PHYSICAL PROPERTIES OF THE X-RAY ABSORBER IN APM 08279+5255 AND THE SEARCH FOR SPECTRAL VARIABILITY

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ABSTRACT

BALQ X-ray absorption features provide an important opportunity to study powerful gas outflows from quasars. Recently, Chartas et al. (2002) and Hasinger, Schartel & Komossa (2002) have reported the detections of a deep X-ray absorption trough at a centroid of $E = 1.67$ keV (corresponding to a rest-frame energy of $E = 8.1$ keV) in both the *Chandra* and *XMM-Newton* observations of BALQ APM 08279+5255 at a redshift $z = 3.91$. Our analysis of both the *Chandra* and *XMM-Newton* spectra of APM 08279+5255 is consistent with a model in which either Fe XXVI or Fe XXV outflowing with relativistic velocities which range from 0.15 c to 0.19 c, in agreement with the conclusions of Chartas et al. (2002). The presence of a highly ionized iron implies the existence of other ions, including Ni XXVI, Ni XXVII, Ni XXVIII, Ca XX and Ar XVIII that also absorb in the observed X-ray band pass, and thus suggests a high mass-loss rate which can be used to estimate the launch radius of X-ray BAL gas. Our best-fit model yields a total iron column density of $\sim 10^{18}\ cm^{-2}$. Over a period of 18 months covered by these observations, the data do not exhibit significant variability in the structure of the absorption troughs, which suggests that the jets are launched from relatively large radius.

Key words: BALQ; APM 08279+5255; Absorption lines; Outflows; X-rays.

INTRODUCTION

Broad absorption lines are observed in approximately 20% of radio-quiet quasars (Hewett & Foltz, 2003; Reichard et al., 2003). These are interpreted as signs of large mass outflow with speeds $\sim 0.03c$ from the accretion disks orbiting massive black holes. As such, they provide insight into the fueling mechanisms in quasars and its interaction with the host galaxy, e.g. (Scannapieco & Oh, 2004; Springl et al., 2005; Pounds et al., 2003; Reeves et al., 2003).

Recently, broad X-ray absorption features have been seen with velocities of $\sim 0.2c$, suggesting that these outflows may be even more powerful than estimated from optical observations and may provide active feedback to the surrounding gas e.g. (Chartas et al., 2002; Reeves et al., 2003; Pounds et al., 2003). As both the velocities and the level of ionization is higher, the X-ray absorbing gas is expected to originate from smaller radii than UV-absorbing gas. Detailed study of this gas may therefore be quite prescriptive concerning the outflow acceleration mechanism. These outflows are generally believed to be accelerated through resonance scattering of UV continuum photons by highly ionized ions e.g. (Arav & Li, 1994; Murray et al., 1995; Proga et al., 2000; Chelouche & Netzer, 2001). Many of these models predict the BAL clouds to be launched near the supermassive black hole at $r_{\rm launch} \approx 10^{16}$ cm (Murray et al., 1995). However, one problem with this model is that the outflows might be expected to vary on timescales of order the orbital period at the launch radius, $\sim 0.1(M_{\rm hole}/10^8 {\rm M}_{\odot})^{-1/2}(R/100AU)^{3/2}(1+z)$ yr. Such variations appear to be rare in optical observations (Weymann, 1997). There is therefore considerable interest in the variability of the X-ray lines.

We have independently analyzed data of APM 08279+5255 from the *Chandra* observations on 2000 October 11 and 2002 February 24 (Chartas et al., 2002) and those by *XMM-Newton* on 2001 October 30 and 2002 April 28-29 (Hasinger et al., 2002), and have searched for spectral variability of the X-ray BALs in APM 08279+5255 among these epochs. We chose this source because it has a large gravitational lensing magnification of 100 and high redshift of $z = 3.91$, which makes it a unique object with high signal-to-noise X-ray spectra. Chartas et al. (2002) modeled the *Chandra* data of APM 08279+5255 using gaussian absorption lines and interpreted it as due to a blueshifted absorption line from either Fe XXV K α or Fe XXVI K α , which requires a presence of a relativistic outflow. On the other hand, Hasinger et al. (2002) interpreted this feature as an absorption edge from Fe XV - Fe XVIII with zero bulk velocity in the quasar's frame.

SPECTRAL ANALYSIS

We studied both the *Chandra* and *XMM-Newton* spectra using spectral/atomic models, which contain line and continuum absorption that are computed with the Flexible Atomic Code (Gu, 2003) in the low-density limit. The detection of a deep resolved discrete feature at a centroid of $E = 1.67$ keV (corresponding to a rest-frame energy of $E = 8.1$ keV) in APM 08279+5255 is statistically significant and strongly suggests the presence of highly ionized iron (Fe XXVI and/or Fe XXV). To model the spectra, we assumed a uniform absorber with ionization parameter in the range $\log \xi \sim 3 - 5$. Other ions are likely to be present, such as Ni XXVIII, Ni XXVII, Ni XXVI, Ca XX, Ar XVIII and contribute to the total absorption. In addition, we included cold local and Galactic absorption components and a single power-law continuum. During the fitting, the intrinsic absorption column density, the normalization and the slope of the power-law component, the column densities of ions, the turbulent velocity and the outflow velocity of the absorber were allowed to vary and the bulk velocities of the individual ions were assumed to be identical to each other.

This model provides a reasonable fit to the data from both *Chandra* and *XMM-Newton* . The results reveal a detection of $1 \sim 2 \times 10^{18}$ cm^{-2} of either Fe XXVI or Fe XXV and other elements with column densities that are an order of magnitude or more lower, which are more or less consistent with solar abundances. The outflow velocities are estimated to be either 0.15 c or 0.18 c for *Chandra* and 0.17 c or 0.19 c for *XMM-Newton* observations, in agreement with Chartas et al. (2002). The ambiguity in the redshift is a result of whether the single absorption trough is interpreted as either Fe XXV or Fe XXVI. Contributions from other lines, like Ni XXVII and Ni XXVIII, are expected as well, as predicted for example by Monte Carlo radiative transfer calculations of Sim (2005). The relative strength of the iron feature to the other lines can be used to constrain both the mass-loss rate and opening angle of the outflow. Based on the computed spectra by Sim (2005), the appearance of Ar XVIII and Ca XX in the hard X-ray band suggests a mass-loss rate near or higher than $6 M_{\odot}/yr$. Adopting the best-fit hydrogen column density of $N_H \sim 5 \times 10^{22}$ cm^{-2}, a global covering factor of 0.2, a outflow velocity of 0.2 c and the ratio of the distance to the absorber thickness $R/\Delta R \sim 1$ (Chartas et al., 2002), the launch radius of the X-ray BAL gas would be larger than 3×10^{17} cm, which corresponds to a variability time scale of roughly four months in the source frame. We have searched for spectral variability in observations of APM 08279+5255 separated by $2 - 18$ months, which correspond to timescales of a few weeks to three months in the quasar's rest frame. All of the data are consistent with the same spectral model suggesting that the the variability is not significant over timescales of ~ 3 months in the quasar's rest frame.

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