EUVE Observations of the Seyfert Galaxy MRK 279

C.-Y. HWANG, S. BOWYER, AND M. LAMPTON

Center for EUV Astrophysics, 2150 Kittredge Street,
University of California, Berkeley, CA 94720–5030, USA

We report *EUVE* spectral and photometric data of the Seyfert 1 galaxy MRK 279. The photometric data show large amplitude variations over time scales less than 10,000 s. The spectrum is characterized by several features between 80 and 100 Å. We compare the observed data with several models. We can rule out the possibility that the EUV emission is from a diffuse corona or intercloud medium. Models that assume the soft X-ray/EUV emission results from reprocessing in an optical BLR region are also inconsistent with the data. A collisional excitation model is consistent with the observations but requires a cloud density $\geq 10^{11}$ cm^{-3}.

1. Introduction

The relation between the optical-/ultraviolet (OUV) blue bump and soft X-ray excess is an important topic in AGN studies. It has been conjectured that the accretion disk around the black hole of an AGN will manifest itself as a strong EUV emitter (e.g., Ross et al. 1992). On the other hand, reprocessing of X-ray photons due to cold (neutral) and warm (partially ionized) material in the AGN can significantly alter the appearance of the emergent spectrum in the EUV and soft–X-ray range (e.g., Netzer 1993). Observations of AGNs in the EUV range have the potential to clarify the physical mechanisms that are operative in these systems.

The Seyfert 1 galaxy MRK 279 is one of the brightest Seyfert galaxies detected during the *EUVE* all-sky survey (Bowyer et al. 1995) where it is designated J1352+692. The Galactic hydrogen column density toward this object determined by high angular-resolution H I measurements (Elvis et al. 1989) is $N_{\rm HI} = 1.64 \times 10^{20}$ cm^2, which suggests that this object may be detected well into the EUV range. We report here an EUV observation of MRK 279 obtained with *EUVE.*

2. Observations and Data Reduction

The Seyfert 1 galaxy MRK 279 was observed simultaneously with the short wavelength spectrometer (70–190 Å) and the Deep Survey telescope on the *Extreme Ultraviolet Explorer* (*EUVE*) over a period of 7 days from 1994 April 22 to April 29. We first plotted the photometer and spectrometer counts in time sequence and rejected time intervals with obvious excess count rates. The remaining data were further processed by eliminating points that deviated more than 2 σ from the median. This left 199,191 s of exposure time for analysis.

Deep Survey data of MRK 279 were binned with bin sizes of 5400 s and 600 s. The light curve with bin sizes of 5400 s is shown in Figure 1a; this shows amplitude variations by a factor of 2 on time scales of one day and a trend of increasing fluxes toward the end of the observation. The light curve with bin sizes of 600 s shown in Figure 1b. This is a magnified portion of the Figure 1a data, revealing for the first time the substantial short term EUV variability of the object.

S. Bowyer and R. F. Malina (eds.), Astrophysics in the Extreme Ultraviolet, 75–80.

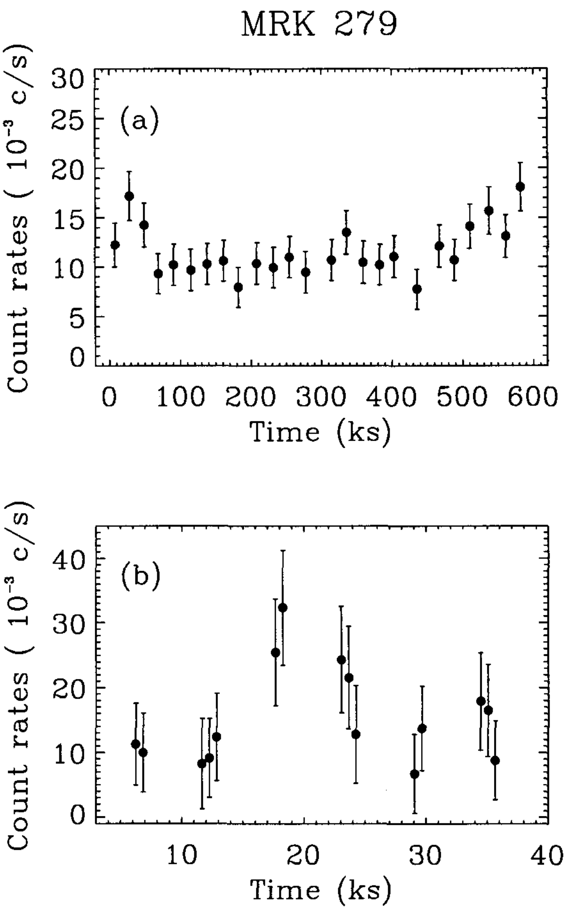

FIGURE 1. *EUVE* Deep Survey light curves of MRK 279. (*a*) The light curve with a bin size of 5400 s illustrates the EUV flux variation over the 7-day observation. The data begin at JD = 2449465.53. Amplitude variations by a factor of 2 are detected on time scales of 1 day. (*b*) The light curve with a bin size of 600 s. This subset of the data begins at the same starting point as (*a*) and illustrates the rapid EUV flux variation. Amplitude variations by a factor of 3 are detected on time scales less than 10,000 s.

The spectrum of MRK 279 was obtained from the spectrometer by subtracting backgrounds evaluated from both sides of the spectrum. The spectrum with $\lambda < 80$ Å has been excluded because of uncertain background estimations. The spectrum is shown in Figure 2. It is characterized by several line features. Some of these features exceed the extrapolation of the *ROSAT* power-law fit (Walter & Fink 1993) by 2–3 σ. The error bar shown on Figure 2 provides an estimate of the standard deviation of the data. Comparing the error bar with these features, we conclude that it is very unlikely that these features are all due to statistical deviations of a smooth photon distribution.

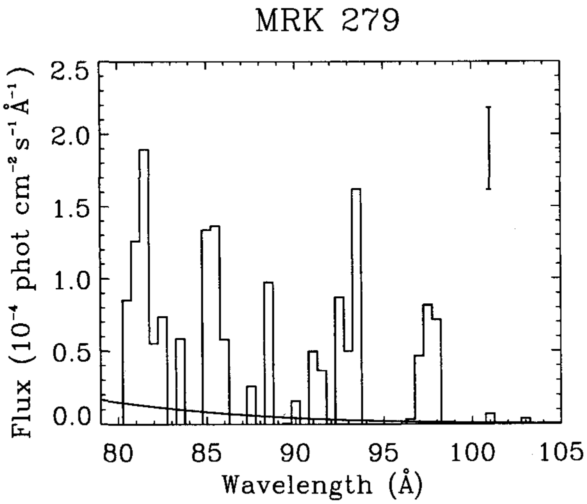

FIGURE 2. *EUVE* spectrum of MRK 279. The histogram is the background-substracted EUV flux. The solid curve is an extrapolation of the *ROSAT* power-law fit.

3. Models

Considerable quantities of warm and/or cold gas have been found near active galactic nuclei with optical and X-ray observations (e.g., Antonucci & Miller 1985; Turner et al. 1991). This gas can affect the emergent spectra in the EUV and soft X-rays by absorbing and reflecting the intrinsic spectra. In addition, warm gas can also produce soft X-ray and EUV emission. A complete model should take into account all these processes in the gas. In this section we discuss various models suggested for Seyfert galaxies and compare these models with the observed data.

3.1. *Power Law Model*

A simple power-law extrapolation of X-ray can not fit the observed EUV flux. The comparison of the observed EUV spectrum with the extrapolation of the *ROSAT* power-law fit (Walter & Fink 1994) shows a difference with 98% significance. The power-law extrapolations from other X-ray observations (Malaguti et al. 1994) have even larger deviations from the EUV spectrum. The best power-law fit differs from the *EUVE* spectrum at the 96.7% significance level, and is inconsistent with the observed features in the EUV spectra discussed below.

3.2. *Photoionization Model*

Line and line-like features can be produced by reflection from a gas photoionized by a continuum flux. However, a photoionization model that can take into account all necessary line emission mechanisms in the EUV region is not available. For example, line emission from photoionized gas in this wavelength band comes mostly from dielectronic recombination, which requires a detailed many-body treatment and is only treated approximately in most models. We must therefore be careful regarding conclusions from a comparison of current models with the *EUVE* data.

We have calculated the emission from a photoionized gas using the photoionization code XSTAR (Kallman & Krolik 1993) for several representative ionization parameters and column densities. The model consists of a spherical gas cloud photoionized with a point source of continuum radiation at the center. A power law of $\alpha = 0.84$, which is the best-fit power law of X-ray observations (Malaguti et al. 1994), has been used for the continuum radiation at the center. The ionization parameters explored range from 1 to 1000 and the column densities from 5.0×10^{20} to 1.0×10^{22}. Despite the wide range of parameters explored, we were unable to find suitable physical parameters to explain the *EUVE* spectrum. It is unclear whether this is due to limitations in the theoretical models or if the model is fundamentally inappropriate.

3.3. *Collisional Excitation Model*

The EUV features of MRK 279 may be emission lines from a collisionally ionized thermal plasma around the central source of the AGN. We have calculated the theoretical EUV spectra at different temperatures using the thermal plasma code of Landini and Monsignori Fossi (Landini & Monsignori Fossi 1990; Monsignori Fossi & Landini 1994) and compared the results with our data. The best fit temperatures occur in a relatively narrow range from 3.0×10^5 to 6.0×10^5 K where the χ^2 has an improvement $\geq 90\%$ significance over the other temperature fits. We have modeled the emission using the Landini-Monsignori Fossi model plus the *ROSAT* power law $\alpha = 1.15$ (Walter & Fink 1994). The results are shown in Figure 3 where they are compared with the data. The theoretical spectrum has been averaged over 0.5 Å to simulate the data binning. Most of the lines are emission lines of the ionized heavy elements Mg, Si, Ne, and Fe. The total luminosity between 70 and 100 Å is 5.6×10^{42} erg s^{-1} assuming $H_0 = 50$ km s^{-1} Mpc^{-1} and a red shift z = 0.029 (Bowyer et al. 1984, Helou et al. 1991). The volume emission measure required is $\gtrsim 1.0 \times 10^{66}$ cm^{-3}. The time scale of the EUV variation (10,000 s) sets an upper bound to the size of the emitting region of 3×10^{14} cm by the argument of light travel time. To obtain the line emission that we have observed with *EUVE*, the density of the plasma must exceed 1×10^{11} cm^{-3}. If the emitting gas is in a form of homogeneous corona, the Thomson optical depth would be ~ 20 and would wash out the lines completely. Thus the *EUVE* results are inconsistent with models of diffuse corona with a homogeneous intercloud medium (Emmering et al. 1992).

One way to circumvent this problem is to assume that the gas is clumped into clouds and the total gas density is $> 10^{11}$ cm^{-3}. For example, let us assume each individual cloud has density of 10^{14} cm^{-3} (e.g. Ferland & Rees 1988) and column density of 10^{22} cm^{-2}. The Thomson optical depth is ~ 0.007 for every cloud. The filling factor of these clouds is only 10^{-6} and a typical line of sight encounters only $\sim$ three clouds. Such clouds would be similar to the optical BLR clouds except that the EUV emitting clouds are closer to central source of the AGN and thus have higher densities and ionization parameters than their optical counterparts.

The total luminosity required to heat the gas to the inferred temperature in this model is 1.6×10^{44}, which is comparable to the luminosity 2.6×10^{44} derived from dynamical models (Wandel 1991).

4. Conclusions

We have obtained *EUVE* spectral and photometric observations of MRK 279. The light curve of MRK 279, which is among the first EUV light curves of Seyfert galaxies obtained, sets a strong constraint of 3.0×10^{14} cm on the size of the EUV emitting region assuming that the emission is correlated. This size is much smaller than the optical BLR region, which is order of 10 light days (Stripe et al. 1994). We can thus rule out models assuming the EUV emission arising from the BLR region. Models that assume a

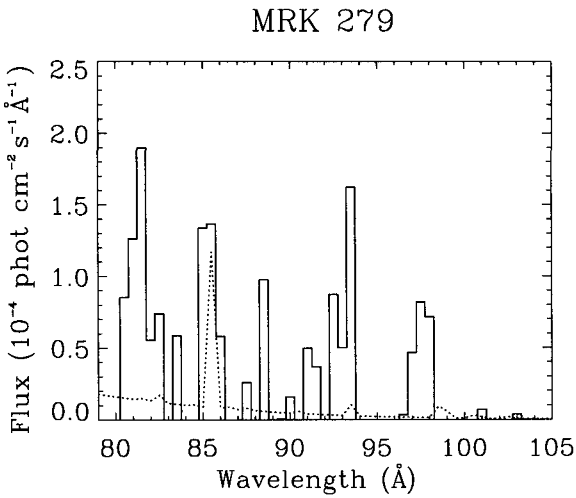

FIGURE 3. Comparison of line emission from a collisionally excited plasma with the EUV data. The histogram is the EUV data. The dotted-line emission features are red-shifted lines of Mg, Si, Ne, and Fe from a thermal plasma at temperature 4.5×10^5 K as predicted by the Landini & Monsignori Fossi model. A power law of $\alpha = 1.15$ has been added. The line at 85.5 Å is from Si VI.

diffuse corona or intercloud medium for the origin of EUV excess in MRK 279 are also inconsistent with the observations. A model with collisionally excited gas clouds is more consistent with the line features of the spectrum. The photometric data in combination with the spectrometer data suggest emission from clouds with densities $\geq 10^{11}$ cm^{-3} near the center of the AGN.

We thank Arieh Königl and Steven Kahn for valuable comments. This work has been supported by NASA contract NAS5-30180.

REFERENCES

ANTONUCCI, R. R., & MILLER, J. S. 1985, ApJ, 297, 621

BOWYER, S., LAMPTON, M., LEWIS, J., WU, X., JELINSKY, P., LIEU, R., & MALINA, R. F. 1995, ApJ, submitted

BOWYER, S., BRODIE, J. P., CLARKE, J. T., & HENRY, J. P. 1984, ApJ, 278, L103

ELVIS, M., LOCKMAN, F. J., & WILKES, B. J. 1989, AJ, 97, 777

EMMERING, R. T., BLANDFORD, R. D., & SHLOSMAN, I. 1992, ApJ, 385, 460

FERLAND, G. J., & REES, M. J. 1988, ApJ, 332, 141

HELOU, G., MADORE, B. F., SCHMITZ, M., BICAY, M. D., WU, X., & BENNETT, J. 1991, in Databases and On-Line Data in Astronomy, ed. M.A. Albretch & D. Egret, Dordrecht: Kluwer, 89

KALLMAN, T. R., & KROLIK, J. H. 1993, NASA Internal Report

LANDINI, M., & MONSIGNORI, FOSSI, B. C. 1990, A&AS, 82, 229

MALAGUTI, G., BASSANI, L., & CAROLI, E. 1994, ApJS, 94, 517

MONSIGNORI FOSSI, B. C., & LANDINI, M. 1994, Solar Physics, 152, 81

NANDRA, K. & POUNDS, K. A. 1992, Nature, 359, 215

https://doi.org/10.1017/S0252921100035788 Published online by Cambridge University Press

NETZER, H. 1993, ApJ, 411, 594

ROSS, R. R., FABIAN, A. C., & MINESHIGE, S. 1992, MNRAS, 258, 189

STRIPE, G. M., ET AL. 1994, A&A, 285, 857

TURNER, T. J., WEAVER, K. A., MUSHOTZKY, R. F., HOLT, S. S., & MADEJSKI, G. M. 1991, ApJ, 381, 85

WALTER, R., & FINK, H. H. 1993, A&A, 274, 105

WANDEL, A. 1991, A&A, 241, 5

https://doi.org/10.1017/S0252921100035788 Published online by Cambridge University Press