DISCOVERY OF Hα ABSORPTION IN THE UNUSUAL BROAD ABSORPTION LINE QUASAR SDSS J083942.11+380526.3

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ABSTRACT

We discovered Hα absorption in the broad Hα emission line of an unusual broad absorption line quasar, SDSS J083942.11+380526.3, at z = 2.318, through near-infrared spectroscopy with the Cooled Infrared Spectrograph and Camera for OHS (CISCO) on the Subaru telescope. The presence of nonstellar Hα absorption is known only in the Seyfert galaxy NGC 4151 to date; thus, our discovery is the first case for quasars. The Hα absorption line is blueshifted by 520 km s⁻¹ relative to the Hα emission line, and its redshift almost coincides with those of UV low-ionization metal absorption lines. The width of the Hα absorption (~340 km s⁻¹) is similar to those of the UV low-ionization absorption lines. These facts suggest that the Hα and low-ionization metal absorption lines are produced by the same low-ionization gas, which has a substantial amount of neutral gas. The column density of the neutral hydrogen is estimated to be ~10¹⁵ cm⁻² by assuming a gas temperature of 10,000 K from the analysis of the curve of growth. The continuum spectrum is reproduced by a reddened [E(B − V) ~ 0.15 mag for the SMC-like reddening law] composite quasar spectrum. Furthermore, the UV spectrum of SDSS J083942.11+380526.3 shows a remarkable similarity to that of NGC 4151 in its low state, suggesting that the physical condition of the absorber in SDSS J083942.11+380526.3 is similar to that of NGC 4151 in the low state. As proposed for NGC 4151, SDSS J083942.11+380526.3 may also be seen through the edge of the obscuring torus.

Subject headings: galaxies: active — quasars: absorption lines — quasars: emission lines — quasars: individual (SDSS J083942.11+380526.3)

Online material: color figures

1. INTRODUCTION

Broad absorption line (BAL) quasars are characterized by the absorption troughs of UV resonance lines, the velocity widths of which are typically ~2000-20,000 km s⁻¹. The troughs are blueshifted relative to emission lines from 2000 km s⁻¹ to as much as ~0.2c. BAL quasars are divided into three subtypes, depending on what kind of ions are seen as absorption. High-ionization BAL quasars (HiBALs) show absorption from C iv, N v, Si iv, and Lyα. Low-ionization BAL quasars (LoBALs) show absorption from Mg ii, Al iii, and Si ii, in addition to the high-ionization absorption. A fraction of LoBALs show absorption from excited fine-structure levels of the ground term and excited terms of Fe ii and Fe iii (Hazard et al. 1987; Becker et al. 1997, 2000; Hall et al. 2002). They are called iron LoBALs (FeLoBALs). BAL quasars comprise 10%–20% of optically selected quasars (Weymann et al. 1991; Hewett & Foltz 2003; Reichard et al. 2003). The fraction of LoBALs among BAL quasars is 13%–15%, and ~2% in all quasars (Weymann et al. 1991; Reichard et al. 2003). FeLoBALs are rare and comprise only 15% of LoBALs (Hall et al. 2002).

The number of known FeLoBALs has been increasing. After the discovery of the first FeLoBAL, LBQS 0059-2735 (Hazard et al. 1987), Cowie et al. (1994) discovered a similar object to this in their K-band survey (Hawaii 167). Becker et al. (1997, 2000) also discovered five FeLoBALs in their radio-selected quasar sample, the FIRST Bright Quasar Survey (FBQS; White et al. 2000). The Sloan Digital Sky Survey (SDSS; York et al. 2000) is dramatically increasing the number of FeLoBALs. Reichard et al. (2003) discovered 10 FeLoBALs in the SDSS Early Data Release quasar catalog (Schneider et al. 2002). Hall et al. (2002) identified more than one dozen FeLoBALs whose spectral characteristics are very different from those of previously known BAL quasars. Some of them have tremendous numbers of UV absorption lines. Others have absorption troughs that remove almost all (~90%) of the flux shortward of Mg ii. At least one FeLoBAL has Fe iii absorption but does not have Fe ii absorption. Many of them are heavily reddened by up to E(B − V) ~ 0.5 mag. Such unusual FeLoBALs may occupy a new parameter space (the black hole mass, mass accretion rate, viewing angle, outflow rate, etc.) of quasars. An extensive search for such BAL quasars is therefore important to understanding the structure and evolution of quasars.

There is still no consensus concerning whether BAL quasars are intrinsically different from non-BAL quasars. Weymann et al. (1991) pointed out the close similarity in the emission-line and continuum properties of BAL quasars and non-BAL quasars. They concluded that BAL quasars are non-BAL quasars seen from a different viewing angle, i.e., both types of quasars belong to the same population. The results of spectropolarimetry of BAL quasars (e.g., Goodrich & Miller 1995; Cohen et al. 1995; Hines & Wills 1995; Ogle et al. 1999; Schmidt & Hines 1999) have also been interpreted in such a way that BAL quasars could be quasars seen through the edge of the obscuring tori. On the other hand,
TABLE 1
PHOTOMETRIC DATA OF SDSS J0839+3805

| Band | Magnitude |
|------|-----------|
| u    | 21.597 ± 0.149a |
| g    | 19.631 ± 0.020a |
| r    | 18.933 ± 0.022a |
| i    | 18.953 ± 0.019a |
| z    | 18.604 ± 0.034a |
| J    | 16.782 ± 0.167a |
| H    | 16.278 ± 0.245a |
| Ks   | 15.386 ± 0.147a |

a Magnitude measured by PSF-fitting photometry in AB system.

b Magnitude in Vega system.

some authors argue that BAL quasars, especially LoBALs, are young or recently refueled quasars (Boroson & Meyers 1992; Voit et al. 1993; Becker et al. 2000). They infer that the absorption troughs of BAL quasars appear when the nuclei are blowing the obscuring dust off; through this BAL phase, quasars may evolve from a dust-enshrouded stage (the infrared luminosity is therefore expected to be large) to a normal quasar phase (Sanders et al. 1988). All four LoBALs/FeLoBALs currently known at $z < 0.4$ are, in fact, ultraluminous infrared ($L_{IR} > 10^{12} L_{\odot}$) galaxies and major mergers (Canalizo & Stockton 2002). The discovery of a population of unusual BAL quasars (Hall et al. 2002) may suggest that there is a population in a different evolutionary phase or structure.

During our search for LoBALs and FeLoBALs by visual inspection of $\approx 4800$ spectra between redshifts of 2.1 and 2.8 in the SDSS Data Release 3 (DR3; Abazajian et al. 2005), we found an unusual BAL quasar, SDSS J083942.11+380526.3 (hereafter SDSS J0839+3805). Photometric data of SDSS J0839+3805 from SDSS DR3 and the Two Micron All Sky Survey (2MASS) Point Source Catalog are tabulated in Table 1. The absolute magnitude in the $i$ band of SDSS J0839+3805 is $-26.8$ mag (AB) with the $k$-correction (Schneider et al. 2005), assuming $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$, $\Omega_m = 0.3$, and $\Omega_{\Lambda} = 0.7$. Figure 1 shows its rest UV spectrum from SDSS data. SDSS J0839+3805 is an FeLoBAL; it shows absorption in the excited-state Fe II as well as C iv $\lambda \lambda 1548, 1551$ and Al iii $\lambda 1855, 1863$. The troughs at wavelength regions of the spectra free of absorption features. The model profile wavelengths.

2. OBSERVATIONS AND DATA REDUCTION

The $K$- and $JH$-band spectra of SDSS J0839+3805 were obtained with the Cooled Infrared Spectrograph and Camera for OHS (CISCO; Motohara et al. 2002) attached to the Subaru 8.2 m telescope (Iye et al. 2004) on 2005 March 26 (UT). It was cloudy, but the seeing was good ($\approx 0\farcs5$ in $K$ band). The slit width was set to be $0\farcs6$. This results in a resolution of 50 and 46 Å in $K$ band and $JH$ band (i.e., $R \approx 300 - 400$), respectively, which were measured by using night sky lines. The slit position angle was $0^\circ$. We obtained four exposures in each band, dithering the telescope to observe the quasar at two positions with a separation of $10^\prime$ along the slit. The total integration times on the quasar were $1000$ s ($250$ s $\times 4$) in $K$ band and $1200$ s ($300$ s $\times 4$) in $JH$ band. The A0 star SAO 061318 was observed immediately after the observation of SDSS J0839+3805 for sensitivity calibration and removal of atmospheric absorption lines.

The data were reduced using IRAF$^7$ for the standard procedures of flat-fielding, sky subtraction, and residual sky subtraction. Wavelength calibration was performed using OH night-sky lines. The rms wavelength calibration error is 2.6 Å in $K$ band and 1.5 Å in $JH$ band, corresponding to $36$ km s$^{-1}$ at $21780$ Å (redshifted H$\alpha$ line of the SDSS J0839+3805) and $28$ km s$^{-1}$ at $16170$ Å (redshifted H$\beta$ line), respectively. The sensitivity calibration was performed as a function of wavelength, and the atmospheric absorption feature was removed by using the spectrum of SAO 061318. Since the weather conditions were not photometric, the absolute flux calibration was made using photometry in the 2MASS Point Source Catalog, as described below.

3. RESULTS

Figure 2 displays the $K$-band spectrum of SDSS J0839+3805, as well as the fitting result. It clearly shows the presence of a strong H$\alpha$ broad emission line with an absorption line. The absorption line is clearly visible in all the spectra from the individual exposures. The absorption line must be real, since there is no atmospheric absorption line at this wavelength and no bad pixel at this position of the detector. In addition, the spectrum of the standard star does not show any absorption features at the same wavelength. The H$\alpha$ emission line was fitted with a combination of three Gaussians and a linear continuum by using the wavelength regions of the spectra free of absorption features. The model profile

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{Observed spectrum of SDSS J0839+3805 in the SDSS DR3. Ordinate is a flux density in units of $10^{-17}$ ergs s$^{-1}$ cm$^{-2}$ Å$^{-1}$, and abscissa is the observed wavelength in angstroms. The rest wavelength is given along the top axis. The spectrum is smoothed by a 3 pixel boxcar filter. Dotted lines show the wavelengths of the absorption lines.}
\end{figure}

\footnote{IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy (AURA), Inc., under cooperative agreement with the National Science Foundation.}
an extreme case of effective continuum, which is shown as the dotted line in Figure 2. The lower limit of the EW thus obtained is 4.9 Å. The redshift determined by the bottom of the H$\alpha$ absorption line is $2.3121 \pm 0.0002$, and is blueshifted by $520$ km s$^{-1}$ relative to the H$\alpha$ emission line. The FWHM$_{\text{obs}}$ of the absorption line is $770 \pm 50$ km s$^{-1}$. Since the FWHM$_{\text{inst}}$ is $~690$ km s$^{-1}$ at $K$ band, the line is marginally resolved, and the FWHM$_{\text{true}}$ is $340^{+150}_{-130}$ km s$^{-1}$. The properties of absorption lines and emission lines are tabulated in Table 2.

Figure 3a displays the H-band spectrum of SDSS J0839+3805. The signal-to-noise ratio of the spectrum is not high because of the bad weather and strong OH sky emission lines. The feature at $1.617$ μm is the H$\beta$ emission line, and the feature at $1.659$ μm is probably [O iii] $\lambda$5008. A narrow absorption-like feature is seen at $1.609$ μm in the H$\beta$ emission line. However, its width (25 Å) is significantly narrower than the spectral resolution (46 Å), it is not real. The H-band spectrum was modeled with a combination of Gaussians representing the H$\beta$ broad emission line and [O iii] $\lambda$4960, 5008 emission lines, and a linear continuum. The result is displayed in Figure 3a with a solid line, as well as in Table 2. In order to trace the asymmetric shape, we fitted the H$\beta$ emission profile with two Gaussians. We ignored the possible absorption feature corresponding to the H$\alpha$ absorption. The peak of the model H$\beta$ emission-line profile is at $1.617$ μm ($z = 2.325$), and it is redshifted by $640$ km s$^{-1}$ relative to the H$\alpha$ emission. This apparent redshift relative to the H$\alpha$ emission is probably caused by absorption at the blue side of the H$\beta$ emission line. The FWHM$_{\text{true}}$ of H$\beta$ emission is $3280 \pm 140$ km s$^{-1}$, which is much narrower than that of H$\alpha$ emission. This would also be expected if an absorption line exists and distorts the H$\beta$ emission at the blue side, as stated above.

We fitted [O iii] $\lambda$4960, 5008 with a Gaussian for each line. The width and redshift were assumed to be the same for both of these two [O iii] lines (see Table 2), and the intensity ratio of [O iii] $\lambda$5008–4960 was fixed to be 3.0. The peak of [O ii] $\lambda$5008 is at $1.6590 \pm 0.0005$ μm ($z = 2.3126 \pm 0.0009$). The [O iii] emission line is blueshifted by 480 km s$^{-1}$ relative to the H$\alpha$ emission. The width of the [O iii] emission line is resolved and the FWHM$_{\text{true}}$ is $1310 \pm 90$ km s$^{-1}$. Such broad and blueshifted [O iii] emission lines have been discovered in more than one dozen narrow-line Seyfert 1 galaxies and narrow-line quasars (Aoki et al. 2005; Marziani et al. 2003; Zamanov et al. 2002). We note that rest-frame EW of [O iii] $\lambda$5008 is $13 \pm 1$ Å for SDSS J0839+3805, which is much larger than those found in other LoBALs/FeLoBALs. All four LoBALs/FeLoBALs in Boroson & Meyers (1992) have no or weak [O iii] $\lambda$5008 (EW $< 2$ Å). The EWs of six LoBALs in Yuan & Wills (2003) are less than

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**TABLE 2**

| Line          | Absorption/Emission | $z$               | $\Delta v$ (km s$^{-1}$) | FWHM$_{\text{true}}$ (km s$^{-1}$) |
|---------------|---------------------|-------------------|-------------------------|----------------------------------|
| H$\alpha$     | Emission            | $2.3179 \pm 0.0002$ | ...                     | $6500 \pm 50$                    |
| H$\beta$      | Absorption          | $2.3121 \pm 0.0002$ | $-520 \pm 20$          | $340^{+150}_{-130}$              |
| H$\beta$      | Emission            | $2.325 \pm 0.002^a$ | $+640 \pm 180^b$        | $3280 \pm 140^b$                |
| [O ii] 5008    | Emission            | $2.3126 \pm 0.0009$ | $-480 \pm 80$          | $1310 \pm 90$                    |
| He i 3890     | Absorption          | $2.3114 \pm 0.0009$ | $-90 \pm 90$           | $390^{+500}_{-300}$              |
| Ly$\alpha$    | Emission            | $2.3163 \pm 0.0002$ | $-140 \pm 20$          | $930 \pm 25$                     |

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* Velocity shift relative to the H$\alpha$ emission line. Negative value means blueshift.

* Redshift and FWHM of the H$\beta$ emission line are probably affected by the absorption.

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**Fig. 2.**—Top: K-band spectrum of SDSS J0839+3805. Ordinate is a relative flux density in units of ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$, and abscissa is the observed wavelength in vacuum in microns. The rest wavelength is given along the top axis. The H$\alpha$ emission line is fitted with three Gaussians. The best fit is shown as a thick solid line. The extreme case of the effective continuum is shown by a dotted line. Bottom: The sky emission spectrum (solid line) and the atmospheric transmission curve (dotted line), which is obtained from the United Kingdom Infra-Red Telescope (UKIRT) Web page. It is produced using the program IRTRANS4.
The Hα absorption among quasars. The Hα absorption of SDSS J0839+3805 is deeper than continuum height. Since an absorber cannot remove more light from a continuum than is initially present, and since the depth of the absorption exceeds the height of the continuum, the absorption line is of nonstellar origin. We cannot consider a case in which only the continuum suffers from absorption. Two cases are possible: both the continuum and broad emission line region suffer from absorption, or only the broad emission line does. In either case the absorber is thus located outside the broad emission line region, and at least partially absorbs the light from the broad emission line region.

In order to compare the Hα absorption to UV absorption lines, we measured their redshifts and widths in the spectrum of SDSS DR3. We selected low-ionization lines and less blended lines. The results are tabulated in Table 3. The redshifts of UV low-ionization absorption lines are almost the same as those of the Hα absorption line. The widths of the UV low-ionization absorption lines are 360 (Zn ii) to 880 (Si ii) km s\(^{-1}\), which is similar to that of Hα absorption. These facts suggest that the Hα and UV low-ionization absorption lines are produced by the same ions.

### Table 3

**Properties of Low-Ionization UV Absorption Lines**

| Line       | z   | \(\Delta v^a\) (km s\(^{-1}\)) | FWHM\(_{\text{true}}\) (km s\(^{-1}\)) |
|------------|-----|---------------------------------|---------------------------------------|
| Si ii 1527 | 2.3100 | -720                           | 810                                   |
| Si ii 1533 | 2.3110 | -620                           | 880                                   |
| Al iii 1855| 2.3101 | -710                           | 890                                   |
| Al iii 1863| 2.3101 | -710                           | 970                                   |
| Fe iii 1914| 2.3109 | -630                           | 730                                   |
| Zn ii 2026 | 2.3124 | -500                           | 360                                   |

\(^a\) Velocity shift relative to the Hα emission line (z = 2.3179). Negative value means blueshift.

![Fig. 3.—(a) H-band spectrum of SDSS J0839+3805 (top). Ordinate is a relative flux density in units of ergs s\(^{-1}\) cm\(^{-2}\) \(\mu\)m\(^{-1}\) and abscissa is an observed wavelength in vacuum in microns. The rest wavelength based on the redshift of Hα emission line is given along the top axis. The Hβ emission is fitted with two Gaussians, and [O iii] \(\lambda\)4960, 5008 are fitted with a fixed intensity ratio of 3.0 and the same redshift and width of a Gaussian for each line. Bottom panel is as in Fig. 2. (b) J-band spectrum of SDSS J0839+3805 (top). Ordinate is a relative flux density in units of ergs s\(^{-1}\) cm\(^{-2}\) \(\mu\)m\(^{-1}\) and abscissa is an observed wavelength in vacuum in microns. The rest wavelength is given along the top axis. Bottom panel is as in Fig. 2.](#)

6 Å. The current observations suggest that [O iii] in LoBALs/FeLoBALs is weak in general, and that the strength of [O iii] in SDSS J0839+3805 is exceptional. There are, however, only a dozen observations of [O iii] in LoBALs/FeLoBALs. We should wait for more observations.

The J-band spectrum is shown in Figure 3b. The possible absorption feature at 1.288 \(\mu\)m may be He i \(\lambda\)3889, 74. If the absorption is real, its redshift is 2.3114 ± 0.0009, and its rest EW is 4.8 ± 0.7 Å. The line is marginally resolved and the FWHM\(_{\text{true}}\) is 390\(^{+300}_{-290}\) km s\(^{-1}\). The redshift and FWHM are similar to those of the Hα absorption.

### 4. Discussion

#### 4.1. Hα Absorption

Our spectroscopy has discovered the presence of an Hα absorption line in SDSS J0839+3805. This is the first case of detection of the Hα absorption among quasars. The Hα absorption of SDSS J0839+3805 is deeper than continuum height. Since an absorber cannot remove more light from a continuum than is initially present, and since the depth of the absorption exceeds the height of the continuum, the absorption line is of nonstellar origin. We cannot consider a case in which only the continuum suffers from absorption. Two cases are possible: both the continuum and broad emission line region suffer from absorption, or only the broad emission line does. In either case the absorber is thus located outside the broad emission line region, and at least partially absorbs the light from the broad emission line region.

In order to compare the Hα absorption to UV absorption lines, we measured their redshifts and widths in the spectrum of SDSS DR3. We selected low-ionization lines and less blended lines. The results are tabulated in Table 3. The redshifts of UV low-ionization absorption lines are almost the same as those of the Hα absorption line. The widths of the UV low-ionization absorption lines are 360 (Zn ii) to 880 (Si ii) km s\(^{-1}\), which is similar to that of Hα absorption. These facts suggest that the Hα and UV low-ionization absorption lines are produced by the same ions.

![Fig. 4.—Spectral energy distribution of SDSS J0839+3805. Ordinate is the logarithm of an observed flux density in units of ergs s\(^{-1}\) cm\(^{-2}\) Å\(^{-1}\), and abscissa is the logarithm of an observed wavelength in vacuum in angstroms. The rest wavelength is given along the top axis. The rest UV spectrum by the SDSS and rest optical spectra by us are shown with the spectra on the left-hand side and right-hand side, respectively. Our rest optical spectra are scaled to the photometry by 2MASS (triangles), except for J-band (see text). The SDSS photometric data are shown in squares. The SDSS composite quasar spectrum reddened by the SMC-type extinction law with E(B – V) = 0.15 mag is shown with a dashed line. [See the electronic edition of the Journal for a color version of this figure.](#)
outflowing low-ionization gas, which contains a substantial amount of neutral gas.

Since our spectroscopy marginally resolved the absorption-line profile, the column density can be derived from the curve of growth (Spitzer 1978). The FWHM$_{\text{true}}$ of the H$\alpha$ absorption line is 340 km s$^{-1}$, corresponding to the Doppler parameter of $b = 200$ km s$^{-1}$ [$b = \text{FWHM}/(4 \ln 2)^{1/2}$]. The EW of 8.0 Å is on the “linear” regime of the curve of growth for H$\alpha$, with $b = 200$ km s$^{-1}$, and the column density $N_j$ for the hydrogen atoms that absorb H$\alpha$ photons is $3.2 \times 10^{13}$ cm$^{-2}$. In the case of the
extremely low EW (4.9 Å), the column density would be $2.0 \times 10^{13}$ cm$^{-2}$. Assuming that the absorber is in thermal equilibrium at a temperature of 10,000 K, the number ratio of hydrogen atoms at the $n = 2$ level, relative to those at the ground level, is calculated to be $3.0 \times 10^{-3}$ using the Boltzmann equation. Therefore, the neutral hydrogen column density is expected to be $\approx 10^{18}$ cm$^{-2}$.

The lack of information about the temperature of the absorber is the limitation of our analysis; high-resolution spectroscopy of the Hα absorption is needed. We cannot be certain whether the absorption is saturated or not from our low-resolution spectroscopy. As a result, we cannot determine whether the absorber fully covers the continuum and the broad emission line region. In the case of partial coverage of either source, our effective continuum used in the above analysis would be an overestimate. The
Fig. 7.—Same as Fig. 5, but for the region between 2300 and 3100 Å. [See the electronic edition of the Journal for a color version of this figure.]
EW and column density would therefore be underestimated. On the other hand, since the level population is very sensitive to temperature, the number ratio of hydrogen atoms at the $n = 2$ level relative to those at the ground level would be larger if the temperature is higher than 10,000 K. The column density would be overestimated in that case. The uncertainty in temperature may cause an orders-of-magnitude error in column density.

### 4.2. Reddening of the Continuum

Since the color of SDSS J0839+3805 ($g - r = 0.698$ mag and $g - i = 0.678$ mag) is redder than the median color of quasars at $z = 2.3$ ($g - r = 0.08$ mag and $g - i = 0.2$ mag) in SDSS (Richards et al. 2003), the spectrum is probably reddened. In order to estimate the reddening, we assume the presence of dust in the quasar with the SMC-like reddening law (Pei 1992). We also tried two other types of reddening laws (Milky Way and LMC), but the Milky Way–like reddening law is rejected by the absence of the 2200 Å feature in the spectrum. Although the LMC-like reddening law is acceptable, the SMC-like reddening law gives us a better fit to the observed spectrum. We also assume the composite quasar spectrum from the SDSS (Vanden Berk et al. 2001) as the unreddened spectrum. The spectral energy distribution (SED) of SDSS J0839+3805 is composed of the spectrum from the SDSS DR3, the photometry from 2MASS, and our spectra, and is shown in Figure 4. We also plotted the SDSS photometric data, except for $u$ band, with the SED in Figure 4. Our spectra were scaled to the 2MASS photometric data. Since our $J$- and $H$-band spectra were taken simultaneously, the scaling factors should be the same value, but they are different by 50%. As seen in Figure 4, the $J$-band 2MASS photometry looks discrepant from the SDSS data, and 2MASS $H$- and $K$-band data. We therefore scaled both $J$- and $H$-band spectra by using the factor adequate for the $H$-band spectrum. The SDSS photometric data match the SDSS spectrum well.

The SED of SDSS J0839+3805 is reasonably well reproduced by a reddened SDSS composite spectrum with a reddening of $E(B - V) \sim 0.15$ mag, which is shown by a dashed line in Figure 4; the reddened composite spectrum delineates the continuum level of the spectrum of SDSS J0839+3805. This amount of reddening is larger than those derived from comparisons between the composite spectrum of LoBALs and that of non-BAL quasars. Brotherton et al. (2001) estimated that LoBAL composites are reddened by $E(B - V) \sim 0.1$ mag by using the data from FBQS, and Reichard et al. (2003) found the average reddening for LoBALs is $E(B - V) \sim 0.08$ mag from SDSS data. However, two known FeLoBALs are extremely reddened. Hawaii 167 has $E(B - V) \geq 0.54 - 0.7$ mag (Egami et al. 1996), and FIRST J155633.8+351758 has $E(B - V) \geq 0.6$ mag (Najita et al. 2000). Hall et al. (2002) discovered several FeLoBALs reddened by $E(B - V) \sim 0.1 - 0.7$ mag. FeLoBALs may be more reddened than LoBALs. Hopkins et al. (2004) also found that 2% of quasars are reddened by $E(B - V) > 0.1$ mag by examining the observed distribution of $z < 2.2$ quasar SEDs including BAL quasars in the SDSS First Data Release quasar catalog (Schneider et al. 2003).

### 4.3. Similarity to NGC 4151

To date, the presence of nonstellar Balmer absorption lines in an active galactic nucleus (AGN) is known only in the spectrum of NGC 4151 (Anderson & Kraft 1969; Sergeev et al. 1999; Hutchings et al. 2002). The EW of H$\alpha$ absorption in NGC 4151 was found to be $2.33 - 5.17$ Å (Anderson 1974; Sergeev et al. 1999), and variable (Anderson 1974; Hutchings et al. 2002). The kinematical characteristics of Balmer absorption are similar to those of H$\alpha$ absorption in SDSS J0839+3805. The velocity blueshift of the H$\beta$ absorption was $\sim 500$ km s$^{-1}$ and FWHMs were $340 - 420$ km s$^{-1}$ in NGC 4151, when the continuum flux of the nucleus was low and the absorption was deep (Hutchings et al. 2002). Interestingly, when the continuum flux of the nucleus was low, there were a large number of Fe ii absorption lines that arose from excited fine-structure levels of the ground term and excited terms in the UV spectrum of NGC 4151 (Crenshaw et al. 2000; Kraemer et al. 2001).

We show the UV spectrum of NGC 4151 in the low state from Kraemer et al. (2001), and compare it to that of SDSS J0839+3805 in Figures 5, 6, and 7. The low-state UV spectrum of NGC 4151 is very similar to that of SDSS J0839+3805, particularly absorption features seen in the wavelength region between 2000 and 2700 Â, although the features of the emission lines such as [N v], [C iv], and [C iii] are different. The remarkable similarity to the low-state UV spectrum of NGC 4151 implies that the conditions of absorbing gas in SDSS J0839+3805 are similar to those in NGC 4151, although a high-resolution spectrum as well as a detailed modeling of it are required to derive a firm conclusion. We also note that a rare He i 3890 absorption line is found in both objects (Anderson & Kraft 1969; Anderson 1974), although there is a possible detection in SDSS J0839+3805. Less than 10 previously known AGNs show He i 3890 absorption lines (Hall et al. 2002).

From the morphology of narrow-line region, NGC 4151 is thought to be seen through the edge of the obscuring torus (Evans et al. 1993). SDSS J0839+3805 may also be a quasar seen from the edge of the torus (Goodrich & Miller 1995; Cohen et al. 1995; Hines & Wills 1995; Schmidt & Hines 1999). As described in § 4.2, SDSS J0839+3805 is indeed reddened by $E(B - V) \sim 0.15$ mag, although the dust-enshrouded quasar model cannot be excluded.

### 5. CONCLUSION

We discovered an H$\alpha$ absorption in the unusual BAL quasar SDSS J0839+3805 with near-infrared spectroscopy. This is the first case for detection of H$\alpha$ absorption in quasars. The H$\alpha$ absorption in SDSS J0839+3805 is blueshifted by 520 km s$^{-1}$ relative to H$\alpha$ emission line, and its redshift is almost coincident with those of UV low-ionization metal absorption lines. The width of H$\alpha$ absorption line is similar to those of the UV low-ionization metal absorption lines ($\sim 340$ km s$^{-1}$). These facts suggest that H$\alpha$ and low-ionization metal absorption lines are produced by the same low-ionization gas, which has a substantial amount of neutral gas. The column density of the neutral hydrogen is expected to be $10^{18}$ cm$^{-2}$ from the analysis of the curve of growth, assuming that the absorbing gas is in thermal equilibrium at a temperature of 10,000 K. SDSS J0839+3805 is found to have $E(B - V) \sim 0.15$ mag when the SED is compared to the quasar composite spectrum. The similarity of the UV spectrum of SDSS J0839+3805 to that of NGC 4151 in its low state is remarkable. This fact suggests the physical conditions of the absorber in SDSS J0839+3805 are similar to those of NGC 4151 in the low state. As proposed for NGC 4151, SDSS J0839+3805 is also considered to be seen through the edge of the obscuring torus.

Observations of H$\beta$ with a much better signal-to-noise ratio are necessary to measure the EW of H$\beta$ absorption. Observations of the H$\alpha$ absorption line with a higher spectral resolution will reveal whether the absorption is a saturated line and whether the absorber fully covers the continuum and the broad emission line...
region. These observations will enable us to estimate the column density of neutral hydrogen more accurately. High-resolution spectroscopy in the optical domain (i.e., rest UV) will also allow us to estimate the column densities of many ions. The ratios of absorption lines from the excited level to that from the ground level, such as Si ii λ15337/Si ii λ1527, provide direct measurements of the electron density. The ionization degree and density of absorbing gas will help us to locate the absorbing gas and find the geometry of the absorber around the nucleus. There are one dozen Hα observations of FeLoBALs (Boroson & Meyers 1992; Egami et al. 1996; Lacy et al. 2002; Najita et al. 2000; Brünger et al. 2003; K. Aoki et al., in preparation). To date, no Hα absorption line has been found except for SDSS J0839+3805. This may be due to such variability as found in NGC 4151 (Crenshaw et al. 2000). The physical origin of Hα absorption is an open question. More spectroscopic data of FeLoBALs in the near-infrared would answer it.

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9 The absorption arising from excited fine-structure levels of the ground term of Si ii is denoted as Si ii'.