THE DISAPPEARANCE OF A NARROW Mg II ABSORPTION SYSTEM IN QUASAR SDSS J165501.31+260517.4

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ABSTRACT

In this paper, we present for the first time the discovery of the disappearance of a narrow Mg II λλ2796, 2803 absorption system from the spectra of the quasar SDSS J165501.31+260517.4 (z = 1.8671). This absorber is located at za = 1.7877 and has a velocity of 8423 km s−1 with respect to the quasar. According to the velocity offset and the line variability, this narrow Mg II λλ2796, 2803 absorption system is likely intrinsic to the quasar. Since the corresponding UV continuum emission and the absorption lines of another narrow Mg II λλ2796, 2803 absorption system at za = 1.8656 are very stable, we believe that the disappearance of the absorption system is unlikely to be caused by the change in ionization of absorption gas. Instead, it likely arises from the motion of the absorption gas across the line of sight.

Key words: galaxies: kinematics and dynamics – quasars: absorption lines – quasars: individual (J165501.31+260517.4)

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1. INTRODUCTION

It is known that absorption lines would be detected in a quasar spectra when the quasar sight line passes through the corresponding foreground absorbers. Absorption lines of quasars are usually split into broad absorption lines (BALs), which have absorption troughs broader than 2000 km s−1 at depths >10% below the continuum (Weymann et al. 1991), and narrow absorption lines (NALs), line widths narrower than 500 km s−1. Absorption lines are traditionally divided into two classes according to their relationship with the corresponding quasars: (1) the cosmologically intervening absorption lines, which are often believed to be caused by the cosmologically intervening galaxies lying on the quasar sight lines (Bergeron 1986; Bond et al. 2001) and hence are physically unrelated to the quasars; (2) the intrinsic (or associated) absorption lines, which are physically associated with the quasars. The intrinsic absorption lines are usually believed to be related to quasar outflows, for which viewing at different angles could give rise to different line types (BALs or NALs; Murray et al. 1995).

Variations of intrinsic absorption lines in equivalent widths and/or shapes have been noted by various authors (e.g., Lundgren et al. 2007; Leighly et al. 2009; Capellupo et al. 2011; Hamann et al. 2011). It was revealed that the fractional change in equivalent width increases with rest-frame timescales over 0.05–5 yr. The variation of absorption lines could arise from the changes in the ionization state or/and in the covering factor of the absorption gas. BALs are undoubtedly intrinsic to the corresponding quasars. Most BAL variations are due to changes in the covering factor of outflow stream lines that partially block the continuum emission, which could be caused by the motion of the outflow (e.g., Hamann 1998; Arav et al. 1999; Proga et al. 2002; Ak et al. 2012; Vivek et al. 2012). While the variation of BALs would be common, extreme events such as the disappearance and the emergence of absorption troughs from the spectra are rare (which might consume many years of observation). Thus far, only a small number of these extreme events of BALs have been reported (e.g., Hall et al. 2011; Vivek et al. 2012; Filiz et al. 2012). Variations in the ionization state of absorption gas are also common. In a recent study, the coordinated line variations of five narrow intrinsic absorption systems imprinted in one quasar spectra could be best explained by global changes in the ionization of absorption gas due to the changes in the quasar’s ionizing emission (Hamann et al. 2011). However, no disappearance and emergence of NALs have ever been reported.

Quasars are capable of driving outflows with speeds up to 30,000 km s−1 (Ganguly et al. 2007). Therefore, the narrow intrinsic absorption lines can occur at large velocity separations from the quasars (e.g., Misawa et al. 2007; Ganguly & Brotherton 2008; Hamann et al. 2011). In addition, NALs imprinted in the quasar spectra are very common for intervening absorption lines. Thus, in many cases, confirming an NAL to be intrinsic to the quasar is very difficult (see Ganguly & Brotherton 2008 for a review).

In this paper, we analyze the spectra of quasar SDSS J165501.31+260517.4 and report our discovery of the disappearance of a narrow Mg II λλ2796, 2803 absorption system. Throughout this paper we use cosmological parameters ΩΛ = 0.7, ΩM = 0.3, and H0 = 70 km s−1 Mpc−1.

2. ANALYSIS

There are about 8000 quasars included in both the SDSS-III (Sloan Digital Sky Survey-III) quasar catalog (Eisenstein et al. 2011; Ross et al. 2012) and the SDSS-II quasar catalog (York et al. 2000; Schneider et al. 2010), meaning that these quasars have been observed twice by the Sloan Digital Sky Survey. This large sample provides us a chance to search for the possible
disappearance of absorption systems. Among these quasars, 33 were detected to possess obvious Mg II $\lambda\lambda$2796, 2803 associated absorption systems by Shen & Ménard (2012) with the data of the SDSS-II quasar catalog. To investigate the variability of the narrow absorption systems, we analyzed the spectra of all 33 quasars available in both SDSS-I/II and SDSS-III. We fitted each spectrum with a combination of cubic splines for pseudo-continuum and Gaussians for line features. The Mg $\ll\lambda$2796, 2803 absorption systems (including all possible associated and intervening absorption systems) were searched in the pseudo-continuum normalized spectra.

We found that all Mg II $\lambda\lambda$2796, 2803 associated absorption systems in the spectra of SDSS-I/II, noted by Shen & Ménard (2012), are also detected in those of SDSS-III. However, in the quasar SDSS J165501.31+260517.4 ($z_{\text{e}} = 1.8671$; Hewett & Wild 2010), we accidentally found that the narrow Mg II $\lambda\lambda$2796, 2803 absorption system at $z_{\text{abs}} = 1.7877$, observed on 2005 April 12 (SDSS-I/II), disappears from the SDSS-III spectra which was observed on 2011 April 13. We show the spectra of this quasar together with the corresponding pseudo-continua in Figure 1, and present the pseudo-continuum normalized spectra in Figure 2. The detection and disappearance of the Mg II $\lambda\lambda$2796, 2803 absorption system can be clearly seen in Figure 2 by comparing SDSS-I/II and SDSS-III spectra. Each absorption line of the detected Mg II $\lambda\lambda$2796, 2803 absorption system in the SDSS-I/II spectra was fitted with a Gaussian component, from which we measured the rest-frame equivalent width ($W_e$). We estimate the uncertainty of the detected absorption lines via

$$(1 + z)\sigma_w = \sqrt{\frac{\sum_i P^2(\lambda_i - \lambda_0)\sigma_f^2}{\sum_i P^2(\lambda_i - \lambda_0)}} \Delta\lambda,$$  

where $P(\lambda_i - \lambda_0)$, $\lambda_i$, and $\sigma_f$ represent the line profile centered at $\lambda_0$, the wavelength, and the normalized flux uncertainty as a function of pixel, respectively (Nestor et al. 2005; Quider et al. 2011). The sum is performed over an integer number of pixels that cover at least ±3 characteristic Gaussian widths. The measurements of the detected absorption lines are presented in Table 1.

![Figure 1. Spectra of quasar SDSS J165501.31+260517.4, observed by SDSS-I/II (lower panel) and SDSS-III (upper panel), respectively. The red solid lines represent the pseudo-continuum, and the solid green line presented in the lower panel is the pseudo-continuum shown in the upper panel.](image-url)

Table 1

| Species     | $W_e$  | $W_e^a$ |
|-------------|--------|---------|
| Mg II $\lambda$2796 | $0.33 \pm 0.10$ | $0.05$ |
| Mg II $\lambda$2796 | $0.51 \pm 0.11$ | $0.05$ |
| Fe II $\lambda$2600 | $0.28 \pm 0.16$ | $0.06$ |
| Ni III $\lambda$1749 | $0.18 \pm 0.06$ | $0.06$ |
| Ni III $\lambda$1741 | $0.12 \pm 0.05$ | $0.06$ |
| Fe II $\lambda$1563 | $0.16 \pm 0.08$ | $0.06$ |
| Si II $\lambda$1527 | $0.15 \pm 0.10$ | $0.06$ |
| Fe II $\lambda$1504 | $0.50 \pm 0.20$ | $0.06$ |
| Ni II $\lambda$1478 | $0.35 \pm 0.10$ | $0.06$ |

Note. $^a$ The equivalent width limits estimated from the corresponding SDSS-III spectrum are also calculated by Equation (1).

3. DISCUSSION AND CONCLUSIONS

Although the disappearance of BALs was previously reported by various authors (e.g., Hall et al. 2011; Vivek et al. 2012; Filiz Ak et al. 2012), thus far the disappearance of NALs has not yet been detected. Here, we show the first discovery of the disappearance of a narrow Mg II $\lambda\lambda$2796, 2803 absorption system in quasar SDSS J165501.31+260517.4. The velocity offset of the corresponding absorber ($z_{\text{abs}} = 1.7877$) with respect to the quasar ($z_{\text{e}} = 1.8671$) is 8423 km s$^{-1}$. The line variability together with the velocity offset suggest that this narrow Mg II $\lambda\lambda$2796, 2803 absorption system is likely to be intrinsic to the corresponding quasar.

Two mechanisms are likely responsible for the disappearance of the narrow Mg II $\lambda\lambda$2796, 2803 absorption system: the motion of the absorbing gas across the line of sight and the fluctuation of quasar ionized radiation which could give rise to the change in the ionization of absorption gas. To check whether the fluctuation of quasar ionized radiation is the origin of the disappearance, let us study the line variability of other narrow Mg II $\lambda\lambda$2796, 2803 absorption systems detected in the same spectra. In this quasar, we have detected another narrow Mg II $\lambda\lambda$2796, 2803 absorption system at $z_{\text{abs}} = 1.8656$ identified in both the SDSS-I/II and SDSS-III spectra.
observed on 2005 April 12 and 2011 April 13, respectively. The velocity offset of this absorber with respect to the quasar is 1562 km s\(^{-1}\) (see Figure 3). We found that this absorption doublet is very stable (within 1\(\sigma\) error) during the two epochs, with \(W_{\lambda}(\lambda2796) = 0.93 \pm 0.09\) Å and \(W_{\lambda}(\lambda2803) = 0.72 \pm 0.09\) Å from the SDSS-III spectrum, and \(W_{\lambda}(\lambda2796) = 0.99 \pm 0.17\) Å and \(W_{\lambda}(\lambda2803) = 0.66 \pm 0.15\) Å from the SDSS-I/II spectrum. If the disappearance of the \(z_{\text{abs}} = 1.7877\) narrow Mg\(^{\text{ii}}\) \(\lambda\lambda2796, 2803\) absorption system is caused by the fluctuation of quasar ionized radiation, it is unlikely that the \(z_{\text{abs}} = 1.8656\) narrow Mg\(^{\text{ii}}\) \(\lambda\lambda2796, 2803\) absorption system can be so stable within the same period. In addition, we found that the near-UV continuum fluxes of this quasar are stable at the two epochs. Therefore, the fluctuation of the quasar ionized radiation is unlikely the origin of the disappearance.

Another mechanism likely accounting for the disappearance is the movement of the absorption gas. It is possible that a clumpy gas partially covers the background emission source, and its motion might cause the disappearance of the narrow Mg\(^{\text{ii}}\) \(\lambda\lambda2796, 2803\) absorption system if the transverse motion of the gas makes it passing through our line of sight, especially when the absorber has a sharp edge and the sight line is close to its edge. Considering the case of a geometric thin and optical thick accretion disk, most of the UV continuum radiation is expected to originate from the inner accretion disk, whose size is on the order of \(D_{\text{cont}} \approx 5R_S = 10G\text{M}_{\text{BH}}/c^2\) (Wise et al. 2004; Misawa et al. 2005). Here, let us take the virial black hole mass \(\text{M}_{\text{BH}} = 10^{9.2}\text{M}_\odot\), estimated based on the Mg\(^{\text{ii}}\) broad emission line (Shen et al. 2011), as the mass of the black hole. That gives rise to \(D_{\text{cont}} = 1.5 \times 10^{10.2}\) km. The disappearance of the narrow Mg\(^{\text{ii}}\) \(\lambda\lambda2796, 2803\) absorption system occurred within a period of 765 days in the quasar rest frame. We assume a face-on accretion disk and that the transverse size of the absorption gas is as large as the UV
continuum emitting region. Taking 765 days as an upper limit of the transverse motion time of the absorption gas, one can estimate the value of the transverse velocity perpendicular to the sight line, which is about 360 km s$^{-1}$. Adopting the virial black hole mass and assuming that the shift velocity of the gas does not exceed the escape velocity, we can constrain the location of the absorber relative to the central region: the gas locates at a radius of $r \sim 0.1$ pc (see, e.g., Misawa et al. 2005). According to the empirical relationship between the radius and luminosity, the radius of the broad emission line region (BLR) is $R_{BLR} \approx 0.08$ pc, which was estimated from the continuum luminosity at 1350 Å (Kaspi et al. 2007), where the continuum luminosity at 1350 Å is directly taken from Shen et al. (2011). In this way, the absorber would locate at the vicinity of the BLR.

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