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X-RAY CONTINUUM AND EVIDENCE FOR AN IRON EMISSION LINE FROM THE QUASAR E1821+643

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ABSTRACT

The high-luminosity radio-quiet quasar E1821+643 has been observed with *Ginga*. The 2–10 keV spectrum has a power-law energy index, α, of 0.9 and the flux is $(2.0 \pm 0.3) \times 10^{-11}$ ergs cm^{-2} s^{-1}. The absorption is consistent with the Galactic value of $N_H = 4 \times 10^{20}$ cm^{-2}. The spectrum shows strong evidence for the presence of a redshifted iron K emission line of center energy 5.1 ± 0.2 keV (6.6 ± 0.3 keV, redshift corrected; $z = 0.297$), and an observed equivalent width of 210 ± 80 eV. There is evidence that E1821+643 may be embedded within a cluster of galaxies which could contribute part of the observed line. The equivalent width (EW) ascribed to the quasar cannot, therefore, be accurately determined, but lies in the range 60 eV $\lesssim$ EW $\lesssim$ 380 eV (after redshift correction). The upper limit to the intrinsic absorption of 1×10^{22} cm^{-2} rules out production of the line by fluorescence in cold material in the line of sight, but several other possible origins for the line are not constrained by our data. The detection of a redshifted iron line opens the possibility that iron emission lines may be a common feature in the X-ray spectra of quasars. This would have a considerable impact on the study of quasars by future X-ray missions.

Subject headings: galaxies: clustering — galaxies: X-rays — quasars — X-rays: spectra

1. INTRODUCTION

Emission or absorption lines have always been extremely useful in many aspects of the study of cosmic plasmas. Lines sometimes identify particular objects or locations in the system. They also yield precise information on temperature, density, size, and motion in the source, which is not easily accessible otherwise. The same has been true in X-ray astronomy: much of our understanding of the physical properties and the geometry of bright X-ray sources has come from observations of iron emission (or absorption) lines (see, e.g., Makishima 1986). With the increase in sensitivity of recent X-ray missions, iron line spectroscopy has become applicable to many extragalactic sources.

Following the discovery of iron emission lines in unresolved extragalactic sources by *Ariel V* (Barr et al. 1977), the gas scintillation counters on *Tenma* and *EXOSAT* were able to locate precisely the line center energy and equivalent width in two AGNs, i.e. NGC 4151 (Matsuoka et al. 1986) and Cen A (Wang et al. 1986). *Ginga* has now confirmed that several type I and type II Seyfert galaxies exhibit significant iron line emission (Koyama et al. 1989; Pounds et al. 1989; Matsuoka et al. 1990). For quasars only upper limits for line intensities had been reported (e.g., Worrall et al. 1980) until *Ginga* which detected an iron emission feature with an equivalent width of ~ 50 eV in the X-ray spectrum of 3C 273 (Turner et al. 1990).

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The quasar E1821+643 has a redshift $z = 0.297$, and it is one of the most X-ray luminous radio-quiet quasars of which the 2–10 keV luminosity $L_X \sim 2 \times 10^{45}$ ergs s^{-1} (Pravdo & Marshall 1984). It was identified by means of an *Einstein* IPC image (Pravdo & Marshall 1984) and retrospectively associated with the *HEAO 1* A-2 soft X-ray source 1824+634 (Nugent et al. 1983) and a hard X-ray source 1814+63 (Marshall et al. 1979). From a combined analysis Pravdo & Marshall (1984) pointed out the possibility of a strong and variable soft excess. The spectrum derived for the combined soft and hard data could be described by a steep power law with an energy index $\alpha = 1.31 \pm 0.3$ and a hydrogen column density less than 7×10^{20} cm^{-2}. The flux F_X in the range 2–10 keV was 3.9×10^{-11} ergs cm^{-2} s^{-1}. Four years later the IPC flux in the range 0.2–4 keV was lower than the *HEAO 1* A-2 result by a factor of about 4 (Pravdo & Marshall 1984).

The source was observed with *EXOSAT* on seven occasions from 1984 July 7 to 1985 October 23 by Warwick, Barstow, & Yaqoob (1989). They were able to separate the hard and soft components using the LE and ME data. They found that the 2–10 keV flux was almost constant (1.8–2.2 $\times 10^{-11}$ ergs cm^{-2} s^{-1}) with a power-law index of $\alpha = 0.8$, while the 0.2–2 keV flux was strongly variable, fluctuating by a factor of 2 over a time scale of months. The overall level of the soft flux was ~ 10 times weaker than the *HEAO 1* A-2 flux quoted by Pravdo & Marshall (1984). Thus E1821+643 is a quasar with a strong and variable soft X-ray excess, while the spectral index of the 2–10 keV spectrum, $\alpha \sim 0.9$, is close to the average value of AGNs (Mushotzky 1984a; Turner & Pounds 1989). The N_H determination was confused by the variable soft flux but was consistent with the Galactic value of 4×10^{20} cm^{-2} (Heiles 1975). Warwick et al. (1989) set an upper limit to the equivalent width of an iron line of ~ 300 eV.

E1821+643 was observed by *IRAS* (Neugebauer et al. 1986) and found to be one of the most luminous radio-quiet quasars in the far-infrared; the luminosity at 60 μm is greater than that of 3C 273. It does not appear in any of the radio catalogs given in Hewitt & Burbidge (1987).

Hutchings, Janson, & Neff (1989) obtained a direct CCD image of E1821+643 in a program investigating the host galaxies of radio-loud and radio-quiet QSOs. The field around E1821+643 contains a substantial enhancement of galaxies over the field. While there is no direct evidence that these galaxies are associated with the QSO, their magnitudes suggest that they are indeed at a redshift of ~0.3 and that E1821+643 may be a member of a moderately rich cluster of galaxies (Hutchings 1989).

Here we report on the 2–10 keV spectrum of E1821+643 obtained with *Ginga* and the detection of an iron emission line. The origin and implications of this emission line are discussed. We employ $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$ throughout the paper.

2. OBSERVATIONS AND RESULTS

2.1. *Observations*

The observations of E1821+643 were carried out with the LAC (large area proportional counters) on two occasions (1987 May 12–14 and 1988 September 27). The LAC instrument on board the *Ginga* satellite (Makino & the ASTRO-C team 1987) has a total effective area of 4000 cm^2, very low intrinsic background, and an energy resolution of 18% FWHM at 6 keV (Turner et al. 1989). The LAC instrument was in MPC-1 mode, and most of the data were taken in low bit rate with a time resolution of 16 s.

The first observation was carried out from 1987 May 12 to May 14. In this observation three X-ray sources (E1821+643, 1803+67, and 3C 371) and two background sky regions were kept in the satellite slew plane, and the field of view of the LAC was switched in its direction every few satellite orbits over 3 days (see Ohashi 1988). Since this observation enabled the background data to be sampled very closely both in time and in position to the source observation, direct background subtraction was possible. Background data taken 37 days before and 37 days after the observation was also used (Hayashida et al. 1989) and gave similar results. The observation occurred only 3 months after launch, before the background caused by induced radioactivity in the satellite (Hayashida et al. 1989) had reached its equilibrium level. This prevented the application of the model background developed by Hayashida et al.

The second observation was carried out on 1988 September 27 and consisted of both pointing and scanning observations. The scanning observations can measure the intensity of E1821+643 as well as that of other sources in the field of view. Figure 1 shows the scanning data fitted with the point source response function. There is an IPC source at R.A.(1950) = $18^h13'39''.6$ and decl.(1950) = $64°24'1''.4$, $0°.5$ away from E1821+643 with an intensity of about one-third of the E1821+643 level (Harris et al. 1989). However, scanning observations with *Ginga* (see below) did not detect significant emission from this source implying a 2–10 keV flux level of less than 0.1 mCrab (with 90% confidence), i.e., we infer a soft spectrum for this weaker IPC source and no significant contamination in the *Ginga* scanning and pointing observations of E1821+643. Warwick et al. (1989) investigated another possible contaminating source, the planetary nebula K16, and conclude that its flux is not a significant contaminant either. Unless otherwise specified the results from spectral analysis reported here used the background taken on the previous day in a nearby sky region. However, the results were cross checked with the model background developed by Hayashida et al. (1989), and results from this analysis are also given.

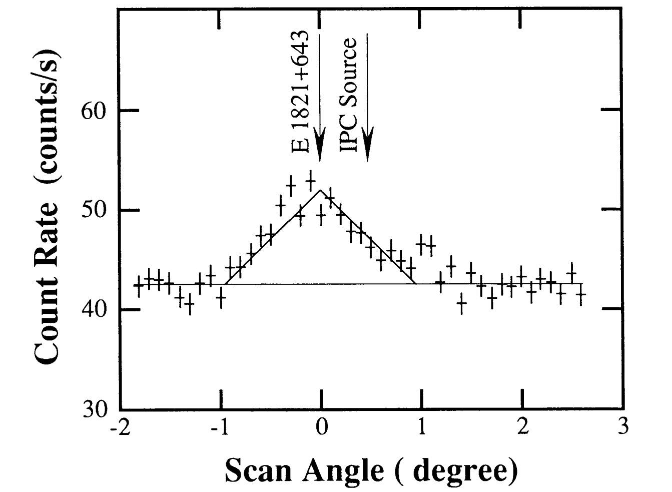

FIG. 1.—Superposition of scanning data of E1821+643 fitted with the collimator response function for a point source. The intensity is about 9.8 counts s^{-1} in the 2–10 keV band (roughly 1 mCrab). No other sources are observed.

Extensive studies of the background properties by Hayashida et al. (1989) have shown that when data are taken in the low-background orbits the rms fluctuation of the final pulse-height spectrum is ~0.03 counts s^{-1} keV^{-1} in 2–10 keV for a typical pointing observation of ~10^4 s. However, the raw background spectrum contains line features (Hayashida et al. 1989; Turner et al. 1989); in particular a 4.9 keV line associated with L emission from the xenon counter gas. It is important to estimate correctly background features which could otherwise mimic emission lines from the source. The background estimation methods described by Hayashida et al. (1989) successfully remove all intrinsic line features from the spectrum; any features in the residual systematic error spectrum are negligible over the relevant energy range. The 4.9 keV feature in the raw background spectrum is considerably stronger in the mid-layer, which does not respond to incident photons below 8 keV. Careful inspection of the background-subtracted mid-layer spectrum for both observations reveals no 4.9 keV peak.

2.2. *Results*

The measured flux of E1821+643 in the energy range 2–10 keV was $(2.1 \pm 0.3) \times 10^{-11}$ ergs cm^{-2} s^{-1} and $(1.9 \pm 0.3) \times 10^{-11}$ ergs cm^{-2} s^{-1} for the observations in 1987 and in 1988, respectively. The errors of the flux indicate the 90% limit due to beam-to-beam fluctuation of the background sky (Hayashida et al. 1989), together with the systematic error due to attitude uncertainty (statistical errors are negligible).

In the spectral analysis, only the data from the top layer taken in low-background orbits (see Hayashida et al. 1989) were used. We included a 1% systematic error in the data of each pulse-height channel for the entire energy range analyzed here (2–18 keV) to allow for calibration uncertainty. The pulse-height spectra of E1821+643 for the observations in 1987 and 1988, after background subtraction and corrections for the aspect, are shown in Figure 2*a* and 2*b*.

Fits to the data were carried out using simple models, initially excluding the energy range 4.1–6.4 keV (the "iron band"). Cross sections for interstellar absorption were taken

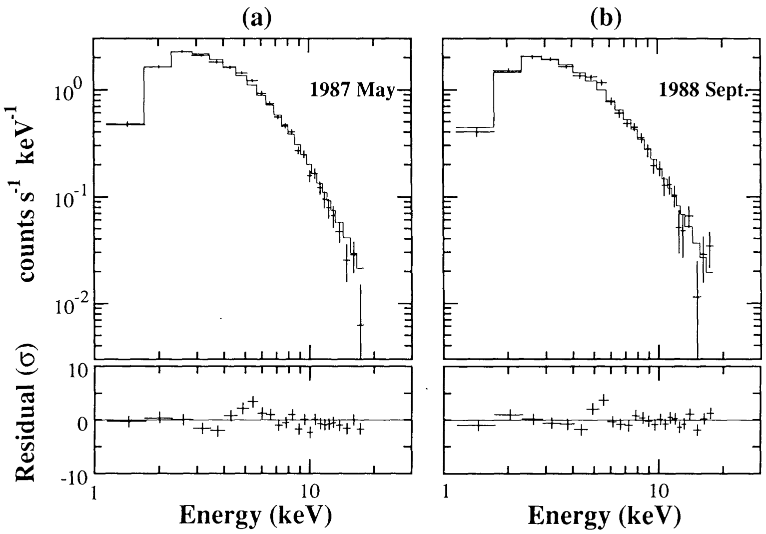

FIG. 2.—The observed pulse-height spectrum of E1821+643 observed in (*a*) 1987 May and (*b*) 1988 September fitted with the best-fit power-law model obtained by fitting the data excluding 4.1–6.4 keV. The data were taken by the top layer of the LAC instrument on *Ginga*. The bottom panels indicate the residuals in units of σ.

from Morrison & McCammon (1983). The results for the two observations, 1987 and 1988, are shown in Table 1, where power-law energy index α or bremsstrahlung temperature, hydrogen column density N_H and χ^2 values calculated for the 1.5–18 keV range are listed. Power-law models gave much better fits than thermal bremsstrahlung. The best-fit power-law models are plotted in Figure 2*a* and 2*b* with solid lines, and the residuals are indicated in the bottom panels. There is a systematic deviation peaked around 5 keV. This deviation from the power-law continuum is $\sim 2.5 \times 10^{-5}$ counts cm^{-2} s^{-1} keV^{-1} for both observations.

To evaluate the significance of the line we fitted the complete spectrum from both observations, first with a simple power law plus absorption, then with the addition of a narrow emission line. The results of the fitting are summarized in Table 2. Applying the F test, the reduction in χ^2/ν in the 1988 September observation from 32/23 to 14/21 is significant at greater than 95% confidence. We note that the power law plus line with absorption model is an adequate fit to the 1988 September data, but that the fit to the 1987 May data is unacceptable at 90% confidence. This is probably due to the problems with the background subtraction for this observation. Figure 3 shows confidence contours with two parameters of interest for the line intensity against line center energy for the 1988 September observation. The equivalent width is corrected for redshift. Figure 4*a* and 4*b* show the implied incident photon spectrum for the observations in 1987 and 1988 corresponding to the best-fit power law with emission-line models in Table 2.

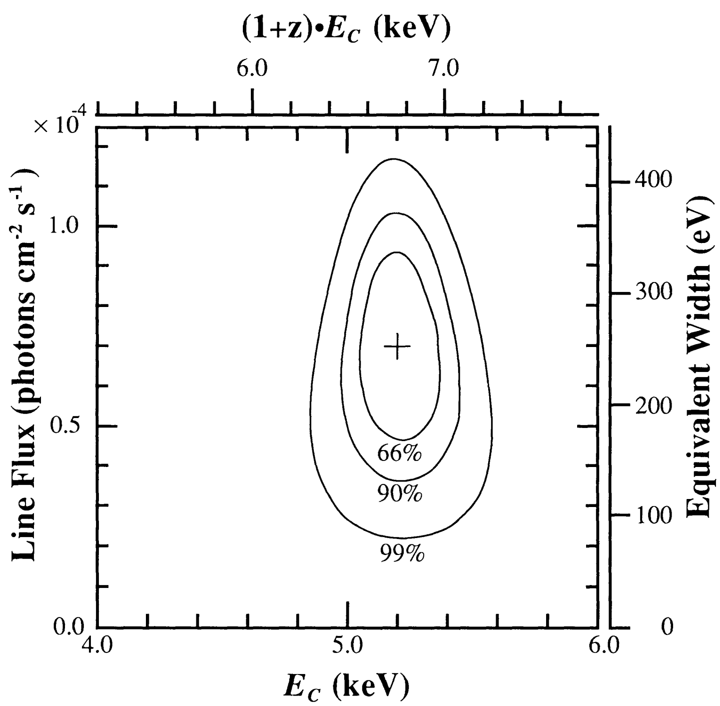

FIG. 3.—Confidence contours at 66%, 90%, and 99% with two interesting parameters for the line intensity against the center energy E_c for the 1988 observation. The equivalent width is corrected for the redshift. The presence of the line is statistically significant at more than 99.7% confidence.

TABLE 1

SPECTRAL FITS TO E1821+643 EXCLUDING THE "IRON BAND"[a]

	Power Law				Thermal Brem	
Observation	F_X (2–10 keV) (10^{-11} ergs cm^{-2} s^{-1})	N_H[b] (cm^{-2})	α	χ^2/ν	Temperature (keV)	χ^2/ν
1987 May	2.1 ± 0.3	$<1 \times 10^{22}$	0.92 ± 0.05	34/20	11 ± 1	63/20
1988 Sep	1.9 ± 0.3	$<1 \times 10^{22}$	0.86 ± 0.07	11/20	13 ± 2	29/20

[a] Spectral fits over 1.5–18 keV, but excluding 4.1–6.4 keV. All parameters allowed to float.
[b] Intrinsic absorption in excess of the Galactic value of 4×10^{20} cm^{-2}.

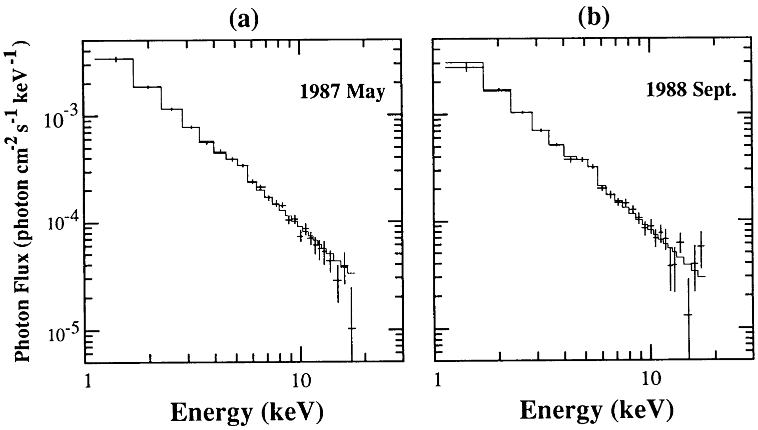

FIG. 4.—The incident photon spectrum of E1821+643 for (*a*) 1987 May and (*b*) 1988 September observations. Power-law continuum and an emission line whose parameters are listed in Table 2 are assumed.

Both the intensity and the center energy of the line show good agreement between the two observations as indicated in Table 2. Since these two observations are separated by 1.4 yr, with different background conditions (see Hayashida et al. 1989), it is very unlikely that the background should cause such an accidental agreement. Furthermore, Ohashi (1988) has shown that during the 1987 May observation sequence the line is only present in the background-subtracted spectrum for those parts of the observation when E1821+634 is in the field of view. Finally we note that analyzing the sum of the top and middle layer data gave results consistent with the top layer alone. The feature at 5 keV is present only in the top layer spectrum, while the middle layer spectrum shows no such excess. We conclude that the line feature in the spectrum of E1821+643 is real.

The background model of Hayashida et al. (1989) was applicable to the 1988 September observation (see above). The results obtained, a line flux of $(6.1 \pm 3.1) \times 10^{-5}$ photons $cm^{-2}\ s^{-1}$ and a line center of 5.04 ± 0.30 keV, were compatible with those in Tables 1 and 2, which were obtained using direct background subtraction. Combining the results from the two background subtraction methods gives a line flux of $(6.5 \pm 3.1) \times 10^{-5}$ photons $cm^{-2}\ s^{-1}$ and a line center of 5.09 ± 0.24 keV. Further combining the data from the two observations, we obtained a line center energy of 5.11 ± 0.20 keV, a flux $(6.2 \pm 2.1) \times 10^{-5}$ photons $cm^{-2}\ s^{-1}$, and an equivalent width, before and after correcting for the source redshift of 210 ± 80 eV and 275 ± 105 eV, respectively.

The continuum spectrum of E1821+643 is well-described by a power-law spectrum with an energy index $\alpha \sim 0.9$. The spectral shape and the intensity are consistent between the two observations performed with *Ginga*, and they also agree with the results of *EXOSAT* (Warwick et al. 1989), suggesting that the source is not highly variable above 2 keV. The possibility of a redshifted iron edge was also checked. Table 3 gives the 90% upper limits for iron K edges at energies corresponding to various degrees of ionization of iron calculated according to the Lampton, Margon, & Bowyer (1976) prescription for 1, 3, and 5 parameters of interest. The low-energy absorption indicates no significant excess over the Galactic column density of $N_H = 4 \times 10^{20}\ cm^{-2}$ (Heiles 1975). The LAC has no sensitivity

TABLE 3

90% UPPER LIMITS TO THE IRON K ABSORPTION EDGE[a]

ENERGY (keV)	EQUIVALENT N_H ($10^{21}\ cm^{-2}$)[b] Parameters of interest: 1	3	5
7.1	51	86	108
7.5	49	88	114
8.0	41	81	108
8.5	37	76	106

[a] Obtained by fitting a power law plus emission line and absorption edge with low-energy absorption. The line energy was fixed at 6.6 keV (at the source) and the edge energy was fixed at the value indicated in the table; all other parameters were allowed to float.
[b] Assuming solar abundances.

TABLE 2

SPECTRAL FITS TO E1821+643 WITH AND WITHOUT AN EMISSION LINE[a]

OBSERVATION	POWER LAW WITH EMISSION LINE[a]: α	Line Energy (keV)	Line Flux (photons $cm^{-2}\ s^{-1}$)	χ^2/ν	POWER LAW[b]: α	χ^2/ν
1987 May	0.91 ± 0.03	5.13 ± 0.32	$0.58(\pm 0.25) \times 10^{-4}$	34/21	0.88 ± 0.03	63/23
1988 Sep	0.87 ± 0.05	5.21 ± 0.24	$0.69(\pm 0.34) \times 10^{-4}$	14/21	0.83 ± 0.05	32/23

[a] Power law plus emission line with absorption fits over 1.5–18 keV. The N_H is fixed at the Galactic value but all other parameters are allowed to float.
[b] Power law with absorption fits over 1.5–18 keV. The N_H is fixed at the Galactic value but all other parameters are allowed to float.

below 1.2 keV, so we were unable to study the soft component detected with *HEAO 1* A-2, IPC (Pravdo & Marshall 1984), and *EXOSAT* (Warwick et al. 1989).

We are able to confirm that the spectral index of E1821+643 (0.82–0.94) is not significantly steeper than the average for AGNs. The mean value derived by Turner & Pounds (1989) is 0.7 ± 0.15 for all AGNs (here we use 1 σ errors). At $z = 0.297$, the K-corrected luminosity in the 2–10 keV band is $L_X = 2 \times 10^{45}$ ergs s^{-1}. On the basis of observations by all workers this seems to vary only weakly, the two *Ginga* measurements being consistent with each other, and with the data of Warwick et al. (1989) and Pravdo & Marshall (1984). This is in strong contrast to the highly variable soft excess.

3. DISCUSSION

The present results give detailed information on the 2–10 keV spectrum of E1821+643, which is a radio-quiet quasar with strong far-infrared and X-ray luminosity. Assuming that the iron line belongs to the quasar itself, then the line luminosity (6×10^{43} ergs s^{-1}) amounts to 3% of the quasar emission. The center energy of the observed iron line is 6.7 ± 0.3 keV in the rest frame of the quasar. This allows emission from neutral to hydrogen-like iron, therefore several possibilities for the origin of the line need to be considered.

3.1. *Cluster Contribution to the Iron Line*

The line energy is consistent with that observed in the emission from moderately rich clusters of galaxies. As E1821+643 is apparently within such a cluster we must first ensure that the line emission does not have a cluster origin before ascribing it to the quasar itself. There are two constraints on the possible contribution of a cluster to the iron line. The first is that the intensity of the thermal continuum, described by thermal bremsstrahlung, must be compatible with the observed spectrum of E1821+643; a relatively hot thermal component, bright enough to account for the observed iron line flux, would be detectable. The second constraint arises from the observed relationship between cluster luminosity and temperature, which has been established from observations of more than 30 clusters (Mushotzky 1984b; Edge 1989; Edge & Stewart 1989; Hatsukade 1989); a relatively cool cluster would not be sufficiently luminous to account for the observed line flux. In the remainder of this section we use these constraints to define the allowed range of any iron line flux, originating from a cluster, as a function of cluster temperature. Unless otherwise specified, we assume a heavy metal abundance of 0.3 solar, since a sample of clusters observed by *Ginga* has a range of abundances from 0.19 to 0.44 times solar (Hatsukade 1989).

The upper three curves in Figure 5 shows the observed iron line flux and 90% confidence limits, while the other curves illustrate the constraints on the possible cluster contribution. To investigate the first of these constraints, we carried out spectral fits to the 1988 September observation (using the background model developed by Hayashida et al. 1989), with a composite model including a power law, a thin thermal bremsstrahlung component, and an additional emission line (originating from the quasar). As noted above, the continuum spectrum of E1821+643 is adequately described by a power law, and no significant improvement in χ^2/ν was obtained using this composite model. The temperature of the thermal component was unconstrained at the 90% level, although the best fit was in the range 3–5 keV. Figure 5 shows the upper

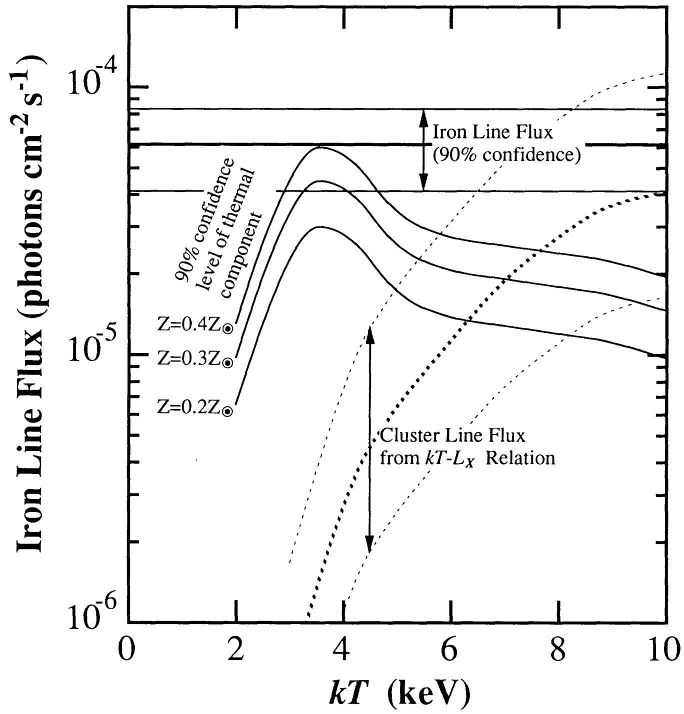

FIG. 5.—Observed iron line flux (three horizontal lines at the top), and upper limits on the line flux from a cluster of galaxies as a function of the cluster temperature. The three dotted curves show the range of iron line flux expected from a cluster, at redshift 0.297, derived from the relationship between bolometric luminosity and temperature. The three curves in the middle of the figure indicate the upper limits of the line flux from a possible thermal component assuming abundances of 0.4, 0.3, and 0.2 solar, respectively, derived by fitting combined thermal bremsstrahlung and power-law models to the data. As long as the cluster satisfies the kT versus L_X relation, the cluster emission cannot explain all of the observed iron line.

limit, as a function of temperature, on the iron line flux from a hot plasma, derived from the 90% upper limit on the thermal component. Using this constraint only, we have derived a conservative lower limit to the line intensity attributable to the quasar: the best-fit line intensity for the quasar is ~65% of the line required in the single power-law fit, with a minimum allowable intensity of 15%. The reduction in the equivalent width of the line relative to the *power-law* continuum is, of course, smaller and the minimum required is ~60 eV.

The relationship between iron line intensity and temperature, derived from the observed correlation between cluster temperature and luminosity, provides the second constraint on the cluster contribution to the iron line. In Figure 5, the dotted curves show the range of iron line intensity from a cluster, as a function of the temperature, derived from the temperature-luminosity correlation obtained during *Ginga* observations of 11 different clusters (Hatsukade 1989). The upper and lower limits are taken from the highest and lowest ratios of luminosity and temperature taken from the Hatsukade sample.

Figure 5 indicates that a significant iron line from the quasar is required for all cluster temperatures. Inspecting the figure, we see that a thermal component must have a temperature of ~3.5 keV if it is to provide a significant fraction of the observed line; if it is substantially hotter or colder its continuum emission would be detectable. Similarly it can be seen that only clusters with temperatures in excess of 6 keV are sufficiently luminous to provide a significant fraction of the observed iron line. Therefore it is impossible to explain all the observed iron line in terms of cluster emission, unless this cluster differs significantly from those so far observed by *Ginga*.

As an example, we consider the most distant cluster in the sample of Hatsukade (1989), A2218 (see also McHardy et al. 1990). This has a redshift of $z = 0.171$, a temperature of 7 keV, an X-ray luminosity $\sim 2 \times 10^{44}$ ergs s^{-1}, and an iron line of $(2.8 \pm 1.2) \times 10^{-5}$ photons cm^{-2} s^{-1}. If E1821 + 643 is embedded in such a cluster it would contribute only $(1.0 \pm 0.4) \times 10^{-5}$ photons cm^{-2} s^{-1} to a line of $(6.2 \pm 2.1) \times 10^{-5}$ photons cm^{-2} s^{-1}, and the quasar cannot be embedded in a substantially more luminous cluster without the thermal continuum being detectable.

We conclude therefore that there is significant evidence for line emission from the quasar and that its equivalent width (EW) lies in the range 60 eV $\lesssim$ EW $\lesssim$ 380 eV. The inclusion of the cluster contribution shifts the quasar iron line energy to a somewhat lower energy, making it more consistent with 6.4 keV.

3.2. *Possible Origin of the Iron Line from the Quasar*

The line emission from the Seyfert nucleus of NGC 4151 has been shown to be from cold iron. *Tenma* observaions obtained a well-defined line center energy 6.39 ± 0.07 keV (Matsuoka et al. 1986); while observations of the radio galaxy Cen A also favor cold iron (Wang et al. 1986), establishing that the iron lines from active or Seyfert galaxies can be generated by fluorescence in cold matter. Iron emission lines have also been observed with *Ginga* from several other type I Seyfert galaxies (Pounds et al. 1989; Matsuoka et al. 1990). The measured line energies are 6.4–6.7 keV and the equivalent widths range between 100 and 300 eV, consistent with the features of the iron line from E1821 + 643.

The present discovery of an iron line in the X-ray emission of E1821 + 643, taken together with the iron line observed in 3C 273 (Turner et al. 1990), suggests that cool material may be present near the cores of both radio-loud and radio-quiet quasars. The presence of a strong and variable soft excess, itself indicative of thermally radiating matter near the core (Turner & Pounds 1989), is another common feature of these two quasars.

An iron emission line can be formed by fluorescence in cold or warm material either in or out of the line of sight. We first consider a uniform spherical distribution of matter surrounding the central source: since we cannot constrain the line energy we examine the case for both cold and highly ionized matter. Previous work by Inoue (1985), for cold matter, and by Krolik & Kallman (1987), for ionized media, indicates that the iron column density of $N_{Fe} \gtrsim 4 \times 10^{18}$ cm^{-2}, corresponding to $N_H \gtrsim 10^{23}$ cm^{-2} assuming a solar abundance, is necessary to produce the observed EW $\sim$ 250 eV. The upper limit on the low-energy absorption ($N_H \sim 1 \times 10^{22}$ cm^{-2}) measured for the continuum of E1821 + 643 immediately excludes the cold spherical absorber. On the other hand, the amount of highly ionized intervening medium is measured only by the depth of the iron K edge. Table 3 gives the 90% upper limits for iron K-edges at energies corresponding to various degrees of ionization for one, three, and five parameters of interest. Only at the most conservative limit, with five parameters of interest, can the allowed column density provide the observed iron line.

A similar situation has been found for Seyfert I galaxies. The iron line intensity in NGC 4151 exceeds the maximum allowed fluorescence (Matsuoka et al. 1986), and for several Seyfert I nuclei the assumption that the observed line originates in cold material distributed isotropically around the core results in a predicted low-energy absorption which exceeds the measured value (Pounds *et al.* 1989; Matsuoka et al. 1990; Nandra, Pounds, & Stewart 1990). These results suggest that the spherically symmetric geometry of the cold or warm fluorescent medium is unlikely to be the case in E1821 + 643.

As a possible situation where fluorescence by material out of the line of sight can occur, we examine reflection from an accretion disk, exposed to the central continuum source. We note that this model has been proposed for Seyfert galaxies with a soft X-ray excess which in itself suggests the presence of an accretion disk. The strength of the line and the edge depend on the inclination of the disk, and the edge is always rather weak. The equivalent width of the iron line varies from ~ 150 eV for a face-on disk to zero for a system viewed at low inclination (George, Nandra, & Fabian 1990). This explanation works well for the iron line in the quasar 3C 273 where the equivalent width and absence of an edge is consistent with reflection from a disk with solar abundances viewed at intermediate inclination (Turner et al. 1990). For E1821 + 643 the poorly determined equivalent width 60–380 eV and the upper limit for the iron edge are also consistent with the model within the errors. Only in the extreme case, in which all the line originates from the quasar, the measured equivalent width exceeds the maximum possible intensity (EW $\sim$ 150 eV) predicted by current models. We note that both 3C 273 and E1821 + 643 do have a strong and variable soft excess, which favors the presence of an accretion disk.

In the absence of any observed variation in the iron line flux, albeit after only two observations, we cannot rule out an origin outside the central region of the quasar. It could, for example, be the result of a strong X-ray beam hitting some dense matter out of the line of sight, as has been proposed for NGC 4151 (Matsuoka et al. 1986). However, for E1821 + 643 there is no requirement to invoke a similar model, because the limits on the iron line variability are weak and the lower limit for the iron line intensity does not exceed the maximum allowed for fluorescence.

Observations of BL Lac objects and optical violent variable (OVV) quasars carried out with *Ginga* show no evidence for iron emission lines with EW > 50 eV (Ohashi 1989; Ohashi et al. 1989; Makino et al. 1989). The radio loud quasar 3C 273 revealed a significant iron emission line with EW $\sim$ 50 eV when the X-ray continuum was the lowest among all the measurements made between 1983 and 1988 (Turner et al. 1990). Although the sample is small, radio-loud or highly polarized objects have so far shown weak or no iron emission line (EW < 50–100 eV), while Seyfert I galaxies exhibit relatively strong lines (EW = 100–300 eV). If the observed continuum emission from the central source is "enhanced" due to beaming or relativistic motion toward the observer, then the weak iron line may indicate the "true" X-ray luminosity, averaged over 4π, of the central object. The radio-quiet quasar, E1821 + 643, discussed in this paper has a relatively "strong" line if the cluster contribution is small, and in such a case beaming or relativistic motion toward the observer is presumably absent. Subsequent observations of quasars with *Ginga* and with future X-ray telescopes, such as *ASTRO-D* and *JET-X*, will reveal whether "strong" iron line emission is truly associated with radio-loud quasars, and also may allow evaluation of the degree of beaming in individual systems.

Finally, we should point out that the iron line enables direct measurement of redshifts. This means that, if iron lines are indeed common to many quasars, and we have now established such a feature in both a radio-loud and a radio-quiet quasar, future X-ray surveys can identify and measure the redshifts of quasars autonomously. In this respect, the present result has revealed an important potential of future X-ray missions with very high spectral resolution.

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