ACTIVE GALACTIC NUCLEI IN THE EXTREME ULTRAVIOLET

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1. EUV Emission from AGNs

The extreme ultraviolet (EUV) wavelength interval (commonly defined to constitute the range 68 – 912 Å, or 13.6 – 182 eV) lies between the intensively studied FUV (912 – 3000 Å) and X-ray (1 – 68 Å) spectral regimes, but until recently has not been subjected to systematic investigations. This lack of information has been particularly acute in the case of active galactic nuclei (AGNs), where the very ability to carry out successful EUV observations has been seriously questioned. This has stemmed from the fact that, for a Galactic H I column density $N_G(\text{H I}) = 1 \times 10^{20}$ cm^{-2}, the interstellar transmission factor is 0.42 at 60 Å, but a factor of 10 smaller at 100 Å. In turn, there are no known regions of the interstellar medium (ISM) that have $[N_G(\text{H I})/10^{20}\,\text{cm}^{-2}] < 0.6$ (resp., 0.8) for positive (resp., negative) latitudes (e.g., Heiles 1991).

There are, however, several reasons why EUV observations of AGNs could provide important information about the nature of these objects. In the case of radio-quiet QSOs, the peak power is known to be emitted in the EUV range (several hundred Å). Furthermore, in these sources there is evidence for a distinct soft X-ray component (representing a "soft excess" over an extrapolation of the ISM-absorbed hard X-ray component), whose properties are at present controversial. In particular, the first results of *ROSAT* PSPC observations of a complete sample of optically selected QSOs (Laor et al. 1994) have pointed to a spectral index $\alpha_X = 1.50 \pm 0.40$ in the $0.2 - 2$ keV range that flattens by $\Delta\alpha_X \approx 0.5$ above ~ 2 keV. This study has concluded that steep-α_X sources are characterized by a week hard component. A similar distribution of α_X has been inferred for soft X-ray–bright QSOs and Seyfert 1 galaxies observed in the *ROSAT* all-sky survey. On the other hand, previous observations (enumerated in Laor et al. 1994) by the *Einstein* and *EXOSAT* satellites yielded different soft X-ray spectral slopes and led to an alternative explanation of the steep-α_X objects. These questions could in principle be clarified by EUV measurements, which would then also help determine the soft X-ray emission mechanism.

EUV observations could also provide valuable information on AGNs whose emission is dominated by a nonthermal component. In particular, the 0.5 – 3.5 KeV spectrum of BL Lac objects (BLOs) appears to be a power-law extension of the UV continuum, and the entire UV–X-ray spectrum can be interpreted in terms of

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beamed synchrotron emission from a relativistic jet (e.g., Königl 1989). Several bright X-ray–selected BLOs (of which PKS 2155-304 is a prototype) do, however, show evidence for a $\lesssim$ 0.6 keV absorption feature (e.g., Madejski et al. 1991), which has been attributed to photoionized gas in the vicinity of the AGN (Krolik et al. 1985). EUV spectral measurements could test this interpretation and probe the physical properties of the absorbing gas. Such measurements could also test the suggestion (Ostriker & Vietri 1985) that some BLOs are not associated with low-redshift galaxies but instead represent gravitationally lensed high-z quasars.

2. EUV Observations of AGNs

The field of extragalactic EUV astronomy has only been opened up during the last 3 years, following the launch of the Wide Field Camera on board *ROSAT* and of the EUV-dedicated *Extreme Ultraviolet Explorer* with its 3 scanning telescopes and deep-survey spectrometer telescope (e.g., Bowyer 1994). Both missions detected AGNs only in the shortest-wavelength bandpass (60 – 140 Å for the WFC and 60 – 180 Å for *EUVE*), in line with the anticipated effect of Galactic absorption. The WFC survey (Pounds et al. 1993) found 7 sources (4 Seyfert-like objects and 3 BLOs), whereas *EUVE* observations have so far identified 6 AGNs (3 Seyferts and 3 BLOs) with a significance of 6σ or better, and a total of 13 objects (7 Seyferts, 5 BLOs, and 1 quasar) detected at 2.5σ or better and lying within 60" of the AGN optical coordinates (Marshall et al. 1994). The relatively high number (compared to hard X-ray surveys) of detected BLOs appears to be compatible with the steeper X-ray spectra of the latter class of objects. Based on the number of Seyfert detections in the WFC and *EUVE* surveys, Marshall et al. (1994) infer a significant EUV excess above the extrapolation of the ν^{-1} hard X-ray spectrum, although the derived constraints are not yet strong enough to discriminate between the different soft X-ray spectral indices indicated by the *Einstein* and *ROSAT* data (see §1).

3. Spectral Observations of PKS 2155-304

Not only have BLOs been detected with a relatively high frequency in the EUV surveys, but they have, in fact, turned out to be the brightest EUV AGNs, with PKS 2155-304 leading the way (0.29 *EUVE* cts/s) and Mkn 421 a distant second (0.06 cts/s) Marshall et al. (1994) have conservatively estimated that BLOs do not contain more than 10^{20} cm^{-2} of *neutral* hydrogen. However, it appears that BLOs have *ionized* hydrogen column densities of that order that give rise to pronounced EUV spectral signatures, and that the latter, in turn, could be used to probe the mass ejection episodes in their central regions.

Using the 3 state-of-the-art spectrometers on board *EUVE* (Bowyer & Malina 1991), Königl et al. (1994) carried out two long observations of PKS 2155-304 during 1993 June ($\sim$ 111 ks) and July ($\sim$ 157 ks). The source was detected in the $\sim 75 - 110$ Å range during both epochs (Fig. 1), but the two spectra differ in detail, and the flux has increased by $\sim$ 50% between the two observations. A power-law fit to the data yields an energy spectral index $\alpha_{\rm EUV} \gtrsim 3$ for the measured Galactic H I column density and likely choices of the He I and He II abundances. Such steep values are inconsistent with the soft X-ray spectral index of 1.65 measured by the *ROSAT* PSPC, which approximately corresponds also to the observed EUV to X-ray flux ratio.

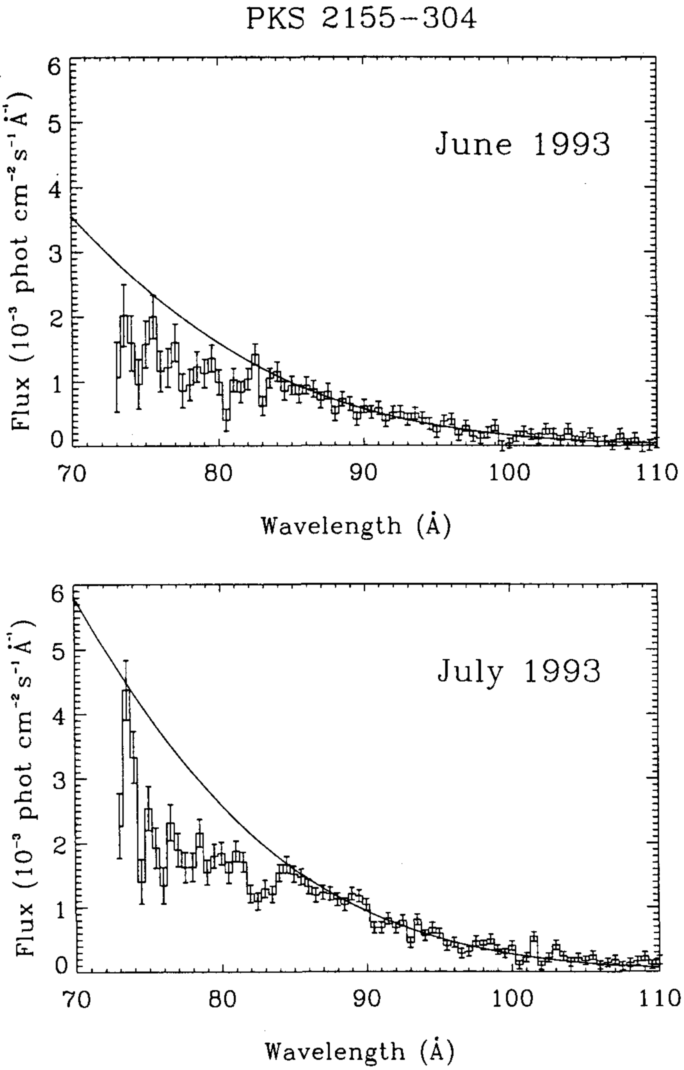

Fig. 1. Background-subtracted spectrum (shown with 1σ error bars) for the 1993 June (*top*) and July (*bottom*) *EUVE* observations of PKS 2155-304. The solid line in each case represents a best-fit (in the range 85 – 105 Å) $\alpha = 1.65$ power-law continuum with Galactic absorption characterized by $N_G(\text{H I}) = 1.36 \times 10^{20}$ cm^{-2}, He I/H I = 0.1, and He II/H I = 0.01.

Fitting a power law with $\alpha = 1.65$ to the EUV data implies strong absorption at the source between ~ 75 Å and ~ 85 Å (see Fig. 1). Königl et al. (1994) have

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argued that this absorption is not due to continuum opacity and demonstrated that it can be attributed, instead, to a superposition of Doppler-smeared absorption lines originating in high-velocity ($\lesssim 0.1\,c$), radially localized Broad Emission Line-type clouds of total column density $\sim 5 \times 10^{20}$ cm^{-2} that are ionized by the beamed continuum of the associated relativistic jet. They identified the lines as mostly L- and M-shell transitions of Mg, Ne, and Fe. The same model also implies a pronounced O VII Kα X-ray absorption feature at roughly the same energy as the feature detected in 1990 by *BBXRT* (Madejski et al. 1994), which provides strong support to the apparent association of this object with a galaxy at $z = 0.116$. It was suggested that the higher-energy X-ray absorption feature detected in 1980 by the *Einstein* OGS (Canizares & Kruper 1984) and identified with a broadened O VIII Lyα line might have originated in outflowing clouds that had a higher abundance of O VIII than of O VII, possibly because they crossed our line of sight closer to the continuum source. Coordinated future EUV and X-ray observations could test whether the long-term X-ray spectral variability is correlated with changes in the EUV spectrum, as would be predicted by this picture, and whether such variations are associated with distinct mass-ejection episodes and exhibit a systematic trend in the underlying ionization and velocity structures.

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