SIMULTANEOUS OBSERVATIONS OF ACTIVE GALACTIC NUCLEI WITH IUE

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ABSTRACT

IUE observations of four active nuclei have been coordinated with radio, infrared, and X-ray measurements to obtain simultaneous determinations of their continuous spectra. The results for the BL Lac objects 0735+178 and I Zw 187 indicate sufficient UV and X-ray fluxes to ionize any gas. Comparison of the X-ray measurements with the extrapolated optical-UV continuum show a definite X-ray excess for I Zw 187 but none for the other BL Lac object.

INTRODUCTION

We present continuum data on four active nuclei of quasar-like extragalactic objects, with frequency coverage from the radio to the X-ray band. Such measurements are an essential first step to the understanding of the mechanisms by which the central energy source produces the emitted radiation. In particular, the ability to measure the UV flux of these objects with IUE supplies crucial data for defining the characteristics of their continuous spectra. Some of the most interesting types of active nuclei, e.g. the BL Lac objects, present particular difficulties in that they vary on timescales as short as days or weeks. Our observations were planned so that simultaneous observations (within hours or days) could be made at all frequencies in order to obtain definitive spectra for these objectives.

OBSERVATIONS

Table 1 presents the four extragalactic objects observed in October 1979. The IUE observations were low dispersion, short and long wavelength (except for I Zw 187) spectra, taken with the large aperture. Near simultaneous observations were made at radio frequencies by H. Aller of the Univ. of Mich. (8 and 14 GHz), and by W. Dent of the Univ. of Mass. (32 and 90 GHz); at infrared wavelengths by R. Rudy of the Univ. of California at San Diego (H,J,K, and L); and at X-ray frequencies with the

Einstein Observatory by the Columbia Astrophysics Laboratory (0.3 - 4 kev). An estimate of the optical flux (V band) was also obtained at the IUE immediately before each exposure. All the measurements were made within two days of the IUE exposures, except for those at 32 and 90 GHz, which were made within seven days.

Table 1. IUE Observations

Object (Type)	V	z	D * (Mpc)	Camera	Exp (Min)	UV slope
0735+178 (BL Lac)	15	>0.424	>1020	SW	225	1.7
				LW	130	
I Zw 187 (BL Lac)	16	0.055	160	SW	285	1.6$
NGC 3516 (Seyfert)	13#	.0093	28	SW	100	2.3
				LW	75	
NGC 2782 (Hotspot)	13#	.0084	25	SW	165	1.4
				LW	105	

* based on H=100 km/s Mpc.
$ infrared-optical-ultraviolet slope
# extended underlying galaxy

The simultaneous multifrequency spectra are given in Figs 1-4. The ultraviolet data have been dereddened for the extinction in the Galaxy using the measurements of gas and dust given by Burstein and Heiles (1979), and the Seaton (1979) fit for the selective extinction.

RESULTS

The continuum spectra cover 8 decades in frequency from the radio region (9.9 GHz) to the kev X-ray band (up to 10(+18) Hz). Although the data are closely simultaneous, the two large gaps in coverage (submillimeter to far infrared, and extreme UV to soft X-ray) make suspect any attempt to draw a single continuum through all the data. Nevertheless, we can see that the BL Lac object 0735+178 is consistent with one smooth continuum, and that the

X-ray data can be fit reasonably well by an extrapolation of the infrared-optical-UV data. This extrapolation is a power law $F \sim \nu^{-\alpha}$ with $\alpha = 1.3$. The total integrated flux at the earth is 1.1 (-10) ergs/cm^{2}s, and the total luminosity is greater than 2.0 (+44) ergs/s, for q=1/2, and H=100 km/s Mpc. The other BL Lac object, I Zw 187, differs in several respects: (1) the total integrated flux is 4.2 (-11) ergs/cm^{2}s, and the total luminosity is 1.1 (+43) ergs/s, at least 20 times fainter than 0735+178; (2) the decrease from the radio to the optical is less, i.e. a factor of 100 instead of 1000; (3) the extrapolated infrared-optical-ultraviolet power law is steeper, $\alpha \simeq 1.7$; and (4) there is evidence for an X-ray excess, i.e. the observed X-ray flux is about 10 times greater than that extrapolated from lower frequencies. The Seyfert I galaxy NGC 3516 continues this trend: (1) the ratio of radio to optical flux is only about 10; (2) $\alpha \simeq 2.3$; and the X-ray excess is about 50. NGC 2782 presents some interesting contrasts which probably arise because it is not a quasar-like object. There is almost no change in flux between the radio and infrared region, and the X-ray flux is much less than what is expected when the UV continuum is extrapolated into the X-ray band.

DISCUSSION

Simultaneous UV and X-ray data allow the total flux of ionizing photons to be estimated more accurately than is possible from optical data alone. The BL Lac object 0735+178 is one of the few to have a large enough red shift ($z>0.424$) to shift the Lyman limit to the short wavelength band of the IUE. The fact that the continuum shows no dip or change of slope below the Lyman limit places an upper limit of about 10 (+18) cm on the amount of neutral hydrogen along the line of sight to 0735+178.

It is interesting to compare the optical-UV continua of the two BL Lacs reported here with the Red QSOs recently studied by Rieke et al. (1979) and by Smith and Spinrad (1980). Although the Red QSIs gave very steep spectra ($\alpha \geq 3$), they possess broad emission lines. The fact that the optical-UV continua of the two BL Lac objects are considerably less steep than those of the Red QSOs suggests that the 'lineless' property of BL Lac objects arises from a lack of gas rather than a lack of ionizing flux.

The ability to reliably extrapolate the infrared-optical-UV flux to higher frequencies is also important for an understanding of the continuum emission mechanism. The clear detection of an X-ray excess in I Zw 187 seems consistent with the inverse Compton process, in which radio frequency photons are raised to X-ray energies by scattering from relativistic electrons. By use of the model of Jones, O'Dell, and Stein (1974), the simultaneous data may be used to estimate the size and magnetic field strength of the emitting region. For I Zw 187 we estimate a magnetic field strength

of about 16 G and a size of about 0.0085 pc (10 light days) - approximately the size deduced from temporal flux variations. The data for 0735+178 yield a lower limit of 0.66 pc (2.2 light years) for the size of the continuum emitting region, which is discrepant with that determined from flux variations (1 light week). This disagreement suggests that some new ingredient must be added to the canonical model of the inverse Compton process for the case of 0735+178, such as relativistic flow (Blandford and Konigl, 1979).

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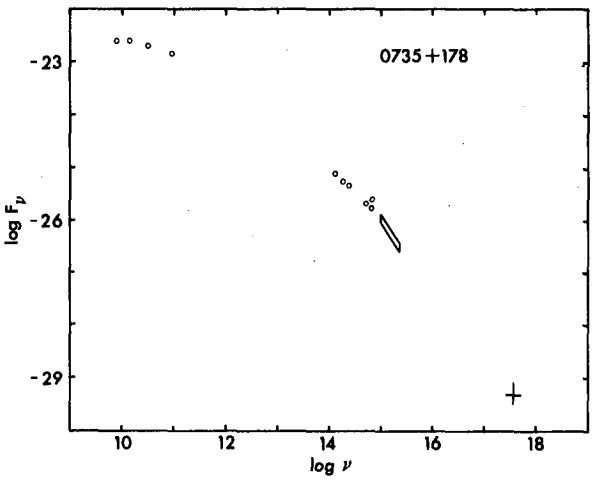
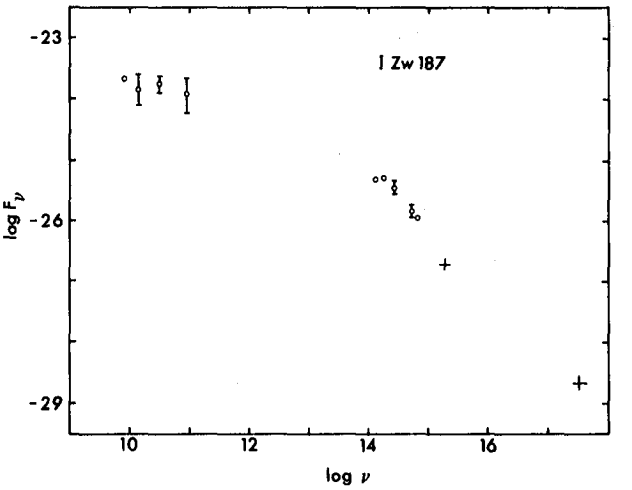


Figure 1



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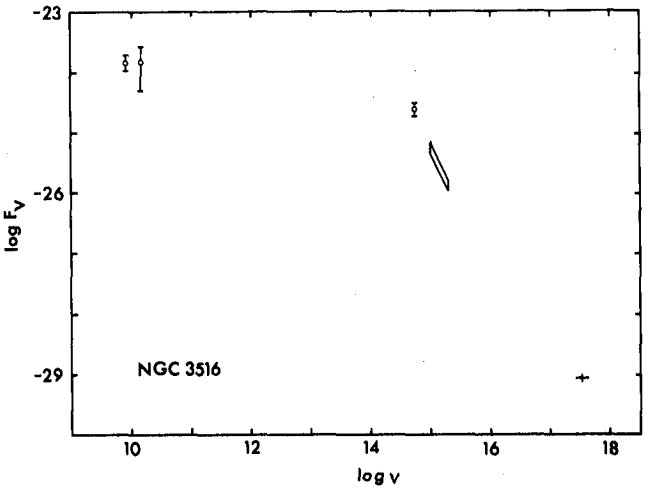

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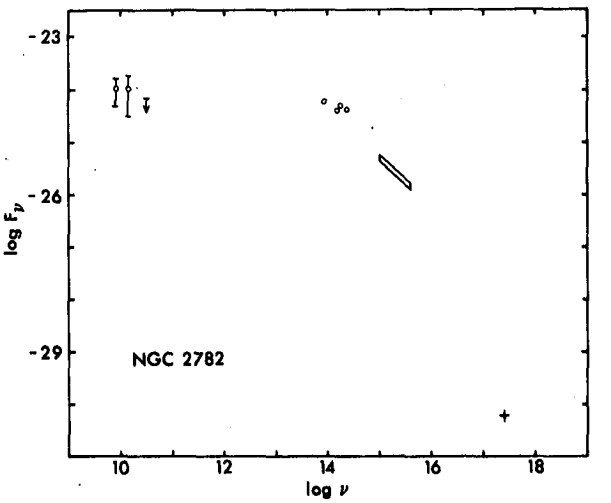

Figure 4