasars there is a large dispersion of values for this ratio, but in most cases this ratio is ~ 3. The ratio I(Lyα)/I(C IV λ1550) is 1.2 and 1.6 in NGC 3516 and NGC 5548, respectively, whereas in quasar spectra this ratio is always greater than 2 with a small dispersion.

In contrast to the situation in quasars, in NGC 3516 and NGC 5548 the line profiles of C IV λ1550, Mg II λ2800, and C III] λ1909 are different. The analysis of the line profiles allows one to partially unravel the structure of the BLR. One can identify at least three types of clouds with different physical conditions and different velocities; the physical conditions correlate with the velocities. A typical quasar BLR scaled down in luminosity and dimension is not exactly like the BLR of NGC 3516 or NGC 4151.

In NGC 3516 there is a prominent absorption line in C IV λ1550 and N V λ1240 but no absorption in Mg II λ2800. It is argued that the apparent variations of the width and EW of the lines are caused by variations in the number of absorbers and not by the variations of the emission profiles. This conclusion, however, is reached by using "reasonableness" as a criterion in interpreting the appearance of the lines, rather than on a strict demonstration. The spectra taken in 1981 June indicate that the covering factor of the BLR in emission by the absorption region is 0.33 if the continuum is absorbed and 0.67 if no continuum is absorbed. A typical value of EW(C IV) is 4 Å, which corresponds to a column density of C^{+3} of 10^{15} cm^{-2} and of H atoms of 4×10^{19} cm^{-2} (assuming normal abundances).

Strong absorption lines like those in the UV spectrum of NGC 3516 have so far been found only in NGC 4151, which like NGC 3516 is an intrinsically weak active nucleus. Statistics on the occurrence of strong absorption lines in all absolute luminosity classes of Seyfert nuclei and in quasars are needed to decide whether such lines occur only in low-luminosity objects or whether they can occur in all luminosity classes but are observable only with a special orientation of the nucleus with respect to the observer.

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