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X-ray physical properties of the quasar APM 08279+5255

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Abstract. We have re-analyzed the X-ray spectra of the *gravitational lensed* high-redshift BAL QSO APM 08279+5255, observed with the *XMM-Newton* and *Chandra* observatories. Previous studies (Hasinger et al. 2002; Chartas et al. 2002) detected unusual, highly-ionized iron absorption features, but differed in their interpretation of these features, regarding the kinematical and ionization structure. For the first time we have performed detailed photoionization modeling on the X-ray spectrum of APM 08279+5255.The absorbing gas in APM 08279+5255 can be represented by a two-absorbers model with column densities $N_H(1) \approx 7 \times 10^{22}$ cm^{-2}, $N_H(2) \approx 6 \times 10^{22}$ cm^{-2}, and ionization parameters $\log \xi(1) \approx 1.5$ and $\log \xi(2) \approx 3$, with the high-ionization component outflowing at $v \approx 0.18(\pm 0.01)c$, carrying large amount of gas out of the system.

Key words. galaxies: active – X-rays: galaxies – quasars: absorption lines – quasars: individual (APM 08279+5255)

1. Introduction

Broad absorption line (BAL) quasi-stellar objects (QSOs) are objects displaying in their spectra broad (FWHM $\approx$ 10 000 km s^{-1}) absorption lines in the rest-frame ultraviolet (UV), originated in outflows of matter from the central engine of QSOs (Foltz et al. 1990; Weymann et al. 1991). The outflow velocity may reach up to 0.2c (e.g., Foltz et al. 1983). Determining the relationship between the material absorbing the X-rays and the one absorbing the UV radiation is key to our understanding of the geometry and the physical state of the medium surrounding the vicinity of supermassive black holes (e.g., Mathur et al. 1995; Murray et al. 1995; Hamann 1998; Proga et al. 2000).

The quasar APM 08279+5255 was observed twice with *XMM-Newton* (Hasinger et al. 2002, hereafter H02). In both observations the quasar is observed clearly out to 12 keV, which corresponds to almost 60 keV in the rest frame. The most apparent feature in the *XMM-Newton* spectrum is an absorption-like feature around 1.55 keV (which they interpret as an absorption edge), corresponding to $\sim$ 7.7 keV in the rest frame of APM 08279+5255. The high-inferred iron abundance at the high redshift, corresponding to a young age of the universe, is of great interest in the context of chemical enrichment models, and provides constraints on the early star formation history of the universe and on its cosmological parameters (e.g., Hamann & Ferland 1993; Hasinger et al. 2002; Komossa & Hasinger 2003).

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APM 08279+5255 was also observed with *Chandra* (Chartas et al. 2002, hereafter C02). The *Chandra* spectrum shows a similar absorption feature as the *XMM-Newton* observation, but the feature led to a different interpretation. In particular, C02 modeled the spectrum with two absorption lines at 8.1 keV and 9.8 keV in the rest frame of the quasar, interpreted as Fe xxv K lines. If the *Chandra* interpretation of the data is right, the *bulk* velocity of the X-ray BALs is $\sim$ 0.2c – 0.4c. The presence of similar outflow velocities has been claimed in a few other AGN X-ray spectra (e.g., Pounds et al. 2003; Chartas et al. 2003; Pounds & Page 2006), but alternative interpretations of the same spectra have been proposed, which do not require these relativistic outflow velocities (e.g., Kaspi & Behar 2006).

However, none of the previous studies include a self-consistent photoionization modeling of the X-ray spectrum of APM 08279+5255. Any constraint on the ionization level of the absorbing gas and its connection with the kinematical properties of the BAL outflow is of major interest to elucidate some of the greatest discrepancies between these two proposed models. Furthermore, a model that can separate the differences between observations (*XMM-Newton vs Chandra*), or unify both in a single frame, is highly desirable. We report a spectral analysis (made of these two observations separated by $\sim$ 2 weeks in the rest frame) of the high-redshifted BAL QSO APM 08279+5255, and present one model that might reconcile both observations in the same physical context, shedding new light on the ionization degree, kinematics and evolution of this system.

2. Photoionization modeling

We performed a photoionization modeling of the X-ray spectrum of APM 08279+5255, using the code XSTAR with the atomic data of Bautista & Kallman (2001).

2.1. Single-Absorber photoionization model

We apply the same photoionization model to both sets of data, the *XMM-Newton* and *Chandra* X-ray observation of APM 08279+5255. The best-fit column density is $(1.14^{+0.07}_{-0.06}) \times 10^{23}$ cm^{-2} ($[1.32^{+0.14}_{-0.10}] \times 10^{23}$ cm^{-2}) with $\log(\xi) = 1.50^{+0.06}_{-0.05}$ ($\log[\xi] = 1.50^{+0.08}_{-0.07}$), for the *XMM-Newton* (*Chandra*) data. These global fits are statistically unacceptable Also, we explored the possibility that the gas absorbing X-rays in APM 08279+5255 is outflowing at intermediate-to-relativistic velocities. For that purpose we have shifted the spectra, produced with our XSTAR-based ionization models, by an array of velocities, from 0.08c to 0.30c, with 0.01c of resolution, and fit in several ways the X-ray spectrum of APM 08279+5255, using the *XMM-Newton* and *Chandra* data. [1] The `single-absorber` model cannot be ruled out (instantaneously), but it does not give a consistent fit to both sets of data (Model B for *XMM-Newton* and Model D for *Chandra*). Therefore, we explore the possibility of a multi-component photoionization model. In Figs. 1 and 2, we plot the residuals between each model presented here and the data. The dashed lines are residuals from a `two-absorbers` model, which we discuss in the next section.

2.2. Two-Absorbers photoionization model

Now that we have explored how the `single-absorber` model fits the data, we can go further, and see if the data supports a multicomponent photoionization model. The simplest such model is a two-photoionized-absorbers model, and we investigate if the addition of an extra component to the best-fit

[1] We made the analysis of best-fit velocity by inspecting the evaluation of χ^2 at every outflow velocity point of our grid of velocities, while the other parameters of interest are varied as usual. Then, we proceed to adopt the velocity-model with the minimum χ^2.

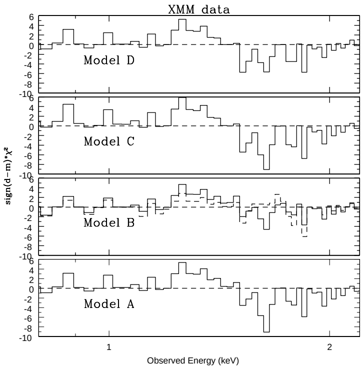

Fig. 1. Residuals (in sign(data-model)χ^2) of our photoionization models A,B,C and D to the *XMM-Newton* data, in the band $(1-2)$ keV observed frame. Dashed line is the residual of the `two-absorbers` model. See text.

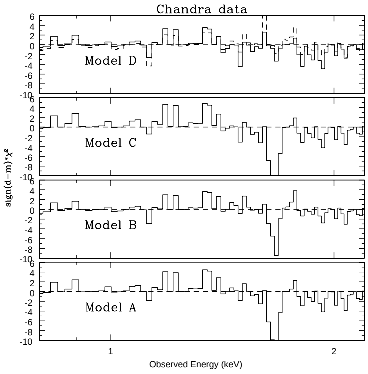

Fig. 2. Residuals (in sign(data-model)χ^2) of our photoionization models A,B,C and D to the *Chandra* data, in the band $(1-2)$ keV observed frame. Dashed line is the residual of the `two-absorbers` model. See text.

`single-absorber` model is statistically significant. This `two-absorbers` model consists of: one component at $v = 0$ km s^{-1} (rest-velocity component), and one at $v = 0.18c$ (high-velocity component) [2]. We take the best `single-absorber` model, selected as the best combination between

[2] This is the best high-velocity component we found able to fit both sets of data with high χ^2−probability.

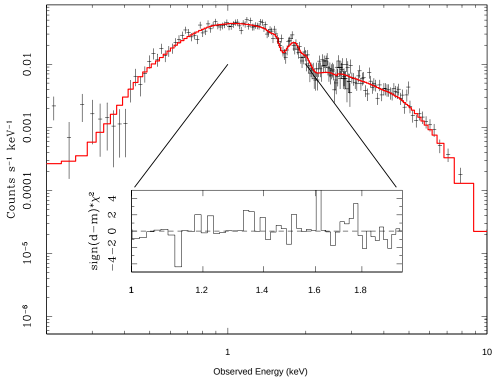

Fig. 3. *Chandra* X-ray spectrum of APM 08279+5255 in the $0.2-10$ keV (observed frame) band.The solid thick line is the best-fit `two-absorbers` model. The inside plot shows the residual (in sign(data-model)χ^2) for the $1-2$ keV band. This model gives good agreement on both sets of data.

global and local P_{ν,χ^2}. Model B is the best for *XMM-Newton* data and Model D is the best for the *Chandra* set. The addition of an extra component (high-velocity component for *XMM-Newton* and rest-velocity component for *Chandra*) significantly improves the fit compared to the `single-absorber` model at the greater than 99.9% confidence level in both cases (according to the F-test), both globally and locally.

First, we fit a `two-absorbers` model to each set of data separately and then we do it simultaneously, to check for inconsistencies between fits. Figures 3 and 4 present plots of the best-fit `two-absorbers` model over the *Chandra* and *XMM-Newton* data, respectively. The fits between data sets give different best-fit parameters at $\gtrsim 1\sigma$, for six out of the seven fitted parameters ($\log\xi[2]$ is fully consistent). The `two-absorbers` model gives acceptable fits with high χ^2−probability for both sets of data, but there exist small differences between best-fit parameters.

If we fit both data sets simultaneously, we find reasonable consistency between them and the separated fits. The most notable discrepancy is seen in the power-law component, with differences of $\sim$ $10-15\%$ in its parame-

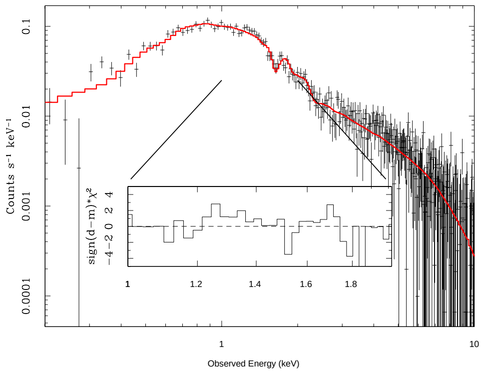

Fig. 4. *XMM-Newton* X-ray spectrum of APM 08279+5255 in the 0.2 – 10 keV (observed frame) band.The solid thick line is the best-fit `two-absorbers` model. The inside plot shows the residual (in sign(data-model)χ^2) for the 1 – 2 keV band. This model gives good agreement on both sets of data.

ter values. However, the errors on the parameters allow us to obtain high χ^2–probability if, apart from the power-law, both observations are fitted with the same physical two absorbers, opening the possibility that *both absorbers have been there in both observations*.

3. Conclusions

To summarize, the absorbing gas in APM 08279+5255 can be represented by a `two-absorbers` model with column densities $N_H(1) \approx 7 \times 10^{22}$ cm^{-2}, $N_H(2) \approx 6 \times 10^{22}$ cm^{-2}, ionization parameters $\log \xi(1) \approx 1.5$ and $\log \xi(2) \approx 3$, with one of them (the HV component) outflowing at $v \approx 0.18(\pm 0.01)c$, carrying large amount of gas out of the system. The feature at $\sim$ 8 keV (rest-frame) is fully predicted and reproduced by our photoionization model, to be a complex of Fe lines coming from high state of ionization, in which the main contributor is the Fe xxv λ1.85 Å, improving the characterization of the kinematics and the quantitative evolution analysis of this high z quasar. We confirm evidence for an overabundance of Fe/O, from the *XMM-Newton* observation of this quasar (previously inferred and discussed in Hasinger et al. 2002; Komossa & Hasinger 2003, based on calcutations of Hamann & Ferland 1993). The analysis is made for the first time on the *Chandra* observation of APM 08279+5255, implying that both absorbers require Fe/O supersolar, placing similar constraints on models as before, and additionally shows that both independent absorbers have a similar chemical history.

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