Optical Spectra of Candidate International Celestial Reference Frame (ICRF) Flat-spectrum Radio Sources. III.

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Abstract

In extending our spectroscopic program, which targets sources drawn from the International Celestial Reference Frame (ICRF) Catalog, we have obtained spectra for ~160 compact, flat-spectrum radio sources and determined redshifts for 112 quasars and radio galaxies. A further 14 sources with featureless spectra have been classified as BL Lac objects. Spectra were obtained at three telescopes: the 3.58 m European Southern Observatory New Technology Telescope, and the two 8.2 m Gemini telescopes in Hawaii and Chile. While most of the sources are powerful quasars, a significant fraction of radio galaxies is also included from the list of non-defining ICRF radio sources.

Key words: BL Lacertae objects: general – galaxies: active – quasars: emission lines – radio continuum: general – reference systems

Supporting material: extended figure, machine-readable table

1. Introduction

The accurate alignment of astronomical catalogs produced at different wavelengths is critical for confident identification of celestial objects. Milliarcsecond positions of compact extragalactic radio sources have been used since 1998 to define the International Celestial Reference Frame (ICRF; Ma et al. 1998). The current realization of the International Celestial Reference System (Arias et al. 1995) is the catalog known as ICRF2 (Second Realization of the ICRF). It is based on the progressive refinement since 1984 of the positions of a set of reference radio sources measured with very long baseline interferometry (VLBI) techniques (Ma et al. 2009; Fey et al. 2015). Some technical details are provided in our previous papers (Titov et al. 2011, 2013). The ICRF2 catalog is based on the assumption that the reference radio sources have significant proper motion, and so their astrometric positions are affected only by their relativistic jets. However, at milliarcsec levels, Bastian (1995), Gwinn et al. (1997), Sovers et al. (1998), and Kovalevsky (2003) have drawn attention to the effect of aberration in proper motions, while a dipole systematic of magnitude ~6 μas yr⁻¹, detected by Titov et al. (2011) and Titov & Lambert (2013), may degrade positions in the same way that the proper motions of stars degraded the old optical catalogs.

The astrometric mission Gaia (Perryman et al. 2001; Mignard 2012) was launched on 2013 December 19 by the European Space Agency, and the first results have recently been published (Lindegren et al. 2016). One of the mission goals has been to improve the high-precision positions and proper motions of ~500,000 quasars. A new astrometric reference frame based on the optical counterparts of the ICRF radio sources is being built, assuming that quasar parallaxes are zero (Michalik & Lindegren 2016). These new data will also test for the presence and magnitude of the dipole proper motion reported by Titov et al. (2011) and Titov & Lambert (2013), as well as any higher-order systematics. The alignment of radio and optical reference frames demands a reliable optical identification of the radio sources and, if possible, a redshift to confirm the identification. However, only approximately half of the ICRF radio sources have a measured redshift (Titov & Malkin 2009).

The reference radio sources are either optically bright quasars or extended radio galaxies. Our ongoing observing strategy first identifies the optical counterpart for each source using either the SuperCOSMOS Sky Survey (Hambly et al. 2001) or the Sloan Digital Sky Survey (SDSS; DR9 through 13; York et al. 2000), and we then obtain a spectrum to secure a redshift. We routinely obtain a short-exposure wideband image of the field prior to starting the spectroscopic exposure; first, to confirm the identification, and second to guard against possible confusion by foreground stars, especially in crowded fields (e.g., see Figure 3 in Titov et al. 2013). Good seeing is a critical issue in the latter case.

The current paper, Part III of our ongoing project, presents redshifts for 112 targets, which are mostly in the southern hemisphere. The majority appear to be point-like in the optical with broad permitted lines or BL Lac objects with featureless spectra; only two clear galaxies with narrow emission lines are presented, although classification of images near the limiting magnitudes of the optical surveys is difficult. We describe the observations and data reduction procedures in Section 2. Our spectra, along with detailed comments on individual sources, are presented in Section 3. A discussion of targets showing interesting emission or absorption properties is given in Section 4, followed by a summary and conclusion in Section 5. Where relevant, a ΛCDM cosmology has been assumed, with H₀ = 70 km s⁻¹ Mpc⁻¹, Ω₀ = 0.29, and Ω₀ = 0.71.

2. Observations

Spectroscopic observations were carried out at three optical facilities.
were calculated as discussed in Titov et al., with a spectral resolution of 21 Å FWHM, giving an rms accuracy of 0.3 Å.

Wavelength calibration used the spectra of a CuAr comparison lamp, giving an rms accuracy of 0.5 Å. The seeing during observations was typically 0′′.5–2′′.0, with a spectral resolution of 21 Å FWHM. Exposure times varied from 5 to 30 minutes depending on the magnitude of each target and current sky conditions. Wavelength calibration made use of HeNeAr comparison spectra, resulting in an rms accuracy of 0.5 Å.

European Southern Observatory (ESO) NTT. We had a five-night observing run in Visitor Mode at the ESO 3.58 m New Technology Telescope (NTT) in 2013 December (Proposal 092.A-0021 (A)) using the ESO Faint Object Spectrograph and Camera system with grism #13 covering the wavelength range 3685–9315 Å. The seeing during observations was typically 0′′.5–2′′.0, with a spectral resolution of 21 Å FWHM. Exposure times varied from 5 to 30 minutes depending on the magnitude of each target and current sky conditions. Wavelength calibration made use of HeNeAr comparison spectra, resulting in an rms accuracy of 0.5 Å.

Gemini. A large number of targets were observed in Service Mode at the Gemini North and Gemini South 8.2 m telescopes through the Poor Weather Program (Proposals GN-2012B-Q-127, GS-2013A-Q-99, GS-2014A-Q-92) using the Gemini Multi-Object Spectrograph (GMOS) system with grating R400 at each site. This grating covers 4500 Å centered at 5200 Å. The wavelength resolution was ~15 Å FWHM, and an exposure time of 20 minutes was used for all targets. Wavelength calibration used the spectra of a CuAr comparison lamp, giving an rms accuracy of 0.3 Å.

Data reduction was performed with the IRAF software suite using standard procedures for spectral analysis. Bias and flat-field correction was applied to each frame, and cosmic rays were removed using the IRAF task SZAP. Where more than one exposure was obtained, the separate exposures were combined. After spectrum extraction, sky subtraction, and wavelength calibration, the final one-dimensional spectra were flux-calibrated with a spectrophotometric standard observed with the same instrumental setup. Because the observing conditions were often non-photometric, especially for Gemini observations made through the Poor Weather Program, the flux calibration should be taken as approximate.

### 3. Results

We present our spectroscopic results in the same format as our previous paper (Titov et al. 2013). The redshifts of 112 IVS objects are listed in Table 1, along with their J2000 ICRF2 positions (Ma et al. 2009; Fey et al. 2015), the telescope used for each spectrum, the identified emission lines (rest and observed wavelengths), the mean redshift and error, and brief notes on individual sources. Additional notes on individual sources, marked with an asterisk in the rightmost column, are given in Section 3.1. The quoted errors in the mean redshift \( \bar{z} \) were calculated, while the red dotted—dashed lines indicate lines that were present, generally at a low S/N.

### Table 1

| Source     | R.A. (J2000) | decl. (J2000) | Telescope | Line     | Rest \( \lambda \) | Obs \( \lambda \) | \( \bar{z} \) | Note* |
|------------|--------------|--------------|-----------|----------|-----------------|-----------------|---------|-------|
| IVS B0001–440 | 00 04 07.2575 | –43 45 10.146 | GS        | Mg II    | 2799.9          | 5582.9          | 0.994 ± 0.001 | S     |
| IVS B0009+081 | 00 11 35.2696 | +08 23 55.586 | GN        | C III    | 1908.7          | 4587.4          | 1.4032 ± 0.0003 |       |
| IVS B0010–873 | 00 11 51.4792 | –87 06 25.453 | GS        | Ly\(\alpha\) | 1215.7          | 5218.9          | 3.2928 ± 0.0026 |       |
| IVS B0016–223 | 00 19 22.8280 | –22 05 27.938 | GS        | Mg II    | 2799.9          | 4637.1          | 0.6559 ± 0.0003 |       |
|            |              |              |           | [Ne \(\lambda\)] | 3345.4          | 5536.8          |         |       |
|            |              |              |           | [O \(\lambda\)] | 3425.5          | 5674.5          |         |       |
|            |              |              |           | N \(\lambda\)   | 3726.8          | 6172.2          |         |       |
|            |              |              |           | [O \(\lambda\)] | 3867.8          | 6405.2          |         |       |
|            |              |              |           | [Ne \(\lambda\)] | 3967.4          | 6571.1          |         |       |
|            |              |              |           | H\(\alpha\)    | 4101.7          | 6789.1          |         |       |
|            |              |              |           | [O \(\lambda\)] | 4340.5          | 7182.6          |         |       |
|            |              |              |           | [O \(\lambda\)] | 4363.2          | 7219.4          |         |       |

Notes.

* ICRF2 radio position.

b Telescope abbreviations: GN—Gemini North, GS—Gemini South, NTT—ESO New Technology Telescope.

c Square brackets indicate that the line was not used for redshift determination.

d “S” denotes a single-line redshift; * indicates a note in Section 3.1.

(This table is available in its entirety in machine-readable form.)

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\[ S / N \]

\[ \Delta z = 0.001 \]

\[ S / N \]

\[ \bar{z} \]

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5 IRAF is distributed by the National Optical Astronomical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.
Figure 1. Optical spectra for 112 emission-line IVS targets. Dashed lines (blue) indicate emission lines used for redshift determination; dotted–dashed lines (red) indicate lines detected at lower signal to noise or blended lines. Short gaps in Gemini spectra are due to physical gaps between the GMOS CCDs. Occasional larger gaps arise from calibration problems or strong cosmic-ray contamination.

(An extended version of this figure is available.)
obtain redshifts for 11 IVS targets at low Galactic latitude were
note.

| Source       | R.A. (J2000) | decl. (J2000) | Telescope |
|--------------|-------------|--------------|-----------|
| IVS B0019−261 | 00 21 32.5495 | −25 50 49.387 | GS        |
| IVS B0138−381 | 01 40 36.8208 | −37 56 45.798 | NTT       |
| IVS B0141+268 | 01 44 33.5538 | +27 05 03.119 | GN        |
| IVS B0142−590 | 01 43 47.4305 | −58 45 51.375 | NTT       |
| IVS B0258−170 | 03 01 16.6227 | −16 52 05.845 | GS        |
| IVS B0839−357 | 08 41 21.6331 | −35 55 05.967 | NTT       |
| IVS B0843−547 | 08 45 02.4822 | −54 58 08.954 | NTT       |
| IVS B1029−854 | 10 26 34.3753 | −85 43 14.295 | NTT       |
| IVS B1101−536 | 11 03 52.2217 | −53 57 00.697 | NTT       |
| IVS B1304−427 | 13 07 37.9835 | −42 59 38.987 | NTT       |
| IVS B1711−670 | 17 16 22.3365 | −67 06 24.119 | GS        |
| IVS B2257+313 | 23 00 22.8374 | +31 37 04.405 | GN        |
| IVS B2308+018 | 23 11 01.2929 | +02 05 05.327 | GN        |
| IVS B2310+062 | 23 13 07.7015 | +06 28 38.847 | GN        |

Note.

* ICRF2 radio position.

An additional 23 targets had low S/N spectra that did not permit a confident spectral classification. These are listed in Table 3 with their ICRF2 positions. Attempts to identify and obtain redshifts for 11 IVS targets at low Galactic latitude were not successful.

3.1. Notes on Individual Targets

1. IVS B0023−354—intervening absorption system at $\zabs = 1.3167 \pm 0.0010$ with lines of Fe II $\lambda \lambda 2586$, 2600, Mg II $\lambda \lambda 2796$, 2803, and Mg I $\lambda 2852$. Although the Mg II doublet is not resolved, the presence of Mg I and Fe II confirm the system.

2. IVS B0048+447—two associated absorption systems are detected within the Mg II emission line: one at $\zabs = 1.2568 \pm 0.0001$ and the other, including Mg I $\lambda 2852$, at $\zabs = 1.2715 \pm 0.0001$. Their velocities relative to the Mg II emission line are $-370$ and $+2300$ km s$^{-1}$, respectively.

3. IVS B0229+262—a possible intervening C IV $\lambda \lambda 1548, 1550$ doublet is detected at $\zabs = 2.5261 \pm 0.0001$.

4. IVS B0307−085—very strong associated absorption in C IV $\lambda \lambda 1548, 1550$, Si IV $\lambda \lambda 1393, 1402$, N V $\lambda \lambda 1238, 1242$, and Ly$\alpha$ $\lambda 1215$ at a redshift of $\zabs = 3.2889 \pm 0.0005$, consistent with zero velocity shift relative to emission.

5. IVS B0521−403—probable intervening absorption system at $\zabs = 0.6974 \pm 0.0001$ based on Mg II $\lambda \lambda 2796$, 2803 (blended) and Mg I $\lambda 2852$ lines. Spectral resolution is too low to separate the Mg II doublet, but the wavelength match is good. There are two further absorption lines at 5023 and 5997 Å that could not be identified but may be additional blended Mg II doublets based on their line widths.

6. IVS B0550−453—intervening absorption system at $\zabs = 0.6859 \pm 0.0001$ based on lines of Fe II $\lambda \lambda 2344, 2382, 2586+2600$ (blended) and Mg II $\lambda \lambda 2796, 2803$ (blended).

7. IVS B0722−068—broad emission from Fe II multiplets both blueward and redward of H$\beta$ (see Figure 5).

8. IVS B0727−365—permitted lines Mg II, H$\gamma$, and H$\beta$ are displaced $\sim 1200$ km s$^{-1}$ to higher redshift relative to the

Table 2

| Source       | R.A. (J2000) | decl. (J2000) | Telescope |
|--------------|-------------|--------------|-----------|
| IVS B0023−354 | 00 21 32.5495 | −25 50 49.387 | GS        |
| IVS B0138−381 | 01 40 36.8208 | −37 56 45.798 | NTT       |
| IVS B0141+268 | 01 44 33.5538 | +27 05 03.119 | GN        |
| IVS B0142−590 | 01 43 47.4305 | −58 45 51.375 | NTT       |
| IVS B0258−170 | 03 01 16.6227 | −16 52 05.845 | GS        |
| IVS B0839−357 | 08 41 21.6331 | −35 55 05.967 | NTT       |
| IVS B0843−547 | 08 45 02.4822 | −54 58 08.954 | NTT       |
| IVS B1029−854 | 10 26 34.3753 | −85 43 14.295 | NTT       |
| IVS B1101−536 | 11 03 52.2217 | −53 57 00.697 | NTT       |
| IVS B1304−427 | 13 07 37.9835 | −42 59 38.987 | NTT       |
| IVS B1711−670 | 17 16 22.3365 | −67 06 24.119 | GS        |
| IVS B2257+313 | 23 00 22.8374 | +31 37 04.405 | GN        |
| IVS B2308+018 | 23 11 01.2929 | +02 05 05.327 | GN        |
| IVS B2310+062 | 23 13 07.7015 | +06 28 38.847 | GN        |

Note.

* ICRF2 radio position.

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Title
Figure 2. Spectra of 14 probable BL Lac objects from our observations, classified on the basis of their featureless spectra; see Table 2 for ICRF2 positions.
29. IVS B2132—638—prominent associated Mg II λλ2796, 2803 absorption close to the peak of the emission line at $z = 1.5349 \pm 0.0001$ with a blueshift of $\sim 250 \text{ km s}^{-1}$.

30. IVS B2155—475—two absorption line systems: an intervening Mg II λλ2796, 2803 system at $z = 0.7929 \pm 0.0044$ and an associated system at $z = 1.7423 \pm 0.0010$ based on Si II λ1526, C IV λλ1548, 1550 (blend), C I λ1560, and Fe II λ1608.

31. IVS B2257+313 (Figure 2)—featureless spectrum with a clear absorption system at $z_{\text{abs}} = 0.9317 \pm 0.0001$ defined by lines of Fe II λλ2586, 2600 and Mg II λ2796, 2803, thereby setting a lower limit on the redshift of this BL Lac object.

32. IVS B2300+386—two intervening absorption systems at $z_{\text{abs}} = 1.0138 \pm 0.0001$ and $z_{\text{abs}} = 1.6005 \pm 0.0001$ based solely on the Mg II λλ2796, 2803 doublet.

33. IVS B2313—182—low-luminosity radio galaxy with narrow [O II] λλ3727 and [O III] λλ4959, 5007 emission on a predominantly stellar continuum with clear Ca II absorption.

### Table 3

| Source | R.A. (J2000)* | decl. (J2000)* | Telescope |
|--------|---------------|----------------|-----------|
| IVS B0002—350 | 00 05 05.9251 | −34 45 49.656 | NTT |
| IVS B0054—451 | 00 56 45.8532 | −44 51 02.141 | GS |
| IVS B0059—628 | 01 01 14.9683 | −62 33 06.339 | NTT |
| IVS B131—795 | 01 31 48.8223 | −79 16 17.486 | NTT |
| IVS B2025—754 | 02 53 10.8817 | −75 13 16.686 | GS |
| IVS B2055+203 | 02 58 07.3094 | +20 30 01.580 | GS |
| IVS B302—063 | 03 05 00.5637 | −06 07 41.500 | GS |
| IVS B3012—512 | 03 14 25.7036 | −51 04 31.562 | GS |
| IVS B5045+221 | 05 48 03.8896 | +22 10 35.593 | GS |
| IVS B1004—500 | 10 06 14.0903 | −50 18 13.471 | GS |
| IVS B1151—324 | 11 54 06.1664 | −32 42 42.983 | NTT |
| IVS B1517—385 | 15 20 40.4844 | −38 45 32.412 | GS |
| IVS B1532—473 | 15 35 52.2412 | −47 30 22.978 | GS |
| IVS B1650—157 | 16 53 34.2064 | −15 51 29.888 | GS |
| IVS B1653—612 | 16 57 49.0993 | −61 21 37.859 | GS |
| IVS B1732—598 | 17 36 30.8521 | −59 51 38.749 | GS |
| IVS B1830—859 | 18 34 27.4734 | −58 56 36.272 | GS |
| IVS B1914—412 | 19 18 16.0574 | −41 11 31.055 | GS |
| IVS B1935—452 | 19 39 30.0868 | −45 10 01.273 | GS |
| IVS B2009+795 | 20 07 13.1610 | +79 42 11.336 | GS |
| IVS B2025—538 | 20 29 35.0553 | −53 39 07.295 | GS |
| IVS B2210+277 | 22 12 39.1030 | +27 59 38.449 | GS |

Note:
* ICRF2 radio position.

### 3.2. Separation of Close Objects

Galactic stars are occasionally found close on the sky to the VLBI radio position, either contaminating the spectrum or so closely aligned with the radio source that the field is completely obscured. Of the three examples shown in Figure 3, redshifts were able to be recovered for IVS B0905—202 and B1813—497, although the latter spectrum, which was taken in poor seeing, is clearly contaminated by stellar absorption lines at rest. In the case of IVS B0758—737, which is relatively bright on VLBI baselines, there is also the opportunity to monitor changes with time in the VLBI position as proper motion of the foreground star changes the gravitational deflection of the quasar light.

### 4. Discussion

The longer integration times in the present data set have brought to light some spectral features, both in emission and absorption, that were either not detectable in the earlier data sets or extremely rare (Titov et al. 2011, 2013). These are discussed briefly in the following sections.

#### 4.1. Mg II Absorption Systems

The generally good S/N has allowed the detection of a number of absorption systems, both those associated with the target quasar and those intervening along the line of sight. The resolution of the NTT spectra is not sufficient to separate the Mg II doublet, but in most cases the system is confirmed by the presence of other lines, notably Mg I and/or Fe II. Absorption line redshifts were determined using SPLOT or SPECFIT in IRAF. Gaussian profiles were fitted to the lines, assuming a single redshift and width for all lines. Redshifts span the range $z_{\text{abs}} = 0.7–1.5$.

A montage of the Mg II systems shifted to the rest frame is shown in Figure 4. The NTT spectral resolution is too low to separate the Mg II doublet and Figure 4 only includes those NTT systems with confirming lines of Mg I and/or Fe II. Mg II doublet ratios in the Gemini spectra are all close to 1, indicating that the doublet is at, or close to, saturation with equivalent widths $W_{\lambda 2796} > 0.5 \text{ Å}$.

The principal interest in IVS quasars showing strong Mg II absorption, both associated and intervening, is their value as potential targets in searches for redshifted neutral hydrogen, taking advantage of the similar excitation potentials (and therefore locations) of H I and Mg II. While our sample is small compared to those from the Sloan Digital Sky Survey (e.g., Nestor et al. 2005), the majority of the Sloan sample is radio quiet. Moreover, ICRF source selection ensures that a substantial fraction of the radio flux density is contained within a few milliarcsec, thereby increasing the likelihood of an H I detection. Source selection played an important role in the first successful detection of redshifted H I with the Australian SKA Pathfinder (ASKAP; Johnston et al. 2007) where the target was the peaked spectrum VLBI source IVS B1740—517 (Allison et al. 2015) at $z = 0.44$; unfortunately, the optical spectrum, obtained at Gemini South through Director’s Discretionary Time, did not cover the Mg II line.

#### 4.2. Fe II Emission Near H β

Three of the low-$z$ quasars show prominent Fe II multiplet emission near H β: IVS B0722—068, B0858—313, and B0917—354. A montage of these three spectra, reduced to the emission rest frame, is shown in Figure 5. Fe II emission in this spectral region was first noted and analyzed by Wampler & Oke (1967) in the spectrum of 3C 273. They noted how the λ4924 line could distort the red wing of the H β profile and the λ5018 line could blend with [O III] λλ4959, 5007.

#### 4.3. The FeLoBAL Quasar IVS B2029—215

An extreme example of broad Fe II emission and absorption is shown in the spectrum of the quasar, IVS B2029—215, which is dominated by broad Fe II emission and absorption.
lines. This object belongs to a rare class of low-ionization broad absorption line quasars known as FeLoBALs, so-named because the spectrum is dominated by excited states of Fe II. The spectrum, shifted to the emission rest frame, is shown in Figure 6.

The spectrum of IVS B2029−215 is very similar to that of the z = 0.692 quasar FIRST J121442.3+280329 (Branch et al. 2002; de Kool et al. 2002) from the FIRST Bright Quasar Survey (White et al. 2000). By analogy with the spectrum of FIRST J121442.3+280329 (de Kool et al. 2002), we show a tentative continuum in Figure 6 on the assumption that broad emission and blueshifted broad absorption are superimposed on a power-law continuum from the accretion disk. The IVS B2029−215 continuum, however, is substantially redder than that of FIRST J121442.3+280329, suggesting the presence of dust in the outflowing gas.

4.4. Continuum Absorption Below Lyα

It is well known that the continuum level in high-redshift quasars is depressed below Lyα relative to an extrapolation of the level above Lyα. The fractional depression, DA, of the continuum between Lyα and Lyβ increases with redshift mainly due to the increasing density of absorption lines of the Lyα forest, with additional contributions from heavy-element lines and, at the highest redshifts, distributed neutral hydrogen (e.g., Jenkins & Ostriker 1991).

Figure 3. Acquisition images for the fields of IVS B0758−737, B0905−202, and B1813−497, all of which are partly obscured by a foreground star; position offsets between the radio source and obscuring star are 1′′3, 1′′6, and 0′′8, respectively. The arms of the cross marking the radio position are all 20 arcsec and the orientation of each finding chart is indicated. The step in contrast in the two leftmost NTT images is the result of fast readout using two amplifiers.

Figure 4. Montage of the Mg II absorption systems shifted back to the absorption rest frame. Telluric lines are marked and short spectral gaps correspond to gaps between the GMOS CCDs.

Figure 5. Montage of three z ∼ 0.4 quasar spectra showing prominent broad Fe II emission both blueward and redward of Hβ. Spectra have been shifted to the rest frame and telluric features are marked. The effect of Fe II emission on the Hβ/[O III] profiles is most clearly seen in the high signal-to-noise spectrum of IVS B0917−354. The solid line (red) shows our estimated continuum level.
In the present sample there are eight quasars with $z > 2.6$ and good spectral coverage down to Ly$\beta$. Of these, five show the expected continuum depression below Ly$\alpha$ but three, IVS B0407 $-$129, B1020 $-$045, and B1044 $-$512, have $D_A \approx 0$. The latter three spectra, all at $z \sim 2.6$, were obtained at the NTT in visitor mode and the spectral response has been well calibrated with standard star observations. The implication is that these sightlines have a lower density of Ly$\alpha$ forest lines, and/or a more highly ionized intergalactic medium. To follow up these possibilities, we are planning to observe the region well below Ly$\alpha$ in these quasars at higher spectral resolution and signal to noise.

5. Summary and Conclusion

We present the redshifts and spectra of a further 112 emission-line objects identified with VLBI radio sources drawn from the candidate International Celestial Reference Catalog. As in our previous papers (Titov et al. 2011, 2013), the chosen targets were mostly in the south so as to improve the uniformity across the two hemispheres. Redshifts were generally based on two or more emission lines, but single-line redshifts, all Mg II, were considered to be reliable on the basis of other spectral information. There were 14 objects with high S/N but featureless spectra that we classified as probable BL Lac objects, while a further 22 had S/N too low for reliable classification.

The majority of the spectra show the broad permitted lines and power-law continua characteristic of quasars, but the sample does include two low-redshift galaxies with only narrow forbidden lines and stellar continua. Morphological differentiation is difficult at redshifts $z > 0.5$.

Among the sample of 112 spectra, we identify 17 low-redshift Mg II absorbers, both associated and intervening. Because these absorbers are seen against very compact radio sources, they are potential targets for H I absorption searches with next generation radio telescopes.

This paper is based on data collected at three telescopes.

1. ESO NTT, under the European Organization for Astronomical Research in the Southern Hemisphere, Chile under program 092.A-0021 (A).

2. Two Gemini Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation on behalf of the Gemini partnership: the National Science Foundation (United States), the Science and Technology Facilities Council (United Kingdom), the National Research Council (Canada), CONICYT (Chile), the Australian Research Council (Australia), Ministério da Ciência, Tecnologia, Inovações e Comunicações (Brazil), and Ministerio de Ciencia, Tecnología e Innovación Productiva (Argentina) under programs GS-2013A-Q-99, GS-2014A-Q-93 (Gemini South), and GN-2012B-Q-127 (Gemini North).

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