The missing UV absorption lines of NGC 4151

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SUMMARY

In this paper we discuss new, near-simultaneous high-dispersion long- and short-wavelength International Ultraviolet Explorer (IUE) observations of the Seyfert galaxy NGC 4151. Previous observations revealed a narrow absorption system in Mg ii not present in Ly α or C iv. The new observations confirm the presence of this system in Mg ii and its absence in the other lines. Possible reasons for this are discussed.

It is hoped this paper will stimulate Hubble Space Telescope (HST) studies of NGC 4151.

1 INTRODUCTION

NGC 4151 is one of the nearest and most carefully studied Seyfert galaxies, primarily because of its low redshift and high apparent brightness. Its continuum and line luminosity vary in the optical (Antonucci & Cohen 1983; Gill et al. 1984), in the UV (Ulrich et al. 1984; Bromage et al. 1985) and in the X-ray continuum (Barr et al. 1977). It has changed its Seyfert classification from a Type I to nearly a Type II (Penston & Perez 1984; Kielkopf, Brashear & Lattis 1985). To remain consistent with our earlier paper (Leech et al. 1987) we will adopt a heliocentric velocity for NGC 4151 of 990 km s⁻¹, although Schulz (1987) suggested a heliocentric velocity of 1000 km s⁻¹. All velocities given in this paper are with respect to NGC 4151.

The narrow emission lines of NGC 4151 have been observed many times and have been shown to contain multiple components. Ulrich (1973) discovered four emission systems in the [O iii]λλ4959, 5007 doublet. Heckman & Balick (1983) imaged NGC 4151 through a narrow-band filter centred on [O iii] and discovered four gas clouds with the same velocities as Ulrich's systems. Recently Schulz (1988) has reported the discovery of an emission component in [O iii] with a velocity of −105 km s⁻¹. Similar clouds to those in [O iii] were reported in Hα and [N ii] by Kielkopf et al. (1985). In addition, Penston et al. (1979) noted several components to Ly α and C iv, Antonucci & Cohen (1983), Ulrich et al. (1984) and Bromage et al. (1985) discuss the variability of NGC 4151 and the response of the various lines to that of the continuum. In particular the last reference discusses the systematics of the UV absorption lines which are related to Anderson & Kraft's (1969) discovery of three optical absorption systems in the He i λ3889 line.

In an earlier paper (Leech et al. 1987) we discussed high resolution UV (∆λ = 0.2 Å) observations made between 1978 August and 1980 March using the short- and long-wavelength cameras on IUE. The main discovery presented there was that of a narrow Mg ii absorption system at a velocity of −165 km s⁻¹ not present in Ly α or C iv. This was surprising because any absorption system present in Mg ii is expected to be present in either C iv or Ly α (see the discussion in Leech et al. 1987). A search of the literature revealed no other distinct absorption reported at −165 km s⁻¹ in any optical or UV line of NGC 4151. Our then proposed explanation was that because of the 1 yr time delay between the sets of observations for the short (C iv and Ly α) and long (Mg ii) wavelength spectra of NGC 4151, some material came into our line-of-sight causing the Mg ii absorption feature. This paper presents new data covering Mg ii and the other lines with the intention of verifying this explanation. It summarizes the state of knowledge of the UV spectrum of NGC 4151 from high dispersion IUE spectra prior to the start of observations with the Hubble Space Telescope.

2 THE NEW OBSERVATIONS

Two near-simultaneous observations were made of NGC 4151 by IUE in 1988 March (Table 1). Each lasted about 12 hr, was started from Vilspa and completed at Goddard. The nucleus of NGC 4151 was observed through the large aperture using either the short- or long-wavelength camera in the high dispersion mode. The echelle spectra were extracted using IUEEDR and FIGARO at the Queen Mary and Westfield College (QMW) STARLINK node.

NGC 4151 was intrinsically much weaker during these later observations compared to the previous epochs of observations – the previous observation's corrected Fine Error Sensor (FES) counts were in the range 220–268 with all except one in the upper part of the range. This, along with the slightly shorter exposure times, has resulted in spectra of
a lower quality than the previous data. The continuum signals in these spectra are very weak while the strong emission lines show data of poor, but acceptable, quality. No low-resolution spectra are available to check our data against as NGC 4151 had, unusually, brightened out of its faint state just as our observations were made and then decreased in luminosity afterwards.

The main points to be noted about each line are given in the following sections.

### 2.1 The Mg Ⅱ doublet

The old and new Mg Ⅱ spectra are shown in Fig. 1. This line appears complex because there are many components. The 2802 Å galactic interstellar absorption line is blended with the narrow −165 km s⁻¹ 2795 Å absorption line in NGC 4151. Between the two epochs of observation the very broad underlying emission weakened as did the broad absorption. The narrow absorption system at −165 km s⁻¹ can still be seen to be present, although its equivalent width (EW) may have decreased by a factor of 3.5. Table 2 gives EW for the new and old spectra. There is a marginal new absorption system with Mg Ⅱ k at 2807.4 Å. The h component is not seen because it lies in the low signal-to-noise (SN) region between orders in both spectra – the feature there is probably noise.

### 2.2 The Ly α line

The two spectra taken 9 yr apart, shown in Fig. 2, look remarkably similar except that the broad emission present in the old spectrum is absent in the new one. No absorption is present at −165 km s⁻¹ (1218.9 Å).

While reducing the Ly α spectra a shift of 0.2 Å between the old and new spectra was noted. Every feature in the new spectrum was shifted by this amount with respect to the old spectrum. If the features were fixed pattern noise they should not move and if they were from NGC 4151 there is no reason why they should all move in unison. We concluded that this shift probably arose in the reduction of the new spectrum and thus chose to shift it by −0.2 Å with respect to the old spectrum.

### 2.3 The C IV doublet

The two C IV spectra, shown in Fig. 3, look superficially different. This is due to the broad emission weakening as expected when the continuum is weak (Ullrich et al. 1984). The broad absorption and narrow emission and absorption components from the earlier epoch are still present, although the broad-band absorption and narrow emission seem to be weaker. Again no absorption system is seen at −165 km s⁻¹ (1552.5 and 1555.0 Å).

<table>
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<th>Name</th>
<th>Epoch</th>
<th>Length</th>
<th>Corrected</th>
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<tr>
<td>SWP 33063</td>
<td>7/3/88</td>
<td>783</td>
<td>244</td>
</tr>
<tr>
<td>LWP 12829</td>
<td>8/3/88</td>
<td>733</td>
<td>243</td>
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### Table 1.

<table>
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<th>Exposure</th>
<th>Epoch</th>
<th>Length</th>
<th>Corrected</th>
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<td>Name</td>
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</tbody>
</table>

### Figure 1. The Mg Ⅱ line. Galactic and −165 km s⁻¹ absorption are marked. Regions where the graph goes to zero indicate réseau marks and an example one is indicated.

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Velocity</th>
<th>Old EW</th>
<th>New EW</th>
<th>Comments</th>
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</thead>
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<tr>
<td>Å</td>
<td>km s⁻¹</td>
<td>Å</td>
<td>Å</td>
<td></td>
</tr>
<tr>
<td>2790.55</td>
<td>-990</td>
<td>1.1±0.2</td>
<td>0.9</td>
<td>Galactic Abs 2795Å component.</td>
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<tr>
<td>2802.28</td>
<td></td>
<td></td>
<td>1.2</td>
<td>Blended galactic 2802Å and NGC 4151 shifted 2795Å absorption</td>
</tr>
<tr>
<td>2810.30</td>
<td>-165</td>
<td>0.7±0.2</td>
<td>0.2</td>
<td>Shifted 2802Å absorption component.</td>
</tr>
<tr>
<td>2807.36</td>
<td>-417</td>
<td></td>
<td>0.2</td>
<td>Marginal new absorption feature</td>
</tr>
</tbody>
</table>

### Table 2. Absorption line equivalent widths in the old and new Mg Ⅱ spectra.

### 2.4 The C III doublet

The old and new C III spectra are shown in Fig. 4. Given the poor SN ratio of the new spectrum the two spectra are quite similar. The width of the emission line is the same in both spectra. From time lag arguments this suggests the C III emission comes from a larger region than the C IV, Mg Ⅱ or Ly α emitting regions. This agrees with Ullrich et al. (1984) who made similar suggestions and placed limits on the sizes of the regions. The C III line probably contains a substantial narrow-line region (NLR) component.

There is one detailed difference between the spectra from the two epochs. An emission line is present at 1917.5 Å in most of the spectra from which the old composite spectrum was made, but is not present in the new spectrum. It is probably associated with the broad-line region (BLR) and may

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not, in fact, come from C iii]. The small peak at 1916 Å is probably fixed-pattern detector noise as a feature is found at this wavelength on blank, long-exposure images. These features were discussed in Leech et al. (1987).

3 DISCUSSION

3.1 The broad lines – where have they gone?

Why have both the broad emission and absorption vanished in the Mg ii, C iv and Ly α lines? Ulrich et al. (1984) noted that when NGC 4151 is faint all the emission lines are relatively narrow. Bromage et al. (1985) noted the vanishing of the absorption lines when the continuum was weak [particularly at anomalous epochs – Perola et al. (1982) and Penston (1988)]. First, high-excitation absorption lines (N v) show a positive correlation with the continuum and would be weak when the continuum is faint. Normally the low excitation absorption lines (e.g. Si ii) show an anticorrelation but are also weak at the lowest epochs. Our results are thus consistent with these correlations since NGC 4151 is currently in a low state (Penston & Perez 1984; Clavel et al. 1987; Ulrich et al., in preparation).

3.2 From where does the – 165 km s$^{-1}$ feature originate?

The earlier idea that we did not see the – 165 km s$^{-1}$ feature in Ly α or C iv because they were observed at a different epoch from the Mg ii observation and conditions along the line-of-sight had changed is disproved by the new observations. The simultaneous presence of the absorption feature in Mg ii and absence in other lines now lacks any simple explanation. Why is the absorption only seen in Mg ii?

Due to the high contrast between the nuclear and extended emission from NGC 4151, the spectrum is very probably dominated by light from the nucleus. This is an important point to make, as it limits all the absorbing components to lie between us and the nucleus. We can place a further constraint on the location of the clouds responsible for the – 165 km s$^{-1}$ Mg ii feature. In the earlier data the central depth of the Mg ii absorption exceeded the continuum strength, implying the absorbing clouds lie on our side of the Mg ii BLR. The difference of 165 km s$^{-1}$ between these clouds and the systemic velocity means that the clouds cannot lie in the disc of NGC 4151. Have they been ejected from the nucleus? We note that if the feature is due to a large number of clouds its observed sharpness places limits on the velocity dispersion within the cloud ensemble.

As discussed in the introduction, many authors have noted the presence of gas clouds outside the nucleus. Do these tie in with these observations of a feature in Mg ii? Two of the clouds discovered by Ulrich (1973) have velocities similar to those of the Mg ii feature. To use her nomenclature, Cloud I, which covers the nucleus, has its blue edge at – 160 km s$^{-1}$ and Cloud II, partially covering the nucleus, extends over the velocity range 0 to – 380 km s$^{-1}$. These clouds are not in the disc of NGC 4151 because of their velocities and
4 CONCLUSIONS

The $-165 \text{ km s}^{-1}$ Mg II narrow absorption feature discovered in observations taken between 1978 and 1980 is still present, although about three times weaker than previously. No corresponding absorption feature is seen in any other UV line and no simple explanation is forthcoming.

We now know that the absorption system present in Mg II is not simultaneously present in C IV or Ly $\alpha$. Why is this? We conclude that only high quality spectra of these emission lines have a chance of solving this mystery. We look forward to the start of HST observations. Its spectral resolution and large collecting area should shed new light on this problem. We hope that its higher signal-to-noise data enables us to solve this mystery.

ACKNOWLEDGMENTS

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REFERENCES