DETECTION OF A TRANSIENT X-RAY ABSORPTION LINE INTRINSIC TO THE BL LACERTAE OBJECT H 2356-309

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ABSTRACT

Since the launch of the Einstein X-ray Observatory in the 1970s, a number of broad absorption features have been reported in the X-ray spectra of BL Lac objects. These features are often interpreted as arising from high-velocity outflows intrinsic to the BL Lac object, therefore providing important information about the inner environment around the central engine. However, such absorption features have not been observed more recently with high-resolution X-ray telescopes such as Chandra and XMM-Newton. In this paper, we report the detection of a transient X-ray absorption feature intrinsic to the BL Lac object H 2356-309 with the Chandra X-ray Telescope. This BL Lac object was observed during XMM-Newton cycle 7 and Chandra cycles 8 and 10, as part of our campaign to investigate X-ray absorption produced by the warm–hot intergalactic medium residing in the foreground large-scale superstructure. During one of the 80 ks Chandra cycle 10 observations, a transient absorption feature was detected at 3.3σ (or 99.9% confidence level, accounting for the number of “trials”), which we identify as the O vii Ke line produced by an absorber intrinsic to the BL Lac object. None of the other 11 observations showed this line. We constrain the ionization parameter (25 ≲ ξ ≲ 40) and temperature (10^5 K < T < 2.5 × 10^7 K) of the absorber. This absorber is likely produced by an outflow with a velocity up to 1500 km s^{-1}. There is a suggestion of possible excess emission on the long-wavelength side of the absorption line; however, the derived properties of the emission material are very different from those of the absorption material, implying it is unlikely a typical P Cygni-type profile.

Key words: BL Lacertae objects: individual (H 2356-309) – quasars: absorption lines

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1. INTRODUCTION

Blazars, characterized by their highly polarized emission in the optical band and strong variability at almost all frequencies, are often interpreted as active galactic nuclei (AGNs) with relativistic jets beamed toward us (see, e.g., Angel & Stockman 1980). BL Lac objects, which are a subclass of blazars, typically exhibit weak or no spectral features in emission or absorption at all wavelengths (e.g., Urry & Padovani 1995). In particular, the very few weak absorption features detected in the optical band are believed to originate in the interstellar medium (ISM) of the host galaxy (e.g., see Shارufatti et al. 2005; Plotkin et al. 2010) and have been used to determine the redshift of the BL Lac object. Therefore, unlike the typical warm absorbers seen in AGNs, optical absorption lines in BL Lac objects offer no information about the immediate environment of the central black holes.

However, in the X-ray band, Canizares & Kruper (1984) reported the first detection of an absorption feature in the spectrum of the BL Lac object PKS 2155-304, using the objective grating spectrometer on the Einstein Observatory. Since then a number of X-ray absorption features have been reported (see, e.g., Urry et al. 1986; Madejski et al. 1991; Grandi et al. 1997; Sambruna et al. 1997), leading to the conclusion that such X-ray absorption features are quite common in the spectra of BL Lac objects. These features were typically broad (with a width of a few tens of eV up to a few hundred eV) in the soft X-ray band and were often interpreted as resonant absorption from highly ionized oxygen originating in a high-velocity outflow (up to a few 10,000 km s^{-1}) intrinsic to the BL Lac object (e.g., Krolik et al. 1985). These discoveries demonstrate that X-ray absorption features can provide an extremely valuable probe of the central region of BL Lac objects.

Since the launch of the Chandra and XMM-Newton X-ray telescopes, a number of BL Lac objects have been observed with unprecedented high spectral resolution. However, so far no intrinsic X-ray absorption lines have been detected. Non-intrinsic X-ray absorption features have been reported in these BL Lac observations. But unlike previously detected features, when observed with high resolution these features are typically narrower (width of a few eV or less) and often attributed to the foreground Galactic (e.g., Nicastro et al. 2002; Fang et al. 2003; Rasmussen et al. 2003) or intergalactic origins (e.g., Fang et al. 2002; Nicastro et al. 2005; Buote et al. 2009, hereafter B09; Fang et al. 2010, hereafter F10). Blustin et al. (2004) and Perlman et al. (2005) examined a number of bright BL Lac objects with XMM-Newton. They did not detect any broad features and argued the previous detections were affected by poor spectral quality, calibration uncertainties, as well as the simplification of the continuum model. Although in Blustin et al. (2004) they found a few highly significant features (more than expected from statistic fluctuations), they were not able to find plausible identification of them, casting doubt on the existence of any absorption lines intrinsic to BL Lac objects.

In this paper, we report the serendipitous detection of a transient absorption feature during our multiple observations of the BL Lac object H 2356-309 with gratings on board the Chandra and XMM-Newton X-ray telescopes. The primary science goal was to study the narrow absorption features produced by the warm–hot intergalactic medium (WHIM) along the sight line toward the BL Lac object. We clearly detected an O vii absorption line produced by the WHIM in the Sculptor...
Wall, a superstructure along the sight line at \( z \approx 0.03 \) (B09; F10). During one of the exposures (observation 10498), a strong absorption feature was identified at \( \sim 22.05 \) Å. None of the other 11 Chandra and XMM-Newton observations showed this feature. In this paper, we discuss several possibilities of the origin of this transient feature and conclude it is unlikely an instrumental feature. The most likely explanation is an intrinsic, transient feature produced by hydrogen-like oxygen. We also discuss the constraints on the temperature and ionization structure.

2. DATA ANALYSIS

H 2356-309 is a BL Lac object located at \( z = 0.165 \pm 0.002 \) (Falomo 1991). Multi-wavelength observations of this target showed its broadband spectrum can be well described by the synchrotron self-Compton emission from the relativistic jet (e.g., HESS Collaboration et al. 2010). Its sight line passes through a large-scale superstructure of galaxies, the Sculptor Wall, at \( z \sim 0.03 \) (see Figure 1 of B09). With XMM-Newton it was observed in 2007 for approximately 130 ks (ObsID 0504370701; see B09). With Chandra it was observed first in 2007 during cycle 8 for 100 ks, and then again in 2008 during cycle 10 in ten separate exposures totaling 500 ks. The Chandra exposures range from \( \sim 15 \) to 100 ks (see Table 1 of F10).

Observation 10498 was performed on 2008 September 22 for 80 ks. As in B09 and F10, we followed the standard procedures to extract the spectra. We used the software package CIAO (Version 4.0)\(^3\) and calibration database CALDB (Version 3.5)\(^4\) developed by the Chandra X-ray Center. We refer readers to B09 and F10 for details of data extraction, and only want to emphasize a few issues here. First, we have generated our own type II pha file, rather than using the file produced by the standard pipeline (Reprocessing III), to take advantage of emphasizing a few issues here. First, we have generated our own type II pha file, rather than using the file produced by the standard pipeline (Reprocessing III), to take advantage of. Second, to account for the high-order contributions of the LETG-HRC, we built a combined response matrix to include the first to the sixth-order contributions (see B09 and F10 for details). Finally, we rebinned the spectrum so that we have at least 40 counts per bin to enhance the spectral signal-to-noise ratio (S/N). We fitted the continuum with a model that includes a power law and the Galactic neutral hydrogen absorption and found this simple model is adequate in describing the overall broadband spectrum. For the observation 10498, we found a power-law photon index of \( \Gamma = 1.784 \pm 0.027 \) and a 0.5–2 keV flux of \( 1.94 \times 10^{-11} \) erg cm\(^{-2}\) s\(^{-1}\) (see F10 for details). Unless otherwise noted, errors are quoted at 90% confidence level throughout the paper.

3. MODELING

3.1. Intrinsic Absorption

In Figure 1 left panel, we plot the X-ray spectrum of H 2356-309 between 1 and 40 Å for the observation 10498, in the observer’s frame. In the right panel, we show the enlarged portion between 21 and 22.5 Å. An absorption feature is prominently located at \( \sim 22.05 \) Å. In the inset, we show the stacked spectrum of the remaining nine Chandra observations and indicate the wavelength of this feature, which was not detected, with a green arrow. In this inset the absorption feature seen at \( \sim 22.3 \) Å is an \( \text{O vii} \) Kα absorption line produced by the WHIM gas in the Sculptor Wall (see B09 and F10). There is no known instrumental feature near this feature (Chandra Proposers’ Observatory Guide, or POG)\(^6\). We examined both plus and minus orders, and this feature is present in both sides with similar strength. The total exposure time of this observation is \( \sim 77 \) ks. We also checked the consistency by splitting the exposure into two 38 ks exposures, and we found this feature is consistently present in both exposures. We also checked the background spectrum and did not find any anomaly at this location that may have caused such an absorption feature.

Considering also the transient nature of this feature, we conclude that it is not instrumental in origin. With the assumption that this feature is intrinsic to H 2356-309, we examine the possible ion species based on a

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\(^3\) See http://asc.harvard.edu/ciao.

\(^4\) See http://asc.harvard.edu/caldb.

\(^5\) See http://cxc.harvard.edu/contrib/letg/GainFilter/software.html.

\(^6\) See http://cxc.harvard.edu/proposer/POG/.
Monte Carlo simulation in each trial, we made 12 mock spectra in this spectral region to mimic the 12 observations. Specifically, each mock spectrum was made with the model obtained from the real observation (see F10 for model parameters) but without any intrinsic line, i.e., we used the same power-law index, normalization, exposure time, and two absorption lines (the Galactic and the WHIM) for that observation. We then searched each mock spectrum between 21 and 22.5 Å to identify any negative feature that could give a decrease of $\Delta C$ equal or larger than $\Delta C_{\text{obs}}$. We ran a total of 40,000 trials and found for 38 trials there is at least one mock spectrum with a change in $\Delta C$ that is equal to or greater than what was observed. This indicates a detection significance of $3.3\sigma$, or 99.9% confidence level, accounting for the number of “trials.”

When evaluating the detection significance, we also fixed the Galactic and the WHIM absorption lines at the values obtained in F10. In principle, the two line parameters should be determined by a joint fit of all the 12 observations. However, such a joint fit in our Monte Carlo simulation is extremely computationally intensive, and our estimate indicated that the change in $\Delta C$ is negligible. Therefore, we decided to fix these two line parameters in our calculation.

We reiterate that the 21–22.5 Å range is the appropriate wavelength region over which to perform the random trials to assess the statistical significance of the 22.05 Å line, because it was only from examining this limited wavelength range that, by chance, we discovered this transient line while studying the Sculptor WHIM in F10. However, for illustrative purposes only, we also computed the significance of this line by performing random trials over the entire 1–40 Å range and obtained a significance of $2.5\sigma$, or 99.0% confidence. For comparison, it is worth noting that if we search the entire 1–40 Å range for other features, the strongest features we find are five candidate lines where the decrease in the C-statistic is greater than 10, with a maximum change of 15 ($\sim 1.7\sigma$). These candidates are even less significant than the 22.05 Å line, and importantly, none of them are associated with ion species (with strong oscillator strength) appropriate for the Milky Way, the blazar, or the Sculptor Wall WHIM absorber.

### 3.2. Physical Properties

Considering the redshift of the O $\text{vii}$ $K_{\alpha}$ absorption line, photoionization by the central black hole of the blazar H 2356-309 likely plays a major role in ionizing the absorber. Therefore, we have used the photoionization code CLOUDY to determine its physical condition. Calculations were performed with version 06.02 of CLOUDY, last described by Ferland et al. (1998).

In general, photoionized gas achieves thermal equilibrium by balancing heating with cooling, where the major heating source is the ionizing photons from the central black hole, and the major cooling mechanism is collisionally excited, atomic and ionic line emission. At high temperatures, heating by Compton scattering and cooling by thermal bremsstrahlung radiation and inverse Compton scattering will become important. Taking all these processes into consideration, we calculated the thermal equilibrium temperature as a function of the ionization parameter $\Xi$, using CLOUDY (see Figure 2). Following Krolik et al. (1981), this ionization parameter is defined as

$$\Xi \equiv \frac{L}{4\pi R^2 n_H c k T}.$$  \hspace{1cm} (1)

where $L$ is the luminosity of ionizing photons, $R$ is the distance of the absorber to the central source, $n_H$ is the gas density, $k$
is the Boltzmann constant, and \( T \) is the gas temperature.\(^7\) For simplicity, we adopted a power-law spectrum with a photon index of \( \Gamma = 1.784 \), obtained from our Chandra spectrum, and also solar metallicity. We will discuss the impact of these choices later.

In Figure 2, cooling dominates over heating above the thermal equilibrium curve, and heating exceeds cooling below the curve. Along the equilibrium curve, the gas is thermally stable in the green parts, and unstable in the red parts where the gradient becomes negative. The stable states include one "cold" (\( T \leq 10^5 \) K), one "hot" (\( T > 10^7 \) K), and one intermediate state (\( T \approx 10^6 \) K).

We calculate the ionization fraction of both O\( \text{vii} \) and O\( \text{viii} \). The top panel of Figure 3 shows the ionization fraction of O\( \text{vii} \) (black line) and O\( \text{viii} \) (red line) as a function of the ionization parameter \( \Xi \), and the bottom panel of Figure 3 shows the ionization fraction as a function of temperature. We do not detect the intrinsic O\( \text{vii} \) K\( \alpha \) line, and estimate a 3\( \sigma \) upper limit of the line EW of 24 mÅ. This puts a tight lower limit of \( \Xi \gtrsim 25 \), and \( T \gtrsim 10^5 \) K. On the other hand, the derived O\( \text{viii} \) column density is about a few \( \times 10^{17} \) cm\(^{-2} \). It is therefore highly unlikely that the ionization fraction of O\( \text{viii} \) is much smaller than \( 10^{-4} \) as this would imply a hydrogen column density much higher than \( 10^{24} \) cm\(^{-2} \) even for solar abundance. This puts a tight constraint on the upper limit of \( \Xi \lesssim 40 \), and \( T \lesssim 2.5 \times 10^7 \) K. Figure 2 shows this allowed region in gray.

The exact shape of the thermal equilibrium curve depends on assumptions such as the photon index of the incident spectrum and the metal abundance (see, e.g., Reynolds & Fabian 1995). A steeper spectrum (e.g., \( \Gamma > 3 \)) will lower the Compton temperature at which Compton heating and cooling balance each other, therefore lowering the temperature of the "hot" stable state in Figure 2. On the other hand, a change in the metal abundance will also result in a change in the peak positions of the thermal equilibrium curve because of the metal line cooling mechanism. However, our estimates indicate unless these assumptions change dramatically, they do not have significant impact on the estimated parameters (ionization parameter, temperature, ionization fractions, etc.) here.

### 3.3. Transient Nature of the Absorber

The observation 10497 was taken immediately before this observation and ended on 2008 September 20 at about 10 a.m., and the observation 10762 was taken immediately after this observation and started on 2008 September 25 at about 2 a.m. This suggests the transient feature lasts at most \( t_{\text{max}} \approx 4 \times 10^5 \) s, and at least \( t_{\text{min}} = 8 \times 10^4 \) s.

Line variability is fairly common in the soft X-ray spectrum of AGNs. In particular, recent observations of AGNs with high-resolution spectroscopy indicate narrow absorption lines can appear and vanish in timescales less than a few 100 ks (e.g., Gibson et al. 2007). There are two likely scenarios that an absorption line can become transient: (1) the ionization structure of the absorber changes (see, e.g., Halpern 1984) or (2) the absorbing material changes, e.g., moving in and out of the sight line (see, e.g., Fabian et al. 1994). We consider both scenarios in the following discussion.

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\(^7\) The other commonly used definition of the ionization parameter is \( \xi \equiv (L_{\text{ion}} / n_\text{H} R^2) \). The conversion between this two definitions (in c.g.s unit) is \( (\xi / \Xi) \approx 52 T_b \), where \( T_b \) is temperature in units of 10\(^6\) K.
To change the physical state of the absorber during such a short period, either the ionizing source varies rapidly, or the absorber is in a physically unstable state. The source flux is extremely stable during our 500 ks Chandra observations that span about four months (it varied at most about 30%; see F10). Furthermore, one Chandra and one XMM-Newton observation performed about one year before these Chandra observations showed variations about a factor of less than two (B09). Hence, the source variation is unlikely to be the cause of this transient feature.

Considering the possibility that the absorber becomes thermally unstable (the red parts in Figure 2), this intrinsic instability can lead to the transient nature of the absorber. In this case, the ionization structure can change rapidly if the photonization timescale is longer than the time interval $t_{\text{min}}$. This photonization timescale can be estimated as

$$t_{\text{ion}} = \left[ \int \frac{L_v \sigma(v)}{4 \pi R^2 h v} dv \right]^{-1}. \tag{2}$$

Here, $L_v \propto v^{-\alpha}$ where $\alpha = \Gamma - 1$ is the spectral index) is the ionizing photon flux, $\sigma$ is the photonization cross section and $\propto (v_{th}/v)^3$, $v_{th}$ is the photonization threshold frequency, and $h$ is the Planck constant. Adopting the numbers for O viii (Verner et al. 1996), we found $t_{\text{ion}} \approx 2 \times 10^5 R_{\text{pc}}^{-1} L_{46}^{-1}$ s. Here, $R_{\text{pc}}$ is the distance to the absorber in units of pc, and $L_{46}$ is the ionizing luminosity in units of $10^{46}$ erg s$^{-1}$. For H 2356-309, $L_{46}$ is the luminosity of the ionizing photons, is $\sim 5 \times 10^{45}$ erg s$^{-1}$. If $t_{\text{ion}} > t_{\text{min}}$, we found the distance of the absorber must be $R \gtrsim 3$ pc. This distance would put the absorbing material somewhere between the typical broad-line region (BLR, sub-pc) and narrow-line region (NLR, 10 pc to 1 kpc) of an AGN.

The density of the absorber then is

$$n_{\text{H}} \approx 7 \times 10^5 R_{\text{pc}}^{-2} T_{6}^{-1} \Xi_{30}^{-1} L_{46} \text{ cm}^{-3}. \tag{3}$$

where $T_{6}$ is the temperature in units of $10^6$ K, and $\Xi_{30}$ is the ionization parameter in units of 30. Taking the typical values for H 2356-309, the density is $n_{\text{H}} \approx 4 \times 10^5$ cm$^{-3}$. With this density, the typical recombination timescale, $t_{\text{rec}} \approx 4 \times 10^6 T_{6}^{-1/2} (n_{\text{H}}/10^5 \text{ cm}^{-3})^{-1} \approx 10^7$ s, is also longer than $t_{\text{min}}$.

If instead the absorber is stable but moves in and out of the sight line between observations, then all the timescales must be shorter than $t_{\text{max}}$. The absorber then has an upper limit on the distance of $R \lesssim 6$ pc (from $t_{\text{ion}} < t_{\text{max}}$), and a lower limit on the density of $n_{\text{H}} \gtrsim 10^6$ cm$^{-3}$ (from $t_{\text{free}} < t_{\text{max}}$).

The P Cygni-type of line profile was originally discovered in 1905 K $\alpha$ and can be associated with the absorber, we measured an O viii line flux of $5 \times 10^{-5}$ photons cm$^{-2}$ s$^{-1}$. The O viii line emissivity peaks at about $3 \times 10^6$ K. Assuming a peak emissivity, we obtained an upper limit of the emission measure of $EM = \int n_e^2 dV \approx 5 \times 10^{10}$ cm$^{-6}$ pc$^3$ at the distance of the BL Lac. Here, $n_e$ is the electron density and the integration is over the emission volume. However, we consider the P Cygni scenario unlikely since if the $n_e \sim 10^6$ cm$^{-3}$, as we estimated for the absorber, the linear size of the emission material ($\sim 0.4$ pc) would be far greater than that of the absorber. Clearly, more sophisticated modeling is necessary to fully understand the structure and physical properties of this material as revealed by the emission/absorption profile.

4.2. Host Galaxy, Intervening or Local Absorption?

The transient nature of this absorption feature makes it very unlikely to be produced by the ISM in the host galaxy, an intervening absorber, or a local absorber. We do notice that the observed wavelength of this feature is very close to the rest wavelength of the O vi K $\alpha$ inner shell transition ($\lambda = 22.02$ Å, see Pradhan et al. 2003; Schmidt et al. 2004). This O vi $K\alpha$ inner shell transition was first reported in Lee et al. (2001) in the X-ray spectrum of MCG-6-30-15.

4.3. Summary

X-ray observations of narrow absorption features offer a unique opportunity to probe the inner region of BL Lac objects. In this paper, we report the detection of a transient absorption line during our H 2356-309 campaign with the Chandra X-ray Telescope. This line is most likely produced by O viii in a
Figure 4. Spectral fitting with a P Cygni-type profile, which includes one absorption-line model on the short-wavelength side and one emission line on the long-wavelength side. The wavelength is plotted in the observer’s frame.

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REFERENCES

Angel, J. R. P., & Stockman, H. S. 1980, ARA&A, 18, 321
Blustin, A. J., Page, M. J., & Branduardi-Raymont, G. 2004, A&A, 417, 61
Brandt, W. N., & Schulz, N. S. 2000, ApJ, 544, L123
Buote, D. A., Zappacosta, L., Fang, T., Humphrey, P. J., Gastaldello, F., & Tagliaferri, G. 2009, ApJ, 695, 1351
Canizares, C. R., & Kroper, J. 1984, ApJ, 278, L99
Cash, W. 1979, ApJ, 228, 939
Crenshaw, D. M., Kraemer, S. B., & George, I. M. 2003, ARA&A, 41, 117
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Fabian, A. C., et al. 1994, PASJ, 46, L59
Falomo, R. 1991, AJ, 101, 821
Fang, T., Buote, D. A., Humphrey, P. J., Canizares, C. R., Zappacosta, L., Maiolino, R., Tagliaferri, G., & Gastaldello, F. 2010, ApJ, 714, 1715
Fang, T., Marshall, H. L., Lee, J. C., Davis, D. S., & Canizares, C. R. 2002, ApJ, 572, L127
Fang, T., Sembach, K. R., & Canizares, C. R. 2003, ApJ, 586, L49
Feinberg, G. J., Korista, K. T., Verner, D. A., Ferguson, J. W., Kingdon, J. B., & Verner, E. M. 1998, PASP, 110, 761
Gibson, R. R., Canizares, C. R., Marshall, H. L., Young, A. J., & Lee, J. C. 2007, ApJ, 655, 749
Grindlay, J. E., Stockton, A., & Stockman, H. S. 1980, ARA&A, 18, 321
Helfand, J. P. 1984, ApJ, 281, B9
H.E.S.S. Collaboration, et al. 2010, A&A, 516, A56
Humphrey, P. J., Liu, W., & Buote, D. A. 2009, ApJ, 693, 822
Kaspi, S., et al. 2001, ApJ, 554, 216
Krolik, J. H., Kallman, T. R., Fabian, A. C., & Reeves, M. J. 1985, ApJ, 295, 104
Krolik, J. H., McKee, C. F., & Tarter, C. B. 1981, ApJ, 249, 422

photionized outflow intrinsic to the BL Lac object H 2356-309. Considering the transient nature of the absorber, we obtain constraints on the absorber’s ionization parameter, \[ 25 \lesssim \Xi \lesssim 40 \], temperature, \[ 10^5 \text{ K} < T < 2.5 \times 10^7 \text{ K} \], and density, a few \[ \times 10^5 \text{ cm}^{-3} \].

Our detection is quite different from X-ray absorption features detected in BL Lac objects before Chandra and XMM-Newton (e.g., Canizares & Kroper 1984; Madejski et al. 1991). Those absorption features typically have a velocity width of up to a few \[ \times 10^4 \text{ km s}^{-1} \], while in H 2356-309 the velocity is at most \[ 1–2 \times 10^3 \text{ km s}^{-1} \]. However, even in our case, the line width is much larger than that expected from thermal broadening, suggesting an outflow as a likely cause of the broadening.

Blustin et al. (2004) studied the XMM-Newton Reflection Grating Spectrometer spectra of four BL Lac objects with previously known, broad X-ray absorption lines and found none. Perlman et al. (2005) also analyzed the X-ray spectra of 13 bright BL Lac objects observed with XMM-Newton. They did not detect any broad, intrinsic features either, but they found strong evidence for the intrinsic curvature of the spectral index of most of the targets. In both studies, they concluded that the previously reported features were due to a combination of calibration uncertainties and the use of an overly simplified, single power-law model. At low resolution and low S/N, a spectral curvature can mimic a broad absorption if the spectrum was fitted with a single power law (Perlman et al. 2005). However, our observation, which has none of these problems, along with their detections of several unexplainable absorption features detected in Blustin et al. (2004), raise again the question of whether or not such absorption is common in BL Lac objects. The high variability of the BL Lac object and its environment make it a challenge to address this issue. We detect this line in one (~80 ks) observation for a total of 12 (~600 ks for Chandra, and ~130 ks for XMM-Newton) observations. Taking this probability at face value, a long-term, monitoring program which focuses on several bright BL Lac objects would be a feasible approach to unveil the nature of these transient absorption lines.
