CATALOG OF NARROW C IV ABSORPTION LINES IN BOSS. II. FOR QUASARS WITH Z_em > 2.4

ZHI-FU CHEN1,2,3, YI-PING QIN1,3,4, MING QIN1, CAI-JUAN PAN1, and DA-SHENG PAN1

1 Department of Physics and Telecommunication Engineering of Baise University, Baise 533000 China; zhichenfu@126.com
2 Department of Astronomy, Nanjing University, Nanjing 210093, China
3 Center for Astrophysics, Guangzhou University, Guangzhou 510006, China
4 Physics Department, Guangxi University, Nanning 530004, China

ABSTRACT

As the second work in a series of papers aiming to detect absorption systems in the quasar spectra of the Baryon Oscillation Spectroscopic Survey, we continue the analysis of Paper I by expanding the sample of quasars to those with z_em > 2.4. This yields a sample of 21,963 appropriate quasars to search for narrow C IV absorption systems whose absorption redshifts cover a range of z_abs = 1.8784–4.3704. From these spectra, we detect 13,919 narrow C IV absorption systems whose absorption redshifts cover a range of z_abs = 1.8784–4.3704. The latter role would enrich the material for future star formation. The two kinds of interactions are strongly affected by the galactic winds, filament infall, mergers, high velocity clouds, etc. (see Putman et al. 2012 for a review).

Key words: quasars: absorption lines – quasars: general

Online-only material: color figures, machine-readable table

1. INTRODUCTION

As we known, galaxies harbor reservoirs of gas know as the circumgalactic medium (CGM). The interactions between galaxies and their surrounding media involve the accretion of material that is required to maintain star formation and the dynamical mechanisms that influence the galactic environment, and move the heavy elements (metal-enriched gas) produced in the stars of galaxies from their places of production into galactic halos, the CGM, and the intergalactic medium (IGM; Veilleux et al. 2005; Fumagalli et al. 2011; Heckman et al. 2011). The latter role would enrich the material for future star formation. The two kinds of interactions are strongly affected by the galactic winds, filament infall, mergers, high velocity clouds, etc. (see Putman et al. 2012 for a review).

Due to the sensitivity of instruments, however, it is unrealistic to directly observe the fine structures and ingredients of the gaseous clouds harbored by the galaxies, especially for faint galaxies. Fortunately, absorption features are often detected in the spectra of distant objects when their sightlines go through the foreground (1) high velocity clouds, (2) IGM, (3) filament gas, (4) CGM, etc. These absorption features are sensitive and unbiased tool for probing the gases of the universe from early periods (Meiksin 2009). Absorption features imprinted in the quasar spectra provide us with an excellent opportunity to investigate the gaseous content (e.g., densities, ionization structures, metallicities, temperatures, and kinematics) of extra-galactic objects. These investigations do not depend on the luminosity and redshift of the corresponding quasar, or on the velocity and luminosity of the extra-galactic object which might otherwise be invisible. The destinies of the galaxies are ultimately connected to the fate of gas within them, and therefore studies of quasar absorption lines are helpful to our understanding of the properties of galaxies (e.g., Zibetti et al. 2007; Ménard et al. 2011; Chen 2013; Burchett et al. 2013; Nielsen et al. 2013; Kacprzak et al. 2013).

Neutral- to high-ionization absorption lines have been observed in quasar spectra (e.g., Misawa et al. 2007; Tombesi et al. 2011; Chen et al. 2013a, 2013d; Chen & Qin 2013c; Gupta et al. 2013). These absorption features have historically been divided into three classes according to their line widths: (1) broad absorption lines (BALs) with line widths of no less than 2000 km s−1 at depths > 10% below the continuum, (2) narrow absorption lines (NALs) with line widths of less than a few hundred km s−1, and (3) mini-BALs with intermediate line widths between those of BALs and NALs (e.g., Weilmann et al. 1979; Rodríguez Hidalgo et al. 2011; Filipiak et al. 2012; Hamann et al. 2013).

Using the quasar spectra of the Sloan Digital Sky Survey (SDSS; York et al. 2000), many authors have conducted campaigns to systematically search for narrow metal absorption lines (e.g., Quider et al. 2011; Qin et al. 2013; Zhu & Ménard 2013; Cooksey et al. 2013; Seyffert et al. 2013). The SDSS program continued with the Third SDSS (SDSS-III) using the same 2.5 m telescope (Gunn et al. 2006; Ross et al. 2012). This program collected data from 2008 to 2014. The Baryon Oscillation Spectroscopic Survey (BOSS) is the main dark time legacy survey of SDSS-III (Paris et al. 2012), which has obtained more than 150,000 quasar spectra with z_em > 2.15 during its five year run time. The BOSS spectrograph has a wavelength range of 3600 Å—10400 Å at a resolution of 1300 < R < 3000. The SDSS Data Release Nine (SDSS-DR9), which is the first spectral data release of BOSS to the public, includes 87,822 quasars detected over an area of 3275 deg² (Paris et al. 2012).

This paper is the second part in a series aiming to analyze absorption lines in the BOSS quasar spectra. We intend to search for narrow absorption doublets (e.g., Mg ii λλ2796, 2803 and C IV λλ1548, 1551) in the BOSS quasar spectra. In the first
paper, Chen et al. (2014a, 2014b; hereafter, the two papers are referred to as Paper I), we focused on narrow C<sup>IV</sup> absorption doublets. Paper I concerned those quasars with z<sub>em</sub> > 2.4 and z<sub>abs</sub> < 2.4. In this paper, we detect C<sup>IV</sup> λλ1548, 1551 absorption on the spectra of the quasars with S/N ≥ 4 and z<sub>em</sub> > 2.4.

(A color version of this figure is available in the online journal.)

This work continues the detection of Paper I by expanding the quasar sample to those quasars with z<sub>em</sub> > 2.4 to search for narrow C<sup>IV</sup> absorption doublets in the BOSS quasar spectra.

We describe our data analysis in Section 2 and present the statistical properties of absorptions in Section 3. The summary is presented in Section 4.

2. DATA ANALYSIS

This work continues the analysis of Paper I by expanding the quasar sample to those quasars with z<sub>em</sub> > 2.4. We adopt the same methods to construct quasar samples and detect narrow C<sup>IV</sup> absorption doublets. Here, we simply summarize the main steps involved in the quasar selection and absorption-line detection procedures. Readers can refer to Paper I for more details.

In order to avoid confusion from Ly<sub>α</sub>, O<sub>I</sub> λ1302, and S<sub>II</sub> λ1304 absorption and the noisy region of the spectra, the spectra regions shortward of 1310 Å in the rest frame or shortward of 3800 Å in the observed frame are not considered. In addition, to detect as much of the intervening C<sup>IV</sup> absorption doublets as possible, we constrain our analysis to the data range within 10,000 km s<sup>−1</sup> blueward of the quasar system. These cuts reduce the number of SDSS DR9 quasars from 87,822 to 70,336.

Each quasar spectrum has a value of the median S/N (median S/N). Based on the median value of the median S/N of these 70,336 quasars, median S/N ≥ 4 is adopted to alleviate the noise confusion superposed on the spectra with low values of S/N. This further reduces the number of quasar samples from 70,336 to 37,241.

As a continuation of the work of Paper I, here we only concern ourselves with high-redshift quasars with z<sub>em</sub> > 2.4. Considering all of the above limitations, we obtain 21,963 appropriate quasars. Figure 1 shows the limits of the median S/N and the redshift. The emission redshift distribution of 21,963 quasars is shown by the red line in Figure 2.

For each quasar, a combination of the cubic spline function and Gaussian functions was invoked to derive a pseudo-continuum in an iterative fashion (e.g., Nestor et al. 2005; Chen et al. 2013a, 2013d, 2013b; Chen & Qin 2013c). C<sup>IV</sup> absorption doublets were detected on the pseudo-continuum fitting normalized spectra. There are several steps in this detection. First, we label the 2σ flux uncertainty level and get rid of the absorption troughs above this level. Second, BALs are disregarded by the program searching for candidate absorptions. Third, in this program, a Gaussian function is adopted to fit each absorption feature, while the absorption figures with FWHM greater than 800 km s<sup>−1</sup> are ignored. Fourth, measurements of the equivalent widths at rest-frame (W<sub>e</sub>) of the candidate absorptions are based on the Gaussian fittings, and estimations of their flux uncertainties are performed via

\[
(1+z)\sigma_w = \sqrt{\frac{\sum_i P^2(\lambda_i - \lambda_0)\sigma_{f_i}^2}{\sum_i P^2(\lambda_i - \lambda_0)}} \Delta \lambda, \tag{1}
\]

where, as a function of pixel, \(P(\lambda_i - \lambda_0)\), \(\lambda_i\), and \(\sigma_{f_i}\) are the line profile centered at \(\lambda_0\), the wavelength, and the normalized flux uncertainty, respectively. The S/N of the candidate absorption lines is estimated using the same method adopted by Qin et al. (2013). The value of 1σ noise is computed via

\[
\sigma_N = \sqrt{\frac{\sum_{i=1}^{M} \left( \frac{F_{\lambda_{\text{rest}}}}{F_{\lambda_{\text{rest}}}} \right)^2}{M}}, \tag{2}
\]
The absorption data are provided in Table 1.

where \( F_{\text{noise}} \), \( F_{\text{cont}} \), and \( i \) are the flux uncertainty, the flux of the pseudo-continuum fitting, and the pixel in the wavelength range of 1548 Å \( \times (1 + z_{\text{abs}}) - 5 \) Å \( < \lambda_{\text{abs}} < 1551 \) Å \( \times (1 + z_{\text{abs}}) + 5 \) Å, respectively. Based on the value determined by formula (2), we can obtain the S/N of the candidate absorption line via

\[
S/N^2 = \frac{1 - S_{\text{abs}}}{\sigma_N},
\]

where \( S_{\text{abs}} \) is the largest depth within an absorption trough with respect to the pseudo-continuum fitting in the normalized spectra. Fifth, all absorption features with \( W_r > 0.2 \) Å and \( S/N^2 \geq 2.0 \) for both lines of the doublet are kept in the catalog.

Using the same method as in Paper I, we find that 9708 quasars from the quasar sample (containing 21,963 quasars) host narrow C IV absorption system(s). From these 9708 quasar spectra, we obtain 13,919 potential intervening C IV absorption systems. The absorption data are provided in Table 1.

3. STATISTICAL PROPERTIES OF THE ABSORBERS

3.1. Properties of the Absorbers in Catalog II

This paper is the second in a series on the analysis of absorption lines in the quasar spectra of BOSS, which expands the quasar sample to quasars with \( z_{\text{em}} > 2.4 \). 21,963 appropriate quasars are adopted to search for narrow C IV \( \lambda \lambda 1548, 1551 \) absorption doublets. Among these, 9708 quasars are observed to host appropriate C IV absorption feature imprinted on their spectra. The distributions of the emission redshifts of the 21,963 quasars and the 9708 quasars are shown in Figure 2. In the 9708 quasar spectra, we detect 13,919 narrow C IV \( \lambda \lambda 1548, 1551 \) absorption doublets with \( 1.8784 \leq z_{\text{abs}} \leq 4.3704 \), and the distribution of these absorption redshifts are also shown in Figure 2. (Note that these absorption doublets only refer to catalog II, and those contained in Paper I only refer to catalog I.)

In Figure 3, we plot the total redshift path covered by the absorbers of catalog II as a function of the S/N of the absorption features, which is calculated by

\[
Z(S/N_{1548}) = \sum_{i=1}^{N_{\text{max}}} \int_{z_{\text{min}}}^{z_{\text{max}}} g_i(S/N_{1548}, z) dz,
\]

where \( z_{\text{max}} \) and \( z_{\text{min}} \) are the redshifts corresponding to the maximum and minimum wavelengths in the survey spectral region of quasar \( i \), respectively; \( g_i(S/N_{1548}, z) = 1 \) if \( S/N_{\text{lim}} \approx S/N_{1548}, \) otherwise \( g_i(S/N_{1548}, z) = 0 \) (see also Qin et al. 2013; Paper I).

In Figure 4, we show the \( W_r \) distributions of detected C IV \( \lambda \lambda 1548, 1551 \) absorption doublets in catalog II, which are similar to those in catalog I. Smooth tails out to \( W_r \approx 3.0 \) Å can clearly be seen in these distributions. The largest and median values of \( W_r \) are 2.95 Å and 0.60 Å, respectively, and those of \( W_r \) are 2.93 Å and 0.47 Å, respectively. In catalog II, only a few absorbers with large \( W_r \) are detected, with only 1.0% (137/13919) and 16.9% (2349/13919) of the total absorbers having \( W_r \approx 2.0 \) Å and 1.0 Å \( \leq W_r \approx 2.0 \) Å, respectively. Most absorbers show small or medium values of absorption strengths, with about 47.2% (6564/13919) and 35.0% (4869/13919) of the total absorbers having 0.5 Å \( \leq W_r \approx 1.0 \) Å and 0.2 Å \( \leq W_r \approx 0.5 \) Å, respectively. These proportions are similar to those in Paper I.

The saturated degree of absorptions can be evaluated by the \( W_r \) ratio (DR; Strömgren 1948). Theoretical values of DR of the C IV \( \lambda \lambda 1548, 1551 \) resonant doublet can vary from 1.0 for completely saturated absorption to 2.0 for completely

Table 1

| SDSS NAME     | PLATEID | MJD  | FIBERID | \( z_{\text{em}} \) | \( z_{\text{abs}} \) | \( W_r \lambda_{1548} \) | \( N_{\text{abs}} \lambda_{1548} \) | \( W_r \lambda_{1551} \) | \( N_{\text{abs}} \lambda_{1551} \) | \( S/N_{1548} \) | \( S/N_{1551} \) | \( \beta \) |
|---------------|---------|------|---------|---------------------|----------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|----------------|----------------|--------|
| 000014.07+012951.5 | 4296 | 55499 | 0370 | 3.2284 | 2.6728 | 0.70 | 4.38 | 0.68 | 4.00 | 4.2 | 3.8 | 0.13994 |
| 000015.17+004833.2 | 4216 | 55477 | 0718 | 3.0277 | 2.5222 | 1.11 | 6.94 | 0.84 | 7.64 | 6.4 | 7.1 | 0.13331 |
| 000027.31+013126.1 | 4296 | 55499 | 0382 | 2.5892 | 2.3169 | 0.35 | 4.38 | 0.37 | 4.63 | 3.9 | 4.1 | 0.07874 |
| 000041.87+001207.2 | 4216 | 55477 | 0274 | 3.0514 | 2.6206 | 0.37 | 6.17 | 0.42 | 5.25 | 6.0 | 4.9 | 0.11195 |
| 000041.87+001207.2 | 4216 | 55477 | 0274 | 3.0514 | 2.6600 | 0.83 | 5.93 | 0.30 | 3.33 | 5.6 | 3.2 | 0.10125 |
| 000046.42+011420.8 | 4216 | 55477 | 0742 | 3.7588 | 3.1522 | 1.50 | 8.33 | 1.39 | 8.69 | 7.9 | 8.2 | 0.13552 |
| 000046.42+011420.8 | 4216 | 55477 | 0742 | 3.7588 | 3.1777 | 1.39 | 9.93 | 1.09 | 8.38 | 9.4 | 7.7 | 0.12950 |
| 000051.56+001202.5 | 4216 | 55477 | 0778 | 3.8953 | 3.3315 | 1.18 | 4.54 | 1.19 | 4.76 | 4.3 | 4.5 | 0.12175 |
| 000051.56+001202.5 | 4216 | 55477 | 0778 | 3.8953 | 3.3721 | 2.43 | 9.00 | 2.87 | 10.63 | 8.5 | 10.0 | 0.11255 |
| 000057.58+010658.6 | 4216 | 55477 | 0750 | 2.5493 | 2.0827 | 0.48 | 4.36 | 0.80 | 8.00 | 4.1 | 7.7 | 0.14002 |

Notes. \( N_{\text{abs}} = (W_r / \sigma_{W_r}) \) represents the significant level of the detection. \( \beta = v/c = ((1 + z_{\text{em}})^2 - (1 + z_{\text{abs}})^2) / ((1 + z_{\text{em}})^2 + (1 + z_{\text{abs}})^2) \).

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)
unsaturated absorption (e.g., Sargent et al. 1988). In Figure 5, we show the DR of the C iv $\lambda \lambda 1548, 1551$ resonant doublet ($W_r \lambda 1548/W_r \lambda 1551$) in catalog II where the theoretical boundaries of the completely unsaturated and completely saturated absorption are plotted with red dash lines. A maximum value (4.7) of the DR and a minimum value (0.2) can be seen in the figure. There are approximately 20.4% (2844/13919) and 7.1% (993/13919) absorbers with $DR < 1.0$ and $DR > 2.0$, respectively. Meanwhile, there are approximately 72.4% (10082/13919) absorbers with $1.0 \leq DR \leq 2.0$. These proportions are similar to those in Paper I. Some narrow absorption features cannot be resolved by a low-/middle-resolution spectrograph, which may result in blending of narrow absorption features. BOSS spectra have a resolution of $1300 < R < 3000$. These low-/middle-resolution spectra can lead to some very narrow C iv absorptions suffering from blending with unrelated absorption features. The “false positive” lines, which happen to have the same separation as the two lines of the C iv doublet but essentially no relation to each other, may confuse the identification of the C iv absorption doublet. We guess that line blending and this kind of “false positive” line would be the main reason accounting for the fact that about a quarter of the narrow C iv systems lie outside the theoretical limits of the $W_r$ ratio. This conjecture could be checked by Monte Carlo simulations. That is an interesting issue that deserves a detailed investigation, and we intend to do so in a later paper.

We calculate the frequency of detected C iv absorption doublets ($f_{\text{NALs}}$) to provide an expression of the false positives/negatives of C iv absorption doublets as follows:

$$f_{\text{NALs}} = \lim_{\Delta S/N \to 0} \frac{\Delta N_{\text{abs}}}{\Delta N_{\text{sdp}}},$$

where $\Delta N_{\text{abs}}$ is the number of detected C iv absorption doublets and $\Delta N_{\text{sdp}}$ is the number of data points in the S/N bin $\Delta S/N$. The derivation of $f_{\text{NALs}}$ is shown in Figure 6. It clearly shows a smooth distribution of $f_{\text{NALs}}$ in the range of $S/N_{\lambda 1548} \gtrsim 4$, which implies a complete detection when the S/N is larger than 4. This is similar to what was found in Paper I.

Figure 6 also suggests a significant incomplete detection when $S/N_{\lambda 1548} \lesssim 4$, whose missing rate ($f_{\text{MR}}$) can be evaluated in several S/N bins by

$$f_{\text{MR}} = \frac{f_{\text{NALs}} - f_{\text{NALs}}}{f_{\text{NALs}}}$$

where $f_{\text{NALs}}$ and $f_{\text{NALs}}$ are the average frequency of NALs in the range of $S/N_{\lambda 1548} > 4$ and the frequency of NALs in the corresponding S/N bin, respectively. The results are provided in Table 2.
The Astrophysical Journal Supplement Series, 215:12 (7pp), 2014 November

Chen et al.

Figure 7. Distributions of redshifts included in catalogs (I–II). See Figure 2 for the meanings of the lines.

(A color version of this figure is available in the online journal.)

Table 2

| S/N Bin     | (2.0, 2.5) | (2.5, 3.0) | (3.0, 3.5) | (3.5, 4.0) |
|-------------|------------|------------|------------|------------|
| fMR         | 0.88       | 0.56       | 0.53       | 0.07       |

3.2. Properties of the Absorbers in Catalogs I–II

As the first two papers in a series concerned with searching absorption lines in the BOSS quasar spectra, we have collected a sample of 37,241 appropriate quasars with median S/N \( \lambda 1548 \geq 4 \) and \( 1.54 \leq z_{\text{em}} \leq 5.16 \) to detect potential intervening C iv \( \lambda \lambda 1548, 1551 \) absorption. From the quasar sample, we have found 15,999 quasars with at least one appropriate C iv \( \lambda \lambda 1548, 1551 \) absorption doublet imprinted on their spectra. From these 15,999 quasar spectra, we have detected 23,336 narrow C iv \( \lambda \lambda 1548, 1551 \) absorptions with \( z_{\text{abs}} = 1.4544–4.3704 \). In Figure 7, we display the distributions of emission redshifts of 37,241 quasars and 15,999 quasars, as well as the absorption redshifts of the 23,336 absorbers.

The redshift path of catalogs I and II is calculated using formula (4) as well. The result is plotted in Figure 8 where the redshift paths covered by catalogs I and II are also shown with dot-dashed and dashed lines, respectively.

The \( W_r \) distributions are plotted in Figure 9 which shows tails up to \( W_r \approx 3 \) Å. The largest and median absorption strengths of the \( \lambda 1548 \) lines are \( W_r \lambda 1548 = 3.19 \) Å and 0.61 Å, respectively, and those of \( \lambda 1551 \) are \( W_r \lambda 1551 = 2.93 \) Å and 0.48 Å, respectively. We find that in catalogs I and II, there are a few absorbers with large \( W_r \), namely, only 1.1% (249/23336) and 17.8% (4124/23336) absorbers of the total with \( W_r \lambda 1548 \geq 2.0 \) Å and \( 1.0 \leq W_r \lambda 1548 < 2.0 \) Å, respectively. Most of the absorbers show small or middle absorption strength values. That is, about 46.6% (10879/23336) and 34.6% (8084/2336) of the total absorbers have \( 0.5 \leq W_r \lambda 1548 < 1.0 \) Å and \( 0.2 \leq W_r \lambda 1548 < 0.5 \) Å, respectively.

The distribution of the \( W_r \) ratio is displayed in Figure 10. The \( W_r \) ratio has a maximum value of 4.7 and a minimum value of 0.2. About 21.2% (4958/23336) and 6.7% (1565/23336) of absorbers have \( DR < 1.0 \) and \( DR > 2.0 \), respectively. Also, approximately 72.1% (16813/23336) absorbers have \( 1.0 \leq DR \leq 2.0 \).

The detected frequency of the C iv absorptions is calculated using formula (5). The derived result is plotted in Figure 11 where the distributions of \( f_{\text{NALS}} \) obtained from catalogs I and II are displayed with dot-dashed and dashed lines, respectively. The smooth curves are the distributions of \( f_{\text{NALS}} \) with \( S/N_{\lambda 1548} \geq 4 \).

We estimate the missing rate of absorption systems with \( S/N_{\lambda 1548} \leq 4 \) in several bins of the S/N using formula (6). The derived results are provided in Table 3.
4. SUMMARY

This paper continues the work of Paper I aiming to detect absorption lines by expanding the quasar sample to those quasars with $z_{\text{em}} > 2.4$. This sample contains 21,963 quasars, of which 9708 quasars have at least one potential intervening C IV $\lambda \lambda 1548, 1551$ absorption system with $W_r \geq 0.2 \, \text{Å}$ for both lines. From these quasar spectra, we have detected 13,919 appropriate C IV $\lambda \lambda 1548, 1551$ absorption systems with $z_{\text{abs}} = 1.8784–4.3704$. About 35.0%, 47.2%, 16.9%, and 1.0% of the total absorbers have $W_r \lambda 1548 = 0.2–0.5 \, \text{Å}$, $W_r \lambda 1548 = 0.5–1.0 \, \text{Å}$, $W_r \lambda 1548 = 1.0–2.0 \, \text{Å}$, and $W_r \lambda 1548 \geq 2.0 \, \text{Å}$, respectively.

The absorption doublets detected in this paper refer to catalog II, and those from Paper I refer to catalog I. Catalogs I and II contain a total of 15,999 quasars that have been detected as hosting appropriate C IV absorptions imprinted on their spectra. These quasars are selected from a sample of 70,336 quasars in the limit of median S/N $\geq 4$. From these quasar spectra, we have detected 23,336 narrow C IV absorption systems with $z_{\text{abs}} = 1.4544–4.3704$. The largest absorption strengths are 3.19 Å and 2.93 Å for the $\lambda 1548$ and $\lambda 1551$ lines, respectively. Only a few absorbers show large values of $W_r$, with most of the absorbers having small or middle values of $W_r$. About 34.6%, 46.6%, 17.8%, and 1.1% of the total absorbers have $W_r \lambda 1548 = 0.2–0.5 \, \text{Å}$, $W_r \lambda 1548 = 0.5–1.0 \, \text{Å}$, $W_r \lambda 1548 = 1.0–2.0 \, \text{Å}$, and $W_r \lambda 1548 \geq 2.0 \, \text{Å}$, respectively.

We thank the anonymous referee for helpful comments and suggestions. This work was supported by the National Natural Science Foundation of China (No. 11363001), the Guangxi Natural Science Foundation (2012jaAA10090), the Guangzhou technological project (No. 11C62010685), Guangdong Province Universities and Colleges Pearl River Scholar Funded Scheme (GDUPS) (2009), Yangcheng Scholar Funded Scheme (10A027S), and the Guangxi University of Science and Technology Research Projects (No. 2013XLX15).

Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy Office of Science. The SDSS-III Web site is http://www.sdss3.org/.

SDSS-III is managed by the Astrophysical Research Consortium for the Participating Institutions of the SDSS-III Collaboration including the University of Arizona, the Brazilian Participation Group, Brookhaven National Laboratory, Carnegie Mellon University, University of Florida, the French Participation Group, the German Participation Group, Harvard University, the Instituto de Astrofisica de Canarias, the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, New York University, Ohio State University, Pennsylvania State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University.

REFERENCES

Burchett, J. N., Tripp, T. M., Werk, J. K., et al. 2013, ApJL, 779, L17
Chen, Z. F. 2013, RAA, 13, 641
Chen, Z. F., Li, M. S., Huang, W. R., Pan, C. J., & Li, Y. B. 2013a, MNRAS, 434, 3275
Chen, Z. F., Pan, C. J., Li, G. Q., Huang, W. R., & Li, M. S. 2013b, JApA, 34, 317
Chen, Z. F., Qin, Y. P., & Gu, M. F. 2013d, ApJ, 770, 59
Chen, Z. F., Qin, Y. P., Pan, C. J., et al. 2014a, ApJS, 210, 7
Chen, Z. F., Qin, Y. P., Pan, C. J., et al. 2014b, ApJS, 212, 17
Cooksey, K. L., Kao, M. M., Simcoe, R. A., O’Meara, J. M., & Prochaska, J. X. 2013, ApJ, 763, 37
Fumagalli, M., Prochaska, J. X., Kasen, D., et al. 2011, MNRAS, 418, 1796
Filiz Ak, N., Brandt, W. N., Hall, P. B., et al. 2012, ApJ, 757, 114
Gunn, J. E., Siegmund, W. A., Mannery, E. J., et al. 2006, AJ, 131, 2332
Gupta, A., Mathur, S., Krongold, Y., & Nicastro, F. 2013, ApJ, 768, 141
Hamann, F., Chatters, G., McGraw, S., et al. 2013, MNRAS, 435, 133
Heckman, T. M., Borthakur, S., Overzier, R., et al. 2011, ApJ, 730, 5
Kacprzak, G. G., Cooke, J., Churchill, C. W., Ryan-Weber, E. V., & Nielsen, N. M. 2013, ApJL, 777, L11
Meiksin, A. A. 2009, RvMPh, 81, 1405
Menard, B., Wild, V., Nestor, D., et al. 2011, MNRAS, 417, 801
Misawa, T., Tyler, D., Iye, M., et al. 2007, AJ, 134, 1634
Nestor, D. B., Turnshek, D. A., & Rao, S. M. 2005, ApJ, 628, 637
Nielsen, N. M., Churchill, C. W., Kacprzak, G. G., & Murphy, M. T. 2013, ApJ, 776, 14
Páris, I., Petitjean, P., Aubourg, É., et al. 2012, A&A, 548, 66
Putman, M. E., Peek, J. E. G., & Joung, M. R. 2012, ARA&A, 50, 491
Qin, Y. P., Chen, Z. F., Lü, L. Z., et al. 2013, PASJ, 65, 8
Quider, A. M., Nestor, D. B., Turnshek, D. A., et al. 2011, AJ, 141, 137
Rodríguez Hidalgo, P., Hamann, F., & Hall, P. 2011, MNRAS, 411, 247
Ross, N. P., Myers, A. D., Sheldon, E. S., et al. 2012, ApJS, 199, 3
Sargent, W. L. W., Boksenberg, A., & Steidel, C. C. 1988, ApJS, 68, 539
Seyffert, E. N., Cooksey, K. L., Simcoe, R. A., et al. 2013, ApJ, 779, 161
Strömgren, B. 1948, ApJ, 108, 242
Tombesi, F., Cappi, M., Reeves, J. M., et al. 2011, ApJ, 742, 44
Weymann, R. J., Williams, R. E., Peterson, B. M., & Turnshek, D. A. 1979, ApJ, 234, 33
Veilleux, S., Cecil, G., & Bland-Hawthorn, J. 2005, ARA&A, 43, 769
York, D. G., Adelman, J., Anderson, J. E., Jr, et al. 2000, AJ, 120, 1579
Zhu, G. T., & Ménard, B. 2013, ApJ, 770, 130
Zibetti, S., Ménard, B., Nestor, D. B., et al. 2007, ApJ, 658, 161