ABSTRACT

Quasar J152645.61+193006.7 ($z_c = 2.5771$) was observed by the Sloan Digital Sky Survey (SDSS) on 2006 May 31 and again on 2011 April 9. The time interval of the SDSS two observations is 497.4 days at the quasar rest frame. From the spectra of this quasar, we detect a phenomenon of the disappearance of a narrow Mg II $\lambda\lambda2796, 2803$ absorption system with a velocity of up to 166,129 km s$^{-1}$ with respect to the quasar. This disappearance event can be caused by changes in the ionization state of absorbing gas or by the bulk motion of the absorbing gas across the quasar sightline. The coverage fraction analysis shows that this absorber partially covers the background emission sources with an effective coverage fraction of $C_T = 0.40 \pm 0.06$. The time variation analysis and the coverage fraction analysis imply that this absorber might be intrinsic to the quasar. However, the scenario of a cosmologically separated foreground object located at $z = 0.9170$ accounting for the phenomenon cannot be ruled out, according to current available data.

Key words: galaxies: active -- quasars: absorption lines -- quasars: individual (J152645.61+193006.7)

Online-only material: color figures

1. INTRODUCTION

The outflow of a quasar is often believed to be the gas blown away from the accretion disk. Later, the gas can be accelerated by the radiation pressure (Castor et al. 1975; Proga et al. 1998; Dorodnitsyn & Novikov 2005 and references therein), the magnetic force (Contopoulos & Lovelace 1994; Li 1996; Kudoh & Shibata 1997a, 1997b; Lery et al. 1998, 1999; Proga 2007 and references therein), and the thermal driving (Bagel et al. 1983; Kallman 2005; Proga 2007; Owen et al. 2012 and references therein). If the gas is heated to a high temperature reaching up to the Compton temperature, the thermal driving would be effective enough to produce a thermal wind (e.g., Proga & Kallman 2002; Chelouche & Netzer 2005). The thermal driving might be less important if the temperature of gas is well below the Compton temperature (Proga 2007).

The outflow was detected most conspicuously via blueshifted absorption lines. These lines can be split into three categories based on line widths: broad absorption lines (BALs), with typical line widths broader than 2000 km s$^{-1}$ at depths >10% below the continuum (Weymann et al. 1991); narrow absorption lines (NALs), with absorption troughs narrower than a few hundred km s$^{-1}$; and intermediate mini-broad absorption lines (mini-BALs), with line widths lying between those of BALs and NALs. They can appear at a very wide range of speeds from 10$^2$ km s$^{-1}$ to 10$^5$ km s$^{-1}$ in multiband spectra (e.g., X-ray, UV and optical spectra; Misawa et al. 2003; Wise et al. 2004; Hamann et al. 2011). Among these methods, time variation analysis and coverage fraction analysis are the most effective and most frequently utilized (Ganguly et al. 1999; Misawa et al. 2003; Wise et al. 2004; Hamann et al. 2011).

Variations of intrinsic absorption lines seem to be common, but extreme cases such as the disappearance and emergence of absorption lines from the spectra are rare. So far, only a small number of disappearance (e.g., Hall et al. 2011; Filiz Akgil et al. 2012; Capellupo et al. 2011, 2012, 2013; Chen et al. 2013a) and emergence (Ma 2002; Hamann et al. 2008; Leighly et al. 2009; Krongold et al. 2010; Rodríguez Hidalgo et al. 2011; Vivek et al. 2012; Chen et al. 2013b) cases have been reported. Such variations, in principle, can be caused by changes in the ionization state of absorbing gas and the coverage fraction of the absorber to the background emission sources. The change in coverage fraction could be driven via the motions of absorbing gas (e.g., Proga & Kallman 2002; Leighly et al. 2009; Krongold et al. 2010; Rodríguez Hidalgo et al. 2011; Vivek et al. 2012; Chen et al. 2013b) cases have been reported. Such variations, in principle, can be caused by changes in the ionization state of absorbing gas and the coverage fraction of the absorber to the background emission sources. The change in coverage fraction could be driven via the motions of absorbing gas (e.g., Proga & Kallman 2002; Leighly et al. 2009; Krongold et al. 2013a). The change in ionization state of absorbing gas could arise from the variations of background emissions (e.g., Hamann et al. 2011).

Absorption lines with very high ionization states (such as Fe xxv) can arise from the outflow with a speed up to 10$^3$ km s$^{-1}$ (e.g., Tombesi et al. 2011), while lines with lower ionization states (such as C iv $\lambda\lambda1548, 1551$) in the outflow can be
Chen et al. (2013a) first reported the disappearance of a narrow Mg $\text{ii}$ absorption system with a speed of 8423 km $s^{-1}$ without blending with the Ly$\alpha$ forest. (Misawa et al. 2007). Chen et al. (2013a) searched effectively at a velocity of up to $\sim 70,000$ km s$^{-1}$ without blending with the Ly$\alpha$ forest. (Misawa et al. 2007). The blue solid lines represent the power-law continuum fittings. The red solid lines represent the pseudo-continua and the green solid line in the lower panel is the pseudo-continuum shown in the upper panel. (A color version of this figure is available in the online journal.)

searched effectively at a velocity of up to $\sim 70,000$ km s$^{-1}$ without blending with the Ly$\alpha$ forest. (Misawa et al. 2007).

Figure 1. Spectra of quasar J152645.61+193006.7 with $z_e = 2.5771$, observed by SDSS-I/II (the lower panel) and SDSS-III (the upper panel), respectively. The blue solid lines represent the power-law continuum fittings. The red solid lines represent the pseudo-continua and the green solid line in the lower panel is the pseudo-continuum shown in the upper panel. (A color version of this figure is available in the online journal.)

search narrow Mg $\text{ii}$, 2803 absorption doublets in the pseudo-continuum normalized spectrum. The rest-frame equivalent widths ($W_i$) of the detected absorption lines are measured from Gaussian fittings. The corresponding uncertainties are estimated via

$$\sigma_w = \sqrt{\frac{\sum_i P^2(\lambda_i - \lambda_0)\sigma_{fi}^2}{\sum_i P^2(\lambda_i - \lambda_0)\Delta\lambda}},$$

where $P(\lambda_i - \lambda_0)$ is the line profile centered at $\lambda_0$, $\lambda_i$ is the wavelength, and $\sigma_{fi}$ is the normalized flux uncertainty as a function of pixel (Nestor et al. 2005; Chen et al. 2013a). The sum is performed over an integer number of pixels that covers at least $\pm 3$ characteristic Gaussian widths.

We note a single phenomenon of disappearance of narrow Mg $\text{ii}$ absorption doublets with velocities up to $10^3$ km s$^{-1}$. For quasar SDSS J152645.61+193006.7 ($z_e = 2.5771$, taken from Hewett & Wild 2010), we observe that a narrow Mg $\text{ii}$, 2803 absorption system with $z_{abs} = 0.9170$ (FWHM$_{2796} = 160$ km s$^{-1}$), which corresponds to 166,129 km s$^{-1}$ with respect to the quasar, imprinted in the SDSS-I/II spectrum disappeared from the SDSS-III spectrum. Both spectra, with the pseudo-continuum fittings, of the quasar are displayed in Figure 1. The corresponding pseudo-continuum normalized spectra are presented in Figure 2. The measurements of the corresponding absorption lines are presented in Table 1 (see also Figure 2).

3. RESULTS AND DISCUSSION

Quasar J152645.61+193006.7 was observed by SDSS-I/II on 2006 May 31 and re-observed by SDSS-III on 2011 April 9. The time interval of the two observations is 497.4 days at the quasar rest-frame. From the two SDSS spectra of this quasar, we detect the disappearance of a narrow Mg $\text{ii}$, 2803 absorption system with $z_{abs} = 0.9170$. This absorption system has a velocity offset 166,129 km s$^{-1}$ with respect to the quasar emission redshift ($z_e = 2.5771$). A rough estimation from the curve of growth gives rise to the ion column density of $N_{2796} \approx 10^{13.4}$ cm$^{-2}$.
Figure 2. Pseudo-continuum normalized spectra of quasar J152645.61+193006.7, observed by SDSS-I/II (lower panel) and SDSS-III (upper panel), respectively. The green curves represent the flux uncertainty levels which have been normalized by the corresponding pseudo-continuum and the blue curves represent the Gaussian fittings. One narrow $\text{Mg}\,\text{II}\,\lambda\lambda\,2796,\,2803$ absorption system with $z_{\text{abs}} = 0.9170$ presented in the SDSS-I/II spectrum disappeared from the SDSS-III spectrum. (A color version of this figure is available in the online journal.)

![Figure 2](image1.png)

Table 1

| Parameter                  | Mg II $\lambda\lambda\,2796$ | Mg II $\lambda\,2803$ | Mg I $\lambda\,2853$ | Fe I $\lambda\,2523$ | Si I $\lambda\,2515$ | Ni I $\lambda\,2348$ | Fe II $\lambda\,2344$ |
|---------------------------|------------------------------|-----------------------|----------------------|---------------------|---------------------|---------------------|----------------------|
| $W_r$ ($\text{Å}$)        | $0.70 \pm 0.15$              | $0.73 \pm 0.16$       | $0.42 \pm 0.18$      | $0.37 \pm 0.14$     | $0.45 \pm 0.14$     | $0.35 \pm 0.13$     | $0.69 \pm 0.23$      |
| $W_r^\alpha$ ($\text{Å}$) | 0.09                         | 0.09                  | 0.09                 | 0.07                | 0.07                | 0.07                | 0.11                 |

Note. * The equivalent width limits estimated from the SDSS-III spectrum are calculated by Equation (1) as well.

3.1. Coverage Fractions

The optical depth ratio of the Mg II $\lambda\lambda\,2796,\,2803$ absorption doublet has a value of $\tau_{2796} : \tau_{2803} \approx 2 : 1$, expected from atomic physics (Savage & Sembach 1991; Verner et al. 1994). If the absorber incompletely covers the background emission sources, the photons apparently leaking through the absorption line region will give rise to a value of optical depth ratio deviated from the theoretical value (e.g., Barlow & Sargent 1997; Hamann et al. 1997; Crenshaw et al. 1999). In principle, the intrinsic absorber is often expected to partially cover the background emission sources. In order to check this, we fit the weaker member of the Mg II $\lambda\lambda\,2796,\,2803$ doublet with a Gaussian profile, scale the model in terms of what atomic physics expects for the stronger member, and compare it with the data. The results are illustrated in Figure 3. It can be clearly seen from the figure that the profile of $\lambda\,2796$ scaled to the atomic physics is inconsistent with the data, which is indicative of partial coverage.

The effective coverage fraction of the absorber to the background emission sources can be computed from the residual intensities of the resonance doublet. The normalized residual intensity as a function of velocity from the line center is

$$R(v) = [1 - C_I(v)] + C_I(v)e^{-\tau(v)},$$  \hspace{1cm} (2)

where $C_I(v)$ is the effective fraction and $\tau(v)$ is the optical depth at velocity $v$. For the Mg II $\lambda\lambda\,2796,\,2803$ doublet, the effective coverage fraction can be evaluated via

$$C_I(v) = \frac{[R_r(v) - 1]^2}{R_b(v) - 2R_r(v) + 1},$$  \hspace{1cm} (3)

where the subscripts $r$ and $b$ refer to the redder and bluer members of the Mg II $\lambda\lambda\,2796,\,2803$ doublet, respectively (e.g., Hamann et al. 1997; Barlow & Sargent 1997; Crenshaw et al. 1999; Misawa et al. 2005, 2007). Due to the low resolution of SDSS spectra, it is inappropriate to evaluate the effective coverage fraction pixel by pixel for the narrow Mg II $\lambda\lambda\,2796,\,2803$ absorption doublet. Therefore, in this paper, we use the
The solid line is determined by Equation (5) with a nominal value of $C_t = 0.4$, and the dashed lines correspond to 1σ errors of $C_t$.

![Figure 4](image)

**Figure 4.** $C_c-C_e$ parameter plane, showing solutions allowed by Equation (4). The solid line is determined by Equation (5) with a nominal value of $C_t = 0.4$, and the dashed lines correspond to 1σ errors of $C_t$.

normalized residual intensities at line cores to evaluate the effective coverage fraction of the Mg ii $\lambda\lambda 2796, 2803$ absorber, and obtain $C_t = 0.40 \pm 0.06$.

In principle, the intrinsic absorber could harbor different coverage fractions to the continuum source and the emission line regions (e.g., Ganguly et al. 1999; Gabel et al. 2005). Therefore, the effective coverage fraction is the fraction of the photons from all background emission sources going through the intrinsic absorber. Here, we consider the situation where the background photons only arise from the continuum source and the broad emission line region (BELR; e.g., Ganguly et al. 1999; Wu et al. 2010; Chen et al. 2013b), and assume that the optical depths are the same from the two emission sources. In this case, the effective coverage fraction is the weighted average of the coverage fractions of the two regions. That is,

$$C_t = \frac{C_c + WC_e}{1 + W},$$  \hspace{1cm} (4)

where $C_c$ and $C_e$ are the coverage fractions of the BELR and the continuum source, and $W = f_c/f_e$ is the flux ratio of the broad emission line (without continuum) and the continuum at the wavelength of the absorption line (e.g., Ganguly et al. 1999; Misawa et al. 2005, 2007; Wu et al. 2010). In order to evaluate the value of $W$, we use the method adopted by Chen et al. (2009) to fit a power-law continuum ($f \propto \lambda^{-\alpha}$) for the quasar spectra of J152645.61+193006.7, where several spectral regions without obvious emission lines are selected. We obtain $\alpha = -1.34$ from the SDSS-III spectrum and $\alpha = -1.08$ from the SDSS-II spectrum. (These continua are also plotted in Figure 1 with blue curves.) The strengths, which are measured from the C iv broad emission line and the power-law continuum at the wavelength of the Mg ii absorption doublet, give rise to a value of $W = 0.23$. Both values of $C_c$ and $C_e$ cannot be determined independently. However, one can constrain a relation for them, which is plotted in Figure 4.

From Equation (4), one can obtain the expression of $C_c$ as a function of $C_t$, $C_e$, and $W$, which is

$$C_c = (1 + W)C_f + WC_e = 1.23C_f - 0.23C_e,$$  \hspace{1cm} (5)

where $W = 0.23$ and $C_t = 0.40 \pm 0.06$. Although the value of $C_c$ cannot be determined without knowing $C_e$, we can derive the upper and lower limits of $C_c$ from this equation by considering two extreme values of $C_e$: $C_e = 0$ and $C_e = 1$. They correspond to $C_c = 0.49$ and $C_c = 0.26$, respectively.

3.2. The Origin of Time Variation

Time variation of absorption lines and partial coverage of the absorber to background emission sources are the two most popular indicators to separate the intrinsic NALs from the intervening NALs. The coverage fraction and time variation analysis (see Figure 3 and Table 1) imply that the narrow Mg ii $\lambda\lambda 2796, 2803$ absorption system with $z_{abs} = 0.9170$ might be truly intrinsic to the quasar J152645.61+193006.7 with $z_e = 2.5771$. If so, what would be the mechanism driving the disappearance of this Mg ii $\lambda\lambda 2796, 2803$ absorption system?

Time variations of absorption lines can be induced by changes in the ionization state of the absorbing gas, which can be driven by the variations of background emissions (from the continuum source or/and the BELR) or caused by a screen of variable optical depth between the absorber and the continuum source (e.g., Misawa et al. 2007), or by the bulk motion of the absorbing gas across our sightline (which might give rise to a change in the coverage fraction of the absorber to the background emission sources). If the disappearance of the Mg ii $\lambda\lambda 2796, 2803$ absorption system is due to the fluctuation of background emissions, it is expected that an observable change of quasar-ionized radiations should be noted during the corresponding period of observations, as the disappearance event is an extreme case of line variation. In fact, it can be clearly be seen from Figure 1 (see the green and red solid curves shown in the lower panel) that the quasar emissions at the two epochs of observation are quite stable. This suggests that the disappearance is not likely to be caused by the fluctuation of the quasar emissions.

A screen of variable optical depth between the absorber and the background emission sources can also bring about a fluctuation of the incidence flux of the absorber (e.g., Misawa et al. 2007), which is capable of causing a change in the absorber’s ionization levels. If so, the variable ionization scenario may still be alive even if the quasar luminosity is stable. Unfortunately, conditions in the screen cannot be determined with the present data.

Perhaps, on the rest-frame time corresponding to 2006 May 31 (when quasar J152645.61+193006.7 was observed by SDSS-I/II), the sightline of the object passed through the absorber (possibly near its edge), while on that corresponding to 2011 April 9 (when the object was observed by SDSS-III), the absorber had already moved away from the sightline due to its proper motion. If so, the disappearance of absorption troughs would be expected. In this way, a notable change of quasar emissions is not required. Therefore, it is likely that the disappearance of the Mg ii $\lambda\lambda 2796, 2803$ absorption system is due to the proper motion of the absorption gas across our sightline. Most of the UV continuum emission originates from the inner region of a geometric thin and an optical thick accretion disk whose size scale is $D_{cont} \sim 5R_S = 10^6 M_{BH}/c^2$ (Wise et al. 2004; Misawa et al. 2005). Let us consider the case of the virial black hole mass estimated by Shen et al. (2011) as the black hole mass, $M_{BH}$. That is $M_{BH} = 10^{9.51} M_\odot$. We then obtain a value of $D_{cont} = 4.8 \times 10^{15}$ cm. In terms of the coverage fraction of the absorber to the continuum emission source, namely, from 26% to 49%, the lower limits of the absorber radius are from 1.2 $\times 10^{15}$ cm to 2.4 $\times 10^{15}$ cm. Assuming a face-on accretion disk and that the movement of the absorber is perpendicular to our sightline, one can derive the transverse velocity of the absorber by $v_{trans} = D_{cont}/t_d$, where $t_d$ is the time interval of the two SDSS observations, which is 497.4 days. That yields
that this absorber partially covers the background emission. The Mg II absorption system contains some neutral species such as Mg II λ2853 and Fe II λ2523, which means that the absorber should be in very low ionization condition and that its size can be quite small (subparsec or smaller) with a very high volume density (e.g., Jones et al. 2010). The crossing velocity ($v_{\text{cross}}$ = 256–545 km s$^{-1}$) could also be explained by the rotational velocities of typical spiral galaxies and/or velocity dispersions of clusters of galaxies. If time variations of the galaxy emission exist, a change in the ionization state of the absorbing gas would be expected, and then may give rise to the disappearance of absorption troughs. However, with the present data, we cannot determine whether the disappearance of the Mg II $\lambda$2796, 2803 absorption system is truly associated with a cosmologically separated foreground galaxy.

### 4. SUMMARY

Quasar J152645.61+193006.7 ($z_e = 2.5771$) was first observed by the SDSS-I/II on 2006 May 31 and re-observed by the SDSS-III on 2011 April 9, spending a time interval of 497.4 days. We identify one narrow Mg II $\lambda\lambda$2796, 2803 absorption system with $z_{\text{abs}} = 0.9170$ from the SDSS-I/II spectrum, which has a relative velocity of $v_t = 166,129$ km s$^{-1}$ with respect to the quasar emission redshift. However, this Mg II $\lambda\lambda$2796, 2803 absorption system cannot be detected from the SDSS-III spectrum. The coverage fraction analysis shows that this absorber partially covers the background emission sources with an effective coverage fraction of $C_t = 0.40 \pm 0.06$.

Time variations of the Mg II $\lambda\lambda$2796, 2803 absorption system may be caused by the change in the ionization state of absorbing gas or by the motion of the absorber perpendicular to the quasar sightline. The quasar emissions (from the continuum source and the broad emission line region) are stable for the two SDSS observations, suggesting that the changes in the absorber’s ionization condition are unlikely to be caused by the variation of the quasar emissions. Therefore, if changes in the ionization state of absorbing gas exist, they might be driven by a screen of absorbing gas or by the motion of the absorber perpendicular to the quasar sightline. The absorber should be in very low ionization condition and that its size can be quite small (subparsec or smaller) with a very high volume density (e.g., Jones et al. 2010). The crossing velocity ($v_{\text{cross}}$ = 256–545 km s$^{-1}$) could also be explained by the rotational velocities of typical spiral galaxies and/or velocity dispersions of clusters of galaxies. If time variations of the galaxy emission exist, a change in the ionization state of the absorbing gas would be expected, and then may give rise to the disappearance of absorption troughs. However, with the present data, we cannot determine whether the disappearance of the Mg II $\lambda\lambda$2796, 2803 absorption system is truly associated with a cosmologically separated foreground galaxy.

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