EXTRAGALACTIC WORK WITH IUE

M.V. Penston
Astronomy Division, ESTEC, Villafranca Satellite Tracking Station, European Space Agency, Apartado 54065, Madrid, Spain

1. INTRODUCTION

The International Ultraviolet Explorer (IUE) is an 18 inch (45 cm) space telescope for ultraviolet spectrophotometry in geosynchronous orbit and is a joint project of the European Space Agency, the American National Aeronautics and Space Administration and the British Science Research Council. (Boggess et al. 1978 ab). It is a small instrument to use for objects of truly high redshift and therefore IUE observations relevant to extragalactic astronomy in general will be covered here.

2. NORMAL GALAXIES

The general form of the ultraviolet energy distributions from normal galaxies had already been foreshadowed before the flight of IUE by the OAO-2 data (Code & Welsh 1979). These are generally confirmed by IUE (e.g. Boksenberg 1978, Johnson 1979, Bertola et al. 1979, Benvenuti et al. 1979, Fosbury et al. 1979). In the wavelength range between 2000–3000 Å, galaxy spectra are basically those of the late-type stellar content of the galaxy and form a natural and expected extension of the optical spectrum. Various programmes are being pursued with IUE on normal galaxies in this spectral region to establish better K-corrections and to reduce the degree of non-uniqueness inherent in population synthesis work.

By contrast there is a less expected result shortward of 2000 Å where a rising component (rising $F\lambda$ with decreasing λ) is seen. In most cases this excess is probably due to a population of hot stars. It is also seen in globular clusters with blue horizontal branches (Dupree et al. 1979) and can very reasonably be attributed either to the stars in these clusters on or above the horizontal branch. In addition the excess from the nucleus of M87 has been shown to be spatially extended in the same way as the late-type stars seen in the optical (Bertola et al. 1979, Perola & Tarenghi 1979). On the other hand more exotic explanations of the ultra-violet excess may be

G.O. Abell and P. J. E. Peebles (eds.), Objects of High Redshift, 247–255.

appropriate in other cases since IUE would be a sensitive way to detect very underluminous Seyfert nuclei.

One should note of course that several of the "normal" galaxies observed to date include objects like M87 and NGC 1052 which have some exceptional qualities. Certainly establishing the systematics of the ultraviolet properties of truly bog-standard galaxies is an important project but it will be a long one given the speed of IUE.

As a footnote to this section, one should record the work of Perola & Tarenghi (1979) on the jet of M87. The brightest knot is detected to 1150 Å with a featureless spectrum similar to that of the BL Lac objects.

3. BL LAC OBJECTS

Before the flight of IUE, there were two rival explanations for the weakness of emission lines in BL Lac objects being the possible absence of gas or alternatively the absence of an ionizing continuum. IUE immediately demonstrated (Boksenberg et al. 1978) the extension of the continuum in Mk421 to 1150 Å and the absence of ultraviolet emission lines. New models soon appeared however (e.g. Krolik et al. 1978) which allowed the presence of hot gas with only OVI λ1032 emission. The only clear statement which can be made is that gas is not present in the same physical and geometrical state as in quasars!

The IUE data show a flattening (in the f_ν/ν plane) of the spectrum shortward of 2000 Å in the spectra of Mk 421 and Mk 501 (Boksenberg et al. 1978, Snijders et al. 1979). This apparent flattening can be removed by allowing a small amount of galactic reddening. In the case of Mk 501 at least, the value of this reddening is consistent with the galactic latitude and leaves a dereddened ultraviolet continuum of the form $f_\nu \propto \nu^{-\alpha}$ which points back (under the optical flux distribution due to stars) and joins up well with the high-frequency radio spectrum.

4. QUASARS

The IUE observations of the objects of largest redshift are those of Wilson et al. (1979) who have since extended this work (Boggess et al. 1979) to detect two 17th magnitude quasars (one radio-noisy, one radio-quiet) down to about 300 Å in the rest frame. The basic result is that the observed ultraviolet flux fits well to the extrapolation of the observed optical spectrum. There is a suggestion that He II λ304 emission may be seen in at least one of the quasars.

By contrast the brightest quasar, 3C273, has been well observed in the ultraviolet both by rocket (Davidsen et al. 1977) and IUE (Boksenberg et al. 1978, Boggess et al. 1979, Ulrich et al. 1979). The last investigation has produced the best data since it used the averages of several spectra at each wavelength. The most significant result is the similarity to the spectra of higher redshift quasars.

This data is shown in Fig. 1.

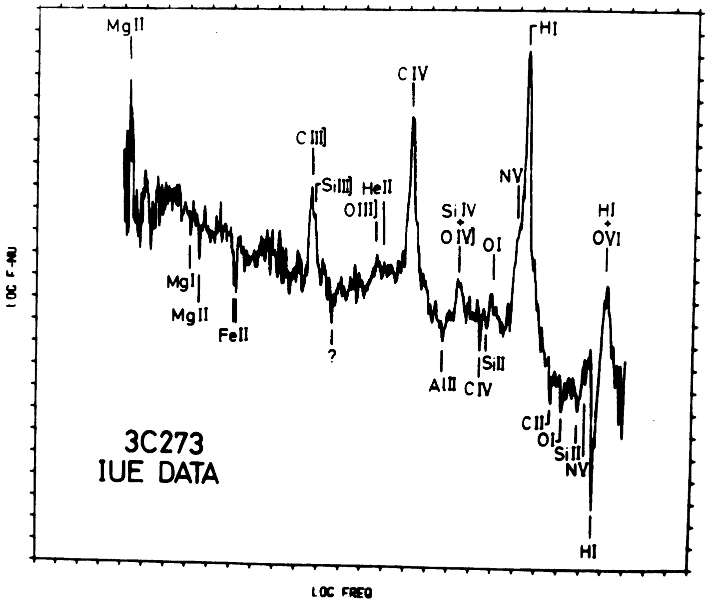

Figure 1. The mean of many IUE spectra of the quasar 3C273. Note the emission lines shifted in frequency by the quasar's redshift, Z=0.158, compared with the absorption lines which originate in the halo of our own galaxy.

One of the most intriguing discoveries is the presence of absorption lines which are at zero redshift and caused by the halo of our galaxy. One interesting point is the excess strength of the CIV absorption compared to its normal value in the disk of the galaxy. This is similar to the discovery of strong CIV in the halos of our galaxy and the Magellanic Clouds by Savage & de Boer (1979). In the strength of CIV (and in the list of lines that are seen) the galactic halo resembles the high-redshift absorption systems in quasars and therefore is consistent with the origin of these features in intervening galaxies.

The previous paper (Davidsen 1979) discussed the Lα/Hβ problem including the important IUE data of Ferland _et al_. (1979). The 3C273 data have been used by Ulrich _et al_. (1979) to undermine the conclusions of Netzer & Davidsen (1979) that all the ultraviolet lines might be too weak. Ulrich _et al_. favour a much lower continuum than earlier investigators (joining the continuum longward of CIII] to that shortward of Lα) and this increases the measured intensities of He II λ1640 and

OI λ1304 on which Netzer & Davidson base their case. Of course such a change in the continuum has a smaller effect on Lα and the original Lα/Hβ anomaly remains.

Before the IUE observations of 3C273, there were two alternative theories for the excitation of the optical lines of Fe II. Proponents of resonance fluorescence predicted absorption in the ultraviolet lines while those favouring collisional excitation predicted emission. In the event (Boksenberg _et al_. 1978),both schools were confounded with no apparent ultraviolet Fe II lines observed in either emission or absorption! The situation is now clearing as theoreticians (Jordan 1979, Collin-Souffrin _et al_. 1979ab) postulate high optical depths in the ultraviolet lines leading to line scattering and a "leak" of photons from the optical lines.

A last result from 3C273 is the confirmation of the excess ultraviolet continuum first discovered by Davidsen _et al_. (1978). The Ulrich _et al_. (1979) data suggest the presence of 2200 dust absorption at the redshift of the quasar and lead to a stronger intrinsic excess when reddening corrections are made. This excess is too big to be explained by gaseous continuum emission processes like Balmer continuum or two-photon emission. As discussed by Rees (1979) earlier in this volume possibly thermal emission from accreting material can account for this excess.

Other IUE observations of quasars have been reported by Baldwin _et al_. (1978), Wu _et al_. (1979), Gondhalekar & Wilson (1979) and Green (1979).

5. SEYFERT GALAXIES

Seyfert galaxies as observed in the ultraviolet also have spectra which are basically similar to those of quasars as seen from the ground. An important point however is that they seem to violate the correlation between CIV equivalent width and luminosity proposed by Baldwin (1977) for quasars. Basically the CIV equivalent widths for Seyferts are similar to those for quasars but the luminosities are of course much lower.

It is interesting to note that in some Seyfert galaxies some ultraviolet FeII lines have now been seen. Blended emission from ultraviolet multiplets 62 and 63 is identified in unpublished spectra of II Zw 136, Mk 231 and NGC 1566. These decays are to low-lying quartet states and it is still so that no resonance lines have been detected in emission.

The brightest Type I Seyfert galaxy, NGC 4151, has been well studied with IUE at both high (Penston _et al_. 1979) and low (Boksenberg _et al_. 1978, Perola _et al_. 1979) dispersion. Prior to IUE (by one day!) a spectrum of NGC 4151 was obtained by rocket (Davidsen & Fastie

1978). This data demonstrated both continuum and absorption line variability that have been confirmed by the later IUE data.

The high dispersion spectra of NGC 4151 are of low signal-to-noise in the continuum but the profiles of the three strong emission lines, Lα, CIV and CIII] are well defined and by contrast to the case of quasars each have clearly distinct profiles. The Lα profile is narrow (FWZI ∿ 1200 km s^{-1}) and obliterated by absorption to the blue of the line centre. The Lα/Hβ varies from 15-25 at the line centre to less than 1.5 elsewhere. The CIV is also cut by absorption in the velocity range -100 to -1100 km s^{-1} relative to the optical narrow emission lines and is broader (FWZI ∿ 8000 km s^{-1}). The absorption varies in depth but not velocity. The CIII] line is narrow (FWZI ∿ 2000 km s^{-1}) and is shifted as if 1907-to-1909 are in their low density ratio i.e. $n_e < 10^{4.5} cm^{-3}$.

Other reported results on active galaxies include work by Oke & Zimmerman (1979) Elvius et al. (1979), Wu et al. (1979) and Clavel et al. (1979).

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https://doi.org/10.1017/S0074180900068625 Published online by Cambridge University Press

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DISCUSSION

Gaskell: I would like to make a couple of remarks. First, I don't think that the mere strength of the 2200 Å absorption feature can be taken as a quantitative indicator of reddening. There are cases in our own galaxy where λ2200 is very much weaker or very much stronger than expected for a given E(B - V).

Second, in a survey of the ultraviolet continua of a large number of flat radio spectrum QSOs that I have almost finished, the continuum to the blue of Lyman-alpha is usually well-represented by an extrapolation of the continuum of 2100 to 1300 Å, if one ignores absorption. Also, in this survey I find that most of the continua have a power-law index (corrected for local extinction) of about 0.8, with almost no indication of intrinsic reddening greater than E(B - V) ~ 0.06

Penston: Well, to take the second point first, I must say that my feeling on looking at the published data was that there were several cases which did have the same kind of jump in the continuum across Lyα as is seen in 3C 273.

On the first point, there are, of course, some special cases where λ2200 is anomalous, but in the vast majority of cases in our galaxy it conforms to a standard law.

Wolfe: I was very interested in the galactic MgII absorption in 3C 273. It seems to me that you could calculate the Mg^+ column densities from a curve-of-growth study, using the 21-cm profiles. You could then calculate the HI column density from the 21-cm emission fluxes. In this way you can calculate the Mg/H abundance ratio in the galactic halo. Would you comment on this?

Penston: What we have done is use the 21-cm profile and the assumption of normal abundances and ionization to compute the equivalent widths. These agree with those observed except in the case of the CIV, which is observed to be too strong.

P. Veron: Are your results affected by the calibration problem recently discovered?

Penston: Of course, there has been a problem with the intensity transfer function for the IUE short wavelength cameras, but it does not seriously affect the data presented here.

Marscher: I'm not convinced that the presence of ultraviolet continuum combined with the absence of detectable emission lines necessarily rules out the presence of dense gas in BL Lac objects. Blandford and Rees have suggested that the continuum radiation might be beamed toward the observer in these sources. If the gas lies in a disk with an axis parallel to the beam, it sees a continuum which is greatly reddened at a very low flux level.

Penston: I am sure that there are many alternative explanations!

https://doi.org/10.1017/S0074180900068625 Published online by Cambridge University Press