ULTRAVIOLET ISOTROPIC EMISSION FROM THE BLAZAR 3C 279

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ABSTRACT

Archival IUE SWP and HST FOS spectra show the presence of a relatively strong, broad Lyman $\alpha$ emission line superposed onto the UV spectral continuum of the blazar 3C 279. As opposed to a factor $\sim$50 variation of the continuum flux during eight years, the emission line did not exhibit significant intensity changes. Simultaneous IUE SWP and LWP spectra of 3C 279 in low emission state are fitted by power-laws of index $\alpha_\lambda \sim 1$ ($f_\lambda \propto \nu^{-\alpha_\lambda}$), significantly flatter than measured during higher states. Our observations suggest that the Lyman $\alpha$ line is not powered by the beamed, anisotropic synchrotron radiation which produces the observed continuum in 3C 279, but rather by an unbeamed component characterized by slower and lower amplitude variability. The latter may account for the UV continuum observed during the very low state of January 1993.

Key words: ultraviolet spectra; blazar emission lines; blazar emission mechanisms; accretion disks.

1. INTRODUCTION

The blazar 3C 279 ($z = 0.54$) is well studied and shows frequent large continuum flares from radio to gamma-ray wavelengths. Inverse Compton scattering of relativistic electrons off synchrotron or ambient photons is likely responsible for the emission at hard X- and gamma-ray energies. Clarifying the exact nature of the seed photons for this mechanism would explain the origin of the huge amplitude variations exhibited by 3C 279 at the highest energies (Maraschi et al. 1994; Hartman et al. 1996; Wehrle et al. 1998). There have been several multi-wavelength observations of this blazar, and hence there are many UV data available in the archives. In particular, 3C 279 was monitored on a nearly daily basis with IUE and ROSAT for three weeks between December 1992 and January 1993, simultaneously with gamma-ray observations by EGRET, and with coordinated optical observations. We present here a study of the correlated variability of the UV continuum and of the broad Lyman $\alpha$ emission line intensity over eight years, and compare our results with the findings of simultaneous optical, UV and X-ray monitoring in the period 2–5 January 1993.

2. DATA ANALYSIS AND RESULTS

IUE SWP and LWP spectra have been extracted with the NEWSIPS routine used for the implementation of the IUE Final Archive (Nichols & Linsky 1996) and dereddened using a neutral hydrogen column density $N_{HI} = 2.22 \times 10^{20}$ cm$^{-2}$ (Elvis et al. 1989). The continuum flux at 1750 Å has been derived through a power-law fit to the SWP spectra; line intensities have been calculated with a Gaussian fit (see Koratkar et al. 1998 for details). To increase the signal-to-noise ratio of the Lyman $\alpha$ emission line, we binned the spectra in four groups depending on the continuum flux at 1750 Å. The SWP spectra in each group were then co-added, as follows: 'high spectrum': $f_{\text{cont}} > 2 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$; 'medium spectrum': $8 \times 10^{-15} < f_{\text{cont}} \leq 2 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$; 'low spectrum': $3 \times 10^{-15} < f_{\text{cont}} \leq 8 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$; 'very low spectrum': $1 \times 10^{-15} \leq f_{\text{cont}} \leq 3 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$.

HST FOS spectra in 1992, 1994, and 1996 have been retrieved from the archive, analyzed with the STSDAS/IRAF reduction package and dereddened (see Koratkar et al. 1998).

ROSAT PSPC spectra were taken from 1992 December 27 to 1993 January 13 on a daily basis. The background, carefully chosen in a region free from faint field sources, was subtracted from the data. The neutral hydrogen column density which yields the best power-law fit for all the spectra is $2.5 \times 10^{20}$ cm$^{-2}$.
which is consistent with Galactic within the 10% 1-σ error. Fixing $N_{HI}$ at this value, good fits to the spectra are obtained with single power-laws of index 0.7 $\div$ 0.8. More details will be reported in a forthcoming paper (Pian et al. 1998).

In all UV continuum flux ranges the Lyman $\alpha$ emission line is visible redshifted to $\sim$1868 Å (Koratkar et al. 1998). Its strength is nearly constant ($\sim$5 x $10^{-14}$ erg cm$^{-2}$ s$^{-1}$), while the continuum at 1750 Å varies by a factor of $\sim$50, from $\sim$ 0.6 to 31.6 x $10^{-15}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$ (Fig. 1). The emission line equivalent width ranges between 1 and 45 Å (Fig. 2).

In 2-5 January 1993, the UV emission of 3C 279 was at a historical minimum in the whole IUE range (SWP and LWP). Power-laws have been fitted to simultaneous pairs of SWP and LWP dereddened spectra. The average spectrum in the 1200-2700 Å interval is described by a spectral index $\alpha_{\nu} \simeq$ 1, which is unusually flat for this object, as apparent from a comparison with spectra taken at epochs of higher UV flux level (Fig. 3), and harder than the simultaneous optical spectrum (Fig. 4).

3. DISCUSSION

In eight years, the UV continuum of 3C 279 has varied by a factor $\sim$50, while the Lyman $\alpha$ line flux has remained nearly constant. This suggests that the observed highly variable continuum, most likely due to beamed synchrotron radiation from a relativistic jet does not contribute significantly in powering the emission line.

In fact the line equivalent width in 3C 279 is smaller than observed in 'normal' quasars, where the observed continuum, probably thermal radiation from an accretion disk, is also the source of ionizing radiation. If the line emitting gas in the broad line region of 3C 279 is also ionized by an inner disk, its radiation, usually swamped by the beamed blazar continuum, may become observable in very low states.

The spectral flattening observed in the 1200-2700 Å range in correspondence with a very low UV continuum level is an uncommon feature in blazars, which generally exhibit spectral hardening during brighter states, and might represent the signature of the putative thermal, isotropic component underlying the highly variable, beamed continuum of 3C 279, and photoionizing the line emitting gas (Fig. 4). The low state soft X-ray spectrum, which is well described ($\chi^2 \sim 1$) by a power-law of index $\alpha_{\nu} \sim$ 0.7 $\div$ 0.8 may also contain a Seyfert-like component. Assuming a simple accretion disk model described by a single black body, this would have a temperature of $\sim$20000 K and a size of $\sim$1 light day. The observation of a still weaker flux in January 1995 at the shorter UV wavelengths (Fig. 3) suggests some variability of this thermal component, albeit modest. More sensitive observations in the hard X-ray / gamma-ray band during a low state would be needed to constrain this hypothesis.

The presence of intense line emission and the suggestion of a thermal component in 3C 279 are consistent with the scenario in which the seed photons for the inverse Compton mechanism producing the gamma-
rays are external to the relativistic jet and provided either by the broad line region or by the inner accretion disk. However, the observed large amplitude variability in gamma-rays accompanied by lower amplitude variability at lower energies requires not only changes in the energetic electrons in the jet, but also variations in the soft photon field, at least in a simple one zone emission model. A possible scenario is proposed by Ghisellini and Madau (1996), whereby some line emission is induced by radiation from the jet. It is interesting to ask whether this mechanism would have some observable consequences on the observed line emission.

Although intriguing and promising, our results on the UV continuum and Lyman α line characteristics in 3C 279 must be taken with caution: the available IUE and HST spectra are too few and too sparse in time to yield a definitive proof of lack of correlated variability between continuum and emission line at the shorter (one day or less) time scales. Moreover, the low signal-to-noise ratio of the data prevent a very accurate measurement of the spectral index in low UV emission state.

Further data are necessary to confirm our findings. An intensive and regular monitoring of the UV spectrum of 3C 279 and other blazars, along with a detailed sampling during low emission states would clarify the existence and role of an isotropic emission component in this class of active galactic nuclei, and possibly lead to a link between blazar and normal quasar properties. This task can be pursued more favourably in the UV spectral range, where the high ionization emission lines are located (at low or intermediate redshift) and which is less diluted by the stellar contribution of the host galaxy. This open problem represents an important heritage of IUE and its solution could be attempted only by a UV observing facility with its same easy and flexible scheduling.

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Figure 3. Dereddened and binned UV spectra with their power-law best fits. The IUE continua (open symbols) have been co-added according to the flux level. Spectral indices are $\alpha = 1.45 \pm 0.04$ (high state), $\alpha = 1.68 \pm 0.03$ (medium), $\alpha = 1.84 \pm 0.08$ (low state), $\alpha = 1.0 \pm 0.2$ (very low state). An extremely low state IUE-SWP spectrum is also shown (Jan 1995, stars), but no fit has been attempted, due to the poor S/N. HST spectra (filled dots) refer to April 1992 (lower state, $\alpha = 1.7 \pm 0.2$) and January 1996 (higher state, $\alpha = 2.25 \pm 0.06$).

Figure 4. De-extincted simultaneous optical (from Grandi et al. 1996), UV (IUE) and soft X-ray (ROSAT) energy distributions in 2-5 January 1993. The power-law fits to the ROSAT data and the black body fit to the IUE LWP and SWP data are shown as solid and dashed curves, respectively (1-$\sigma$ ranges are also reported for the power-laws).