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A Catalogue of Damped Lyman Alpha Absorption Systems and Radio Flux Densities of the Background Quasars

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Abstract: We present a catalogue of the 322 damped Lyman alpha absorbers taken from the literature. All damped Lyman alpha absorbers are included, with no selection on redshift or quasar magnitude. Of these, 123 are candidates and await confirmation using high resolution spectroscopy. For all 322 objects we catalogue the radio properties of the background quasars, where known. Around 60 quasars have radio flux densities above 0.1 Jy and approximately half of these have optical magnitudes brighter than $V = 18$. This compilation should prove useful in several areas of extragalactic/cosmological research.

Keywords: catalogues — quasars: absorption lines — radio continuum: galaxies — early universe

1 Introduction

High resolution spectroscopy of quasars reveals large numbers of absorption lines due to neutral atomic hydrogen. In some cases, the neutral hydrogen column density can be very large ($N_{\rm HI} \gtrsim 10^{20}\,{\rm cm}^{-2}$)* and gives rise to a heavily damped absorption feature (e.g. Wolfe et al. 1986). The aim of this paper is to present a catalogue of these damped Lyman alpha absorption systems (DLAs) and, where known, the radio flux densities of the background quasar. The catalogue has been compiled from the large number of studies reported in the literature.

The nature of DLAs is still open to debate. Interpretations include galactic disks (Wolfe et al. 1986), low surface brightness galaxies (Jimenez, Bowen & Matteucci 1999) or dwarf galaxies (Matteucci, Molaro & Vladilo 1997) intersecting the sight-line towards a background quasar. Despite these possible differing morphologies, DLAs provide a powerful cosmological probe. The highest redshift ($z > 3.5$) DLAs may account for a large fraction of the baryons at high redshift, suggesting they reveal gas prior to the bulk of the star formation history of the universe (Péroux et al. 2002, and references therein). On the other hand, recent work (Lanzetta et al. 2002) seems to indicate star formation rates which continue to increase with increasing redshift up to the highest galaxy redshifts observed in the Hubble Deep Field. The discovery of a DLA with truly primordial abundances would have a major impact on our understanding of the early chemical evolution of the universe, and a crucial reality check on the ever-elusive population III. This will also be important for studies of primordial deuterium abundances (see below), since deuterium is destroyed, and never created, by star formation and evolution.

High resolution spectroscopy can be used to study high chemical abundances over a large redshift range. In particular, the difficult ionisation corrections required to derive meaningful chemical abundances in Lyman-limit absorbers (where $\log N_{\rm HI} > 17.2\,{\rm cm}^{-2}$, so that they are optically thick to Lyman continuum radiation, e.g. Lanzetta 1991) can be avoided using DLAs since the observed hydrogen is probably all neutral (Turnshek et al. 1989; Lanzetta et al. 1991). Additionally, at high neutral hydrogen column densities, species such as Zn II and Cr II may become detectable, which are important since depletion onto dust grains is thought to be negligible for the former, whereas the latter remains in the solid phase. This allows both the study of abundances and depletion patterns/dust reddening (see Pettini, Boksenberg & Hunstead 1990; Pettini et al. 1997). Some further reasons why DLAs are of interest are:

1. Studies of the higher order hydrogen Lyman series in DLAs can be used to investigate the primordial deuterium abundance (Webb et al. 1991). The advantage of using DLAs is that the deuterium column density can be somewhat larger than typical Lyman forest absorbers. This may help to discriminate against H I interlopers mimicking the deuterium line. Two recent observational studies (D'Odorico, Dessauges-Zavadsky, & Molaro 2001; Pettini & Bowen 2001) report such D/H measurements.
2. Radio observations of quasars with a sufficiently high radio flux density can provide information complementary to that of the DLA observations: 21 cm H I measurements reveal more detailed kinematic information since line saturation is less severe and provide a direct spin temperature of the cool component of the gas. Different radio and optical morphology of the

*In the catalogue some column densities less than this are to be found. This is because in order to produce the most comprehensive list, we have also included any Lyman alpha absorbers which are designated as possibly damped in the literature (see Section 2).

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background quasar also provides the opportunity of observing along slightly different sight-lines through the same absorption complex, with the potential of learning about the relative sizes of optical/radio emission regions and the cloud size of the absorbing gas. In those rare cases where the host quasar has a sufficiently strong millimetre flux and a foreground molecular cloud occults the quasar (Wiklind & Combes 1994a; Wiklind & Combes 1996), a wealth of detailed chemistry is revealed (Gerin et al. 1997; Combes & Wiklind 1999).

3. Studies of high redshift dust in DLAs gives a handle on the chemical evolution and star formation rates at various cosmological epochs (Pei, Fall & Hauser 1999) through the contribution of dust to quasar spectral energy distributions (e.g. Klein et al. 1996; Bertoldi et al. 2000; Carilli et al. 2000; Omont et al. 2001).
4. Certain heavy element transitions provide cosmological probes of special interest. For example, species with ground and excited state transitions sufficiently close to each other in energy provide a unique means of measuring the cosmic microwave background temperature at high redshift (Bahcall, Joss, & Lynds 1973; Meyer et al. 1986; Srianand, Petitjean, & Ledoux 2000).
5. Finally, recent detailed studies of the relative positions of heavy element atomic optical transitions and comparison with present day (laboratory) wavelengths, suggest that the fine-structure constant ($\alpha \equiv e^2/\hbar c$) may have evolved with time. Inter-comparing atomic optical transitions with H I 21 cm and molecular millimetre transitions may yield an order of magnitude over the already highly sensitive optical results (Cowie & Songaila 1995; Drinkwater et al. 1998; Murphy et al. 2001b). However, very few such constraints are available due to the paucity of quasar absorption systems where 2 of the 3 types of transition (optical atomic, H I 21 cm or molecular millimetre) exist.

It is this last point which is of interest to us: as well as providing a comprehensive list of these objects for use by the astronomical community in general (Section 2), this catalogue allows us to shortlist those DLAs most likely to exhibit radio absorption lines in order to further constrain the variation in the fine-structure constant. In the final sections we present the DLAs occulting radio-loud quasars along with any radio absorption features published and outline our future plans regarding the sample.

2 Explanatory Comments and References

In Table 1, for the column density we note that Corbelli, Salpeter & Bandiera (2001) argue that when $N_{\rm HI}$ is estimated directly from the absorption line equivalent width, the value is systematically underestimated when compared to the estimate derived using Voigt profile fitting. This may be due to a bias associated with estimating the quasar continuum due the presence of Lyman forest absorption lines. The values of $N_{\rm HI}$ quoted in the table in this paper are those values reported in the original sources, and are not corrected using the relation given in Corbelli et al. (2001).

Note also that the visual magnitude is obtained from the DLA reference, Véron-Cetty & Véron (2001) or, failing these, the NASA/IPAC Extragalactic Database (NED), which gives an approximate value. For the radio flux densities, $S_{0.4}$ is either the 0.33 GHz WENSS, 0.37 GHz Texas or 0.41 GHz MRC flux density (see Section 2.2), and where both flux densities are available the 365 MHz value is quoted. In the case of the Texas survey, 'X' denotes that the quasar was not detected at the flux density limit of 0.25 Jy (Douglas et al. 1992). $S_{1.4}$, etc., are the measured 1.4 GHz, etc., continuum flux densities in Jy, and for $S_{\rm higher}$, the frequency in GHz is given in parentheses. In the appropriate columns 'X' also designates if the object is not considered a 2.7 or 5.0 GHz radio source (Véron-Cetty & Véron 2001), and where the 22 and 37 GHz values are quoted as approximate refers to the average value from 15 years of monitoring by Teräsranta et al. (1998). In general, approximate values are used when the flux density is obtained from more than one reference and the values given do not exactly agree. Finally, '–' denotes that no information could be found.

2.1 The DLA References

The DLAs are compiled from Wolfe et al. (1978)[1], Wolfe & Davis (1979)[2], Wolfe, Briggs & Jauncey (1981)[3], Snijders et al. (1982)[4], Tytler (1982)[5], Bechtold et al. (1984)[6], Wolfe et al. (1986)[7], Black, Chaffee & Foltz (1987)[8], Tytler (1987a)[9], Tytler (1987b)[10], Lanzetta (1988)[11], Sargent, Steidel & Boksenberg (1989)[12], Turnshek et al. (1989)[13], Lanzetta (1991)[14], Lanzetta et al. (1991)[15], Schneider, Schmidt & Gunn (1991)[16], Beaver, Cohen & Junkkarinen (1992)[17], Courvoisier & Paltani (1992)[18], Meyer & York (1992)[19], Bahcall et al. (1993)[20], Lu et al. (1993)[21], Turnshek & Bohlin (1993)[22], White, Kinney & Becker (1993)[23], Chaffee et al. (1994)[24], Wolfe et al. (1994)[25], Lu et al. (1995)[26], Lanzetta, Wolfe & Turnshek (1995)[27], Steidel et al. (1995)[28], Wolfe et al. (1995)[29], Bahcall et al. (1996)[30], Carilli et al. (1996)[31], de Bruyn, O'Dea & Baum (1996)[32], Impey et al. (1996)[33], Lu et al. (1996)[34], Petitjean et al. (1996)[35], Stepanian et al. (1996)[36], Storrie-Lombardi et al. (1996)[37], Ge & Bechtold (1997)[38], Lanzetta et al. (1997)[39], Le Brun et al. (1997)[40], Lu, Sargent & Barlow (1997)[41], Vladilo et al. (1997)[42], Ivison, Harrison & Coulson (1998)[43], Jannuzi et al. (1998)[44], Le Brun, Viton & Milliard (1998)[45], Srianand & Petitjean (1998)[46], Leibundgut & Robertson (1999)[47], de la Varga et al. (2000)[48], Molaro et al. (2000)[49], Petitjean et al. (2000)[50], Pettini et al. (2000)[51], Rao & Turnshek (2000)[52], Storrie-Lombardi & Wolfe (2000)[53], Bowen, Tripp & Jenkins (2001)[54], Cohen (2001)[55], Ellison et al. (2001a)[56], Kanekar & Chengalur (2001)[57], Péroux et al. (2001)[58], Turnshek et al. (2001)[59], the radio selected QSO survey of Ellison et al. (2001b)[60] and finally the five new DLAs at $z > 3$ occulting PSS quasars of Prochaska, Gawiser & Wolfe (2001)[61].

Table 1. Damped Lyman alpha absorption systems and the radio flux densities of the background quasars

The IAU names (obtained from NED), listed in numerical order are given along with the J2000.0 optical positions. z_{em} is the emission redshift of the quasar and z_{abs} and N_{HI} [cm^{-2}] are the redshift and the column density of the Lyman alpha absorber, respectively. The superscript on the column density gives the reference for the DLA (Section 2.1). Note that '*' denotes a candidate DLA which has yet to be confirmed using higher resolution spectroscopy. V is the visual magnitude and the final five columns give the radio flux densities at several frequencies. See Section 2 for further details.

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
[HB89] 0000−263	00 03 22.9	−26 03 17	4.098	3.395	21.4[12,15,29,49]	17.5	X	<0.0015[l,N]	X	X	–
…	…	…	…	3.053	20.3[15*]	…	…	…	…	…	…
PSS J0003+2730	00 03 23.1	27 20 23	4.240	3.51	20.0[58]	19.0	X	<0.003[N]	X	<0.0002[w]	–
…	…	…	…	3.89	20.2[58]	…	…	…	…	…	…
BR J0006−6208	00 06 51.7	−62 08 04	4.455	2.97	20.7[58]	18.3	–	–	X	X	–
…	…	…	…	3.20	20.9[58]	…	…	…	…	…	…
…	…	…	…	3.78	21.0[58]	…	…	…	…	…	…
…	…	…	…	4.14	20.1[58]	…	…	…	…	…	…
LBQS 0007−0004	00 10 16.6	00 12 27	2.273	2.012	19.9[13*]	18.5	X	<0.001[F,N]	–	–	–
…	…	…	…	1.776	19.8[13*]	…	…	…	…	…	…
LBQS 0009+0219	00 12 19.6	02 36 35	2.642	2.486	19.8[29*]	18.0	X	<0.003[N]	X	X	<0.0002(8.4)[h]
…	…	…	…	1.904	19.8[29*]	…	…	…	…	…	…
LBQS 0010−0012	00 13 06.1	00 04 32	2.145	2.026	20.8[29]	18.7	X	<0.001[F,N]	X	X	–
LBQS 0013−0029	00 16 02.4	−00 12 26	2.086	1.9731	20.8[29]	18.2	X	<0.001[F,N]	X	X	<0.004(8.4)[h]
BR 0019−1522	00 22 08.0	−15 05 39	4.528	3.437	20.9[37,53]	19.0	X	<0.003[N]	X	X	–
LBQS 0022+0150	00 24 35.3	02 06 48	2.826	2.138	20.1[29*]	18.4	X	<0.003[N]	–	–	–
…	…	…	…	1.964	20.2[29*]	…	…	…	…	…	…
LBQS 0027+0103	00 30 08.1	01 20 11	2.310	1.937	20.6[29]	18.2	X	<0.0009[F]	X	X	–
BR J0030−5129	00 30 34.4	−51 29 46	4.174	2.45	20.8[58]	18.6	–	–	X	0.07[pmn]	–
LBQS 0028−0148	00 30 59.4	−01 31 49	2.081	1.940	19.9[29*]	18.5	X	<0.001[F,N]	–	–	–
LBQS 0029+0017	00 31 35.6	00 35 21	2.253	2.162	19.9[29*]	18.6	X	<0.0009[F]	–	–	–
PSS J0034+1639	00 34 54.9	16 39 19	4.293	3.75	20.2[58]	19.5	X	<0.003[N]	–	<0.0002[w]	–
…	…	…	…	4.26	21.1[58]	…	…	…	…	…	…
UM 264	00 40 18.2	−01 37 22	2.340	1.962	19.8[7,13*]	19.6	X	<0.001[F,N]	–	–	–
LBQS 0041−2707	00 43 51.9	−26 51 29	2.786	1.831	19.8[29*]	17.8	X	<0.003[N]	X	X	<0.0002(8.4)[h]
LBQS 0042−2930	00 45 08.6	−29 14 33	2.388	1.931	20.5[29*]	17.9	X	<0.003[N]	X	X	<0.0003(8.4)[h]
…	…	…	…	1.806	20.2[29*]	…	…	…	…	…	…
UM 667	00 47 50.1	−03 25 31	3.122	2.830	20.4[11,12,15]	18.6	X	<0.003[N]	–	–	–
UM 278	00 48 06.1	−01 03 21	2.53	1.880	19.6[13*]	18.0	X	0.0016[u,F]	–	–	–

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000) h m s	d ′ ″	z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy) $S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
LBQS 0049−2820	00 51 27.2	−28 04 34	2.256	2.068	20.5[29]	18.4	X	<0.003[N]	–	–	
…	…	…	…	1.885	20.1[29*]	…	…	…	…	…	…
LBQS 0049+0045	00 52 02.4	01 01 29	2.265	1.914	20.1[13*]	17.5	X	0.023[F]	–	–	<0.0004(8.4)[h]
[HB89] 0054+144	00 57 09.9	14 46 11	0.171	0.103	20.1[27*]	16.7	X	0.002[N]	≈0.002[p]	≈0.0007[p]	–
[HB89] 0055−269	00 57 57.9	−26 43 14	3.662	2.408	19.6[27*]	17.5	X	<0.003[N]	X	X	–
LBQS 0056+0125	00 59 17.6	01 42 06	3.154	2.775	21.0[29]	18.6	X	0.0065[m,N]	–	–	–
[WHO91] 0058−292	01 01 04.7	−28 58 03	3.093	2.671	21.2[15,29]	18.7	X	<0.003[N]	X	X	–
LBQS 0058+0155	01 00 54.2	02 11 37	1.954	0.6618	20.1[51]	17.2	X	<0.003[N]	<0.003[a]	<0.003[a]	–
LBQS 0059−2625	01 01 52.8	−26 08 59	2.10	1.952	19.9[29*]	18.6	X	<0.003[N]	–	–	–
LBQS 0059+0035	01 02 27.5	00 51 38	2.545	1.820	19.9[29*]	17.9	X	<0.001[F,N]	X	X	–
LBQS 0100−3105	01 03 02.8	−30 49 38	2.641	2.131	20.5[29*]	18.3	X	<0.003[N]	X	X	<0.0003(8.4)[h]
[HB89] 0100+1300	01 03 11.3	13 16 16	2.681	2.317	21.4[13,24,29]	16.6	X	<0.003[N]	–	≈0.0003[b]	–
UM 669	01 05 16.8	−18 46 42	3.025	2.930	<20[11,12,15*]	18.3	X	<0.003[N]	–	–	–
…	…	…	…	2.367	21.0[15,29]	…	…	…	…	…	…
LBQS 0102−0214	01 05 17.1	−01 58 27	1.979	1.738	20.6[29]	18.5	X	<0.001[F,N]	X	X	–
LBQS 0103−2901	01 05 56.5	−28 45 29	2.870	2.235	20.1[29*]	18.2	X	<0.003[N]	X	X	–
SDSS J010619.24+004823.4	01 06 19.3	00 48 23	4.437	4.150	19.8[37*]	18.6	X	<0.0009[F,N]	X	<0.0002[w]	≈0(250)[z]
PSS J0106+2601	01 06 00.8	26 01 02	4.309	3.96	20.5[58]	19.4	X	<0.003[N]	X	<0.0001[w]	–
QSO 0112−30	See Section 2		2.985	2.702	20.3[14,15,29]	–	X		X	X	–
…	…	…	…	2.419	20.5[14,15,29]	…	…	…	…	…	…
[HB89] 0112+03	01 14 35	03 15 51	2.81	2.422	21.0[15,29]	18.6	X		–	–	–
BRI J0113−2803	01 13 44.4	−28 03 17	4.30	3.104	21.0[53]	18.7	–	<0.003[N]	X	X	–
QSO 0115−30	See Section 2		3.249	2.253	20.3[15*]	–	X		X	X	–
PKS 0118−272	01 20 31.6	−27 01 24	0.559	0.558	20.3[42]	15.6	1.48[T,P]	0.93[N]	0.96[P]	1.18[P]	0.95(8.4)[P]
PSS J0131+0633	01 31 12.2	06 33 40	4.417	3.17	19.9[42,58]	19.1	X	<0.003[N]	X	X	–
…	…	…	…	3.61	19.8[58]	…	…	…	…	…	…
PSS J0133+0400	01 33 30.0	04 00 30	4.154	3.08	20.1[58]	18.3	X	<0.003[N]	X	X	–
…	…	…	…	3.69	20.4[58]	…	…	…	…	…	…
…	…	…	…	3.77	20.5[58]	…	…	…	…	…	…
…	…	…	…	4.00	20.1[58]	…	…	…	…	…	…
PSS J0134+3307	01 34 21.6	33 07 56	4.532	3.76	20.6[58]	18.8	X	<0.003[N]	X	<0.0002[w]	<0.004(250)[M]
UM 366	01 45 51.2	−01 20 31	3.124	1.61	20.3[52]	18.8	X	<0.001[F,N]	–	–	–
PSS J0152+0735	01 52 11.1	07 35 50	4.051	3.84	20.7[58]	19.6	X	<0.003[N]	X	<0.0002[w]	–

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
[HB89] 0149+336	01 52 34.6	33 50 33	2.431	2.136	20.6[13]	18.2	1.65[we]/1.67[T]	0.8[G,N]	–	0.52[c]	–
PKS 0201+113	02 03 46.7	11 34 44	3.610	3.386	21.3[23,32,56]	19.5	0.31[T]	≈0.6[K], 0.78[N]	1.20[P]	1.20[P]	0.71(8.4)[P,K]/0.53(11)/0.43(22)[K]
[HB89] 0201+365	02 04 55.6	36 49 18	2.912	2.461	20.4[27,29]	17.9	0.49[we]/0.46[T]	≈0.6[G,N]	–	0.35[c]	–
…	…	…	…	1.957	20.2[15*]	…	…	…	…	…	…
…	…	…	…	1.768	20.5[15*]	…	…	…	…	…	…
PSS J0209+0517	02 09 44.7	05 17 14	4.174	3.66	20.3[58]	17.8	X	<0.003[N]	X	X	–
…	…	…	…	3.86	20.6[58]	…	…	…	…	…	…
SDSS J0211−0009	02 11 02.7	−00 09 10	4.874	4.64	20.0[58]	24.8	X	<0.001[F,N]	–	–	–
[HB89] 0215+015	02 17 48.9	01 44 50	1.715	1.342	19.9[27]	18.5	1.03[T,P]	0.54[P], 0.75[N]	0.73[P]	1.06[P,pmn]	0.99(8.4)[P]
[HB89] 0216+080	02 18 57.3	08 17 27	2.991	2.2931	20.5[15,29,34]	18.1	X	<0.003[N]	–	–	
…	…	…	…	1.7688	20.0[15,34*]	…	…	…	…	…	…
BR J0234−1806	02 34 55.2	−18 06 09	4.301	3.69	20.2[58]	18.8	X	0.036[N]	X	X	
[HB89] 0235+164	02 38 38.9	16 36 59	0.940	0.524	21.6[1,2,4]	15.5	1.03[T,P]	≈2[G,N]	1.94[V]	1.64[V]	1.90(8.4)/2.48(22)[P]/2.6(86)[q]
BRI 0241−0146	02 44 01.8	−01 34 02	4.053	3.410	20.2[37]	18.2	X	<0.001[F,N]	X	<0.0002[w]	–
[HB89] 0248+430	02 51 34.5	43 15 16	1.31	0.394	21.6[52]	17.7	0.74[T]	≈1.3[G,N]	–	0.66[G]	1.5(7.0)[n]/≈ 0.7(22)/≈ 0.1(37)[r]
UM 678	02 51 40.4	−22 00 27	3.197	2.823	20.2[12,15,53]	18.4	X	<0.003[N]	–	–	–
BR J0301−5537	03 01 21.6	−55 37 11	4.133	3.22	20.3[58]	19.0	–	–	X	X	–
…	…	…	…	3.38	20.1[58]	…	…	…	…	…	…
…	…	…	…	3.71	20.0[58]	…	…	…	…	…	…
QSO 0301−0035	03 03 41.1	−10 23 22	3.219	2.442	20.3[15*]	18.4	X	<0.003[N]	X	X	–
[HB89] 0302−223	03 04 50.1	−22 11 57	1.40	1.014	20.1[27*]	16.0	X	<0.003[N]	–	–	–
…	…	…	…	0.987	19.6[27*]	…	…	…	…	…	…
BR J0307−4945	03 07 22.8	−49 45 48	4.728	3.35	19.8[58]	18.8	–	–	X	X	–
…	…	…	…	4.46	20.8[58]	…	…	…	…	…	…

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
SDSS J0310−0014	03 10 37.0	−00 14 57	4.658	3.42	20.5^{58}	23.4	X	$<0.0009^{F,N}$	–	–	
BR J0311−1722	03 11 15.2	−17 22 47	4.039	3.73	20.2^{58}	17.7	X	$<0.003^{N}$	X	X	–
[HB89] 0316−203	03 18 25.2	−20 12 19	2.869	2.131	19.8^{15*}	18.5	X	0.10^{N}	–	0.04^{f}	–
[HB89] 0329−255	03 31 09.0	−25 24 43	2.689	1.720	19.8^{15*}	17.1	0.50^{T}	0.32^{N}	0.41^{P}	0.38^{P}	–
…	…	…	…	1.697	19.8^{15*}	…	…	…	…	…	…
BR J0334−1612	Not published		4.363	3.56	$20.6^{53,58}$						
UM 683	03 36 27.0	−20 19 38	3.125	2.408	19.8^{15*}	19.1	X	$<0.003^{N}$	–	–	–
…	…	…	…	2.280	19.8^{15*}	…	…	…	…	…	…
…	…	…	…	2.171	20.1^{15*}	…	…	…	…	…	…
[HB89] 0335−122	03 37 55.4	−12 04 05	3.442	3.178	20.8^{60}	20.2	$0.82^{T,P}$	0.48^{N}	0.40^{P}	0.38^{P}	–
PKS 0336−017	03 39 00.9	−01 33 18	3.197	3.062	$21.2^{14,15,29}$	18.8	$1.31^{T,P}$	$0.60^{P,N}$	0.45^{P}	0.30^{P}	–
SDSS J0338+0021	03 38 29.3	00 21 56	5.01	4.06	20.4^{58}	25.0	X	$<0.003^{N}$	–	–	–
[HB89] 0347−383	03 49 43.7	−38 10 31	3.222	3.025	$20.8^{9,10,11,14,15,29}$	17.8	–	$<0.003^{N}$	–	–	–
QSO 0347−211	03 49 57.7	−21 02 47	2.944	1.947	20.3^{60}	–	0.49^{T}	0.30^{N}	0.37^{P}	0.52^{P}	–
BR 0351−1034	03 53 46.9	−10 25 19	4.351	4.140	19.9^{37*}	18.6	X	$<0.003^{N}$	X	X	–
…	…	…	…	3.620	19.9^{37*}	…	…	…	…	…	…
PKS 0405−331	04 07 34.0	−33 03 46	2.570	2.570	20.6^{60}	19.0	0.71^{T}	0.63^{N}	0.70^{P}	$0.63^{P,pmn}$	$0.55(8.4)^{P}$
BR J0415−4357	04 15 15.2	−43 57 52	4.070	3.81	20.1^{58}	18.8	–	–	X	X	–
BR J0419−5716	04 19 50.9	−57 16 14	4.461	2.82	20.0^{58}	17.8	–	–	X	X	–
…	…	…	…	2.90	20.2^{58}	…	…	…	…	…	…
…	…	…	…	2.98	19.7^{58}	…	…	…	…	…	…
BR J0426−2202	04 26 10.3	−22 08 18	4.320	2.98	21.1^{58}	17.9	X	$<0.003^{N}$	X	X	–
QSO 0432−440	04 34 03.2	−43 55 47	2.649	2.297	20.8^{60}	–	0.75^{P}	–	0.29^{P}	0.25^{P}	–
[HB89] 0438−436	04 40 17.2	−43 33 09	2.863	2.347	20.8^{60}	18.8	8.12^{P}	7.52^{P}	6.50^{P}	7.00^{P}	$2.80(8.4)^{P}$
[HB89] 0439−433	04 41 17.3	−43 13 43	0.593	0.101	20.0^{35*}	16.4	–	0.40^{y}	$0.32^{P,V}$	$0.30^{P,V,pmn}$	–
H 0449−1325	04 51 42.6	−13 20 33	3.097	2.052	20.5^{15*}	18.2	X	$<0.003^{N}$	X	X	–
PKS 0454+039	04 56 47.1	04 00 53	1.345	0.859	20.7^{28}	16.5	0.66^{T}	$0.34^{G,N}$	0.40^{V}	$0.43^{V,pmn}$	$\approx0.4(22)/\approx0.2(37)^{r}$
[HB89] 0458−020	05 01 12.8	−01 59 14	2.286	2.0399	$21.7^{13,29}$	18.4	$2.50^{T,P}$	2.2^{P}	$\approx2^{P,x}$	$\approx3^{P,pmn,x}$	$\approx3(8.4)^{P,x}/0.8(90)/0.5(230)^{x}$

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
HE 0515−4414	05 17 07.6	−44 10 56	1.713	1.15	20.4^{48}	14.9	–	–	X	X	–
PKS 0528−250	05 30 08.0	−25 03 29	2.779	2.138	$20.6^{15,29,34}$	19.0	–	1.5^{P},1.2^{N}	1.32^{P}	1.13^{P}	$0.59(8.4)^{P}$
…	…	…	…	2.811	$21.2^{34,46}$	…	…	…	…	…	…
BR J0529−3552	05 29 20.8	−35 52 34	4.172	3.68	20.0^{58}	18.3	–	$<0.003^{N}$	X	X	–
…	…	…	…	3.70	20.0^{58}	…	…	…	…	…	…
BR J0529−3526	05 29 15.9	−35 26 04	4.413	3.57	20.1^{58}	18.9	–	$<0.003^{N}$	X	X	–
[HB89] 0537−286	05 39 54.3	−28 39 56	3.110	2.976	$20.3^{5,10,11,60}$	19.0	$0.77^{T,P}$	0.86^{N}	0.74^{P}	0.99^{P}	$0.90(8.4)^{P}$
[HB89] 0552+398	05 55 30.8	39 48 49	2.363	1.698	20.3^{13*}	18.3	$0.30^{we}/0.43^{T}$	$\approx1.6^{G,N}$	3.53^{V}	5.43^{V}	$4.8(6.0)^{n}/7.0(8.4)/5.9(22)^{s}$
FBQS J074110.6+311200	07 41 10.7	31 12 00	0.635	0.2212	$21.2^{52,55}$	16.1	$1.26^{we}/1.37^{T}$	$\approx2.1^{u,F,N}$	–	–	$\approx1.3(22)/\approx1.1(37)^{r}$
…	…	…	…	0.0912	$21.2^{52,59}$	…	…	…	…	…	…
PSS J0747+4434	07 47 49.7	44 34 16	4.43	3.76	20.3^{58}	18.1	X	$<0.0009^{F,N}$	X	$<0.0001^{w}$	$<0.001(250)^{M}$
…	…	…	…	4.02	20.6^{58}	…	…	…	…	…	…
PSS J0808+5215	08 08 49.5	52 15 16	4.441	3.114	20.6^{61}	18.8	X	$<0.0009^{F,N}$	–	–	–
FBQS J083052.0+241059	08 30 52.1	24 11 00	0.939	0.5247	20.3^{52}	17.3	0.71^{T}	$\approx0.8^{u,F,N}$	0.99^{V}	0.89^{V}	$\approx1.3(22)/\approx1.3(37)^{r}/2.4(86)^{q}$
IRAS F08279+5255	08 31 41.6	52 45 18	3.911	2.974	20.0^{50}	15.2	–	$0.001^{F,N}$	–	–	$0.08(350)^{t}$
[HB89] 0834−201	08 36 39.2	−20 16 59	2.752	1.715	20.5^{15*}	18.5	3.53^{P}	1.97^{N}	4.15^{x}	$1.5^{pmn,x}$	$1.3(8.4)/\approx0.7(90)/\approx0.4(230)^{x}$
[HB89] 0836+113	08 39 33.0	11 12 07	2.696	2.467	$20.6^{13,29}$	19.5	X	$<0.001^{F,N}$	X	X	–
[HB89] 0850+440	08 53 34.2	43 49 01	0.51390	0.16377	19.8^{39}	16.4	X	$<0.0009^{F,N}$	–	–	–
QSO 0913+003	09 15 51.7	00 07 13	3.074	2.774	20.3^{60}	–	0.47^{T}	$\approx0.36^{F,N}$	0.27^{P}	$0.25^{P,pmn}$	–
[HB89] 0913+072	09 16 14.0	07 02 25	2.785	2.630	$20.3^{11,14,15,29}$	18.1	X	$<0.001^{F,N}$	X	X	–
QSO 0933−333	09 35 09.2	−33 32 38	2.906	2.682	20.5^{60}	–	–	0.24^{N}	0.31^{P}	0.32^{P}	–
FBQS J0933+2845	09 33 37.3	28 45 32	3.425		Not given^{W}	17.5	X	$0.12^{F,N}$	–	0.07^{V}	–
[HB89] 0935+417	09 38 45.3	41 29 26	1.98	1.369	$20.3^{15,29,44}$	16.3	X	$<0.001^{F,N}$	–	–	–
[HB89] 0938+119	09 41 13.6	11 45 32	3.191	1.759	19.8^{15*}	18.8	0.35^{T}	$0.21^{F,N}$	0.23^{V}	$0.19^{c,V}$	–
BR 0951−0450	09 53 55.7	−05 04 18	4.369	4.203	$20.4^{37,53}$	18.9	X	$<0.001^{F,N}$	X	X	–
…	…	…	…	3.848	$20.6^{37,53}$	…	…	…	…	…	…

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000)		$z_{\rm em}$	$z_{\rm abs}$	log $N_{\rm HI}$	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	$S_{\rm higher}$
BRI 0952−0115	09 55 00.1	−01 30 07	4.426	4.024	$20.6^{37,53}$	18.7	X	$<0.001^{F,N}$	–	$<0.0001^{w}$	$0.003(240)^{o}/0.001(350)^{t}$
[HB89] 0952+179	09 54 56.8	17 43 31	1.472	0.239	21.3^{52}	17.2	$1.73^{T,P}$	$1.1^{F,N}$	0.94^{P}	0.74^{P}	–
PC 0953+4749	09 56 25.2	47 35 42	4.457	3.890	$\leq 20.9^{53*}$	19.5	X	$<0.001^{F,N}$	X	X	–
…	…	…	…	3.403	$\leq 21.1^{53*}$	…	…	…	…	…	…
FBQS J0955+3335	09 55 38.0	33 35 04	2.499		Not given^{W}	17.2	0.02^{we}	$<0.0009^{F,N}$	–	0.06^{c}	–
PSS J0957+3308	09 57 44.5	33 08 23	4.25	3.279	20.5^{61}	17.6	X	$<0.0009^{F,N}$	–	–	–
…	…	…	…	4.178	20.4^{61}	…	…	…	…	…	…
[HB89] 0957+561	10 01 20.7	55 53 56	1.413	1.3911	20.3^{22}	17.0	1.63^{T}	$\approx 0.5^{F,N}$	–	0.15^{V}	–
FBQS J100841.2+362319	10 08 41.2	36 23 19	3.125		Not given^{W}	17.1	0.18^{we}	0.035^{F}, 0.066^{N}	–	0.035^{V}	–
LBQS 1009−0252	10 12 15.8	−03 07 03	2.746	1.738	19.8^{29*}	17.6	X	$<0.001^{F,N}$	X	X	–
BRI 1013+0035	10 15 49.0	00 20 19	4.405	3.750	20.2^{37*}	18.8	X	$<0.001^{F,N}$	X	$<0.0001^{w}$	–
…	…	…	…	3.103	$21.1^{37,53}$	…	…	…	…	…	…
[HB89] 1017+109	10 20 08.8	10 40 03	3.158	2.380	19.9^{15*}	17.2	$1.64^{T,P}$	0.22^{F}	0.23^{P}	–	$0.004(240)^{o}$
[HB89] 1021−006	10 24 29.6	−00 52 55	2.547	2.398	$19.6^{13,15*}$	18.5	0.47^{T}	$\approx 1.0^{F,N,P}$	0.99^{P}	0.70^{P}	$0.51(8.4)^{P}$, 0.31(11), $0.15(22)^{K}$
…	…	…	…	1.886	19.8^{13*}	…	…	…	…	…	…
FBQS J1021+3001	10 21 56.5	30 01 41	3.115		Not given^{W}	17.4	X	$0.001^{F,N}$	–	–	–
RX J1028.6−0844	10 28 37.7	−08 44 39	4.276	3.42	20.1^{58}	18.9	X	0.27^{N}	0.27^{V}	$0.16^{V,pmn}$	–
…	…	…	…	4.05	19.7^{58}	…	…	…	…	…	…
BR 1033−0327	10 36 23.7	−03 43 20	4.509	4.190	20.2^{37*}	18.5	X	$<0.001^{F,N}$	X	X	–
QSO 1052+04	See Section 2		3.391	2.839	20.3^{15*}	–	X	–	X	X	–
PKS 1055−301	10 58 04.0	−30 24 55	2.523	1.904	21.5^{60}	–	–	0.26^{V}	0.36^{P}	0.43^{P}	–
PSS J1057+4555	10 57 56.4	45 55 52	4.116	2.90	20.1^{58}	17.7	X	$0.001^{F,N}$	–	$<0.0001^{w}$	$0.005(250)^{M}$
…	…	…	…	3.05	20.3^{58}	…	…	…	…	…	…
…	…	…	…	3.32	20.2^{58}	…	…	…	…	…	…
BRI 1108−0747	11 11 13.6	−08 04 02	3.922	3.611	20.2^{37*}	18.1	X	$<0.003^{N}$	X	X	–
…	…	…	…	2.79	20.1^{37*}	…	…	…	…	…	…
SDSSp J111246.30+004957.5	11 12 46.3	00 49 58	3.918	3.28	19.9^{37*}	18.3	X	$<0.001^{F,N}$	–	–	$0.003(250)^{z}$
…	…	…	…	3.25	19.7^{37*}	…	…	…	…	…	…
BRI 1114−0822	11 17 27.1	−08 38 58	4.495	4.258	$20.3^{37,53}$	19.4	X	$<0.003^{N}$	X	X	–
2MASSi J1124428−170517	11 24 42.9	−17 05 17	2.400	0.6819	20.5^{48}	16.2	$0.96^{T,P}$	0.38^{N}	0.27^{P}	0.18^{P}	–

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
[HB89] 1127−145	11 30 07.1	−14 49 27	1.187	0.3127	21.7[52]	16.9	5.38[T,P]	≈6[N,P]	5.97[P]	5.46[P]	3.2(8.4)[P]/ 1.3(90)/≈0.8(230)[x]
[HB89] 1136+122	11 39 19.3	11 58 07	2.894	1.792	20.6[13]	17.6	X	<0.001[F,N]	X	X	–
FBQS J115023.5+281907	11 50 23.6	28 19 07	3.124		Not given[W]	16.9	X	≈0.01[F,N]	–	–	–
[HB89] 1151+068	11 54 11.1	06 34 38	2.762	1.775	21.3[13,29]	18.2	X	<0.0009[F,N]	X	X	–
[HB89] 1157+014	11 59 44.8	01 12 07	1.986	1.9438	21.8[3]	17.7	0.89[T]	0.27[F,N]	0.14[P]	≈0.1[c,pmn]	–
HM 1159+01	See Section 2		3.269	2.678	21.1[15,29]	–	X	<0.001[F,N]	X	X	–
2MASSi J1159065+133738	11 59 06.5	13 37 37	4.073	3.72	20.3[58]	18.5	X	<0.003[N]	X	<0.0001[w]	–
2MASSi J1205231−074232	12 05 23.1	−07 42 32	4.694	4.38	20.5[37]	18.7	X	<0.003[N]	–	0.000[V]	–
…	…	…	…	4.13	20.1[37*]	…	…	…	…	…	…
…	…	…	…	3.38	20.0[37*]	…	…	…	…	…	…
…	…	…	…	3.20	19.7[37*]	…	…	…	…	…	…
LBQS 1205+0918	12 08 21.0	09 01 30	2.073	1.673	20.6[29]	17.6	X	0.003[F,N]	–	–	–
[HB89] 1209+093	12 11 34.9	09 02 23	3.297	2.581	21.4[15,29]	18.8	X	<0.001[F,N]	X	X	–
…	…	…	…	2.333	20.2[15]	…	…	…	…	…	…
LBQS 1209+1046	12 11 40.6	10 30 03	2.193	0.633	20.3[40]	17.8	X	<0.0009[F,N]	X	X	<0.0005(8.4)[h]
LBQS 1209+1524	12 12 32.1	15 07 25	3.059	2.856	19.9[29*]	17.7	X	<0.001[F,N]	X	X	<0.0003(8.4)[h]
LBQS 1210+1731	12 13 03.1	17 14 23	2.543	1.898	20.6[29]	17.6	X	0.002[F,N]	X	X	<0.0002(8.4)[h]
LBQS 1213+0922	12 15 39.7	09 06 08	2.719	2.523	20.1[29*]	18.1	X	0.05[F,N]	–	0.05[c]	0.03(8.4)[h]
…	…	…	…	1.749	20.1[29*]	…	…	…	…	…	…
FBQS J121732.5+330538	12 17 32.6	33 05 38	2.606	2.000	21.0[13,29]	18.1	0.21[we]	0.18[u,N]	0.14[V]	0.08[V]	–
LBQS 1222+1053	12 25 00.3	10 36 57	2.305	1.739	20.1[29*]	18.7	X	<0.001[F]	X	X	–
LBQS 1223+1753	12 26 07.2	17 36 49	2.936	2.4658	21.5[29]	18.1	X	<0.001[F]	X	X	–
LBQS 1225+1610	12 28 29.0	15 54 23	2.237	1.888	19.8[29*]	18.7	X	<0.001[F,N]	X	X	–
PKS B1228−113	12 30 55.5	−11 39 10	3.528	2.193	20.6[60]	–	X	–	0.55[P]	0.46[P]	0.36(8.4)[P]
FBQS J122824.9+312837	12 28 24.8	31 28 38	2.219	1.821	19.1[5,9,18,27*]	15.9	0.36[we]/0.35[T]	0.32[u,F,N]	0.33[V]	0.34[V]	–
LBQS 1229+1414	12 31 46.9	13 57 28	2.875	2.668	20.1[29*]	18.1	X	<0.001[F,N]	X	X	–
QSO 1230−101	12 33 12.7	−10 25 23	2.394	1.931	20.5[60]	–	1.02[P]	0.60[N,P]	0.43[P]	0.34[P,pmn]	–
LBQS 1232+0815	12 34 37.5	07 58 42	2.576	2.3377	20.9[29]	18.9	X	<0.0009[F,N]	X	X	–

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
LBQS 1234+0122	12 37 24.5	01 06 14	2.025	1.851	19.9^{29*}	17.7	X	$<0.001^{F,N}$	X	X	–
LBQS 1240+1516	12 42 53.3	14 59 52	2.297	1.738	20.8^{29*}	18.3	X	$<0.001^{F,N}$	X	X	–
LBQS 1242+0006	12 45 24.6	−00 09 39	2.075	1.823	20.2^{29*}	17.7	X	$<0.001^{F,N}$	–	–	$<0.0003(8.4)^{h}$
LBQS 1244+1129	12 46 40.4	11 13 03	3.147	2.637	19.9^{15*}	18.0	X	$<0.0009^{F,N}$	X	X	–
QSO 1244+3443	Not published		2.48	1.857	$20.6^{13,29}$	18.0					
LBQS 1246−0217	12 49 24.9	−02 33 40	2.106	1.779	21.2^{29*}	18.4	X	$<0.001^{F,N}$	X	X	–
PG 1247+267	12 50 05.8	26 31 08	2.042	1.228	$\geq 18^{5,9,11,18,27*}$	15.8	X	$<0.001^{j,F,N}$	–	$0.0007^{j,V}$	$0.0015(15)^{j}/0.0014(240)^{l}$
PSS J1248+3110	12 48 20.2	31 10 44	4.35	3.696	20.4^{61}	18.8	X	$<0.0008^{F,N}$	–	–	–
PKS 1251−407	12 54 00.5	−40 59 27	4.464	3.533	20.6^{60}	–	–	–	0.25^{P}	0.22^{P}	–
…	…	…	…	3.752	20.3^{60}	…	…	…	…	…	…
PSS J1253−0228	12 53 36.3	−02 28 08	4.007	2.78	21.4^{58}	18.8	X	$<0.001^{F,N}$	X	X	–
…	…	…	…	3.60	19.7^{58}	…	…	…	…	…	…
LBQS 1308−0104	13 11 19.2	−01 20 32	2.584	1.762	20.1^{29*}	17.5	X	$<0.001^{F,N}$	X	X	–
LBQS 1308+0105	13 11 28.3	00 49 01	2.800	1.762	20.6^{29*}	18.7	X	$<0.001^{F,N}$	X	X	–
BR J1310−1740	13 10 26.6	−17 40 29	4.185	3.43	20.1^{58}	19.3	X	$<0.003^{N}$	–	–	–
BRI 1328−0433	13 31 30.8	−04 48 51	4.217	3.08	20.1^{37*}	19.3	X	$<0.001^{F,N}$	X	X	–
3C 286	13 31 08.3	30 30 33	0.849	0.692	21.3^{19}	17.3	$29.6^{we}/27.5^{T}$	$14.7^{v,F,N}$	–	1.41^{g}	$\approx 2.7(22)/1.3(43)/0.9(92)^{i}$
LBQS 1329+0018	13 32 15.0	00 02 53	2.351	1.948	19.6^{29*}	18.0	X	$<0.001^{F,N}$	X	X	–
…	…	…	…	1.892	19.8^{29*}	…	…	…	…	…	…
PG 1329+412	13 31 41.1	41 01 58	1.937	0.519	20.8^{27*}	16.8	X	$<0.0009^{F,N}$	–	0.0003^{k}	–
BR J1330−2522	13 30 52.1	−25 22 19	3.949	2.91	20.0^{58}	18.5	X	$<0.003^{N}$	X	X	–
…	…	…	…	3.08	19.8^{58}	…	…	…	…	…	…
[HB89] 1331+170	13 33 35.8	16 49 02	2.084	1.776	21.4^{2}	16.7	0.62^{T}	$0.4^{F,N}$	–	0.71^{c}	–
[HB89] 1337+113	13 40 03.0	11 06 30	2.919	2.794	$20.9^{11,13,29}$	19.0	X	$<0.0009^{F,N}$	–	–	–
…	…	…	…	2.510	19.9^{13*}	…	…	…	…	…	…
…	…	…	…	2.142	20.1^{13*}	…	…	…	…	…	…
QSO 1338+101	See Section 2		2.459	1.837	$19.9^{7,13*}$						

Quasar	Coordinates (J2000) h m s	d ′ ″	z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy) $S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
[HB89] 1340+099	13 42 29.5	09 44 46	2.942	2.199	19.9^{15*}	18.5	X	$<0.001^{F,N}$	–	–	–
QSO 1345−0137	13 47 49.2	−01 52 24	1.929	1.747	19.8^{29*}	19.2	X	$<0.001^{F,N}$	X	X	$<0.0002(8.4)^{h}$
BRI 1346−0322	13 49 16.7	−03 37 15	3.992	3.734	$20.7^{37,53}$	18.8	X	$<0.001^{F,N}$	X	X	–
…	…	…	…	3.360	19.6^{37*}	…	…	…	…	…	…
…	…	…	…	3.150	19.9^{37*}	…	…	…	…	…	…
[HB89] 1347+112	13 49 53.3	11 01 16	2.697	2.475	$20.3^{13,29}$	18.5	X	$<0.001^{F,N}$	–	–	–
…	…	…	…	2.05	20.3^{13*}	…	…	…	…	…	…
[VCV96] 1352+1050	13 54 48.7	10 36 11	3.150	2.230	20.1^{13*}	19.1	X	$<0.001^{F,N}$	–	–	–
PKS B1354−107	13 56 47.8	−11 01 34	3.006	2.501	20.4^{60}	–	X	0.20^{N}	0.26^{P}	$0.27^{P,pmn}$	–
…	…	…	…	2.966	20.8^{60}	…	…	…	…	…	…
[HB89] 1354+258	13 57 06.6	25 37 25	2.006	1.418	21.5^{52}	18.5	1.15^{T}	$\approx 0.3^{F,N,P}$	0.20^{P}	0.16^{P}	–
[HB89] 1402+044	14 05 01.1	04 15 35	3.211	2.713	19.9^{13*}	19.8	$1.24^{T,P}$	$\approx 1.0^{F,N}$	0.58^{P}	$0.6^{P}/0.9^{pmn}$	$0.90(8)/0.83(11)/0.59(22)^{K}$
…	…	…	…	2.688	20.2^{13*}	…	…	…	…	…	…
…	…	…	…	2.485	20.2^{13*}	…	…	…	…	…	…
[HB89] 1409+095	14 12 17.3	09 16 25	2.856	2.670	$20.2^{14,15}$	18.6	X	$<0.001^{F,N}$	–	–	–
…	…	…	…	2.459	$20.5^{15,29}$	…	…	…	…	…	…
…	…	…	…	2.025	19.9^{15*}	…	…	…	…	…	…
FIRST J141045.7+340909	14 10 45.8	34 09 09	4.351	3.43	20.1^{58}	19.6	X	$0.002^{F,N}$	–	–	–
PKS B1418−064	14 21 07.0	−06 43 39	3.689	3.449	20.4^{60}	18.5	0.37^{T}	$0.39^{F,N}$	0.38^{P}	0.39^{P}	–
SBS 1425+606	14 26 56.6	60 25 51	3.165	2.83	$20.4^{24,36}$	15.8	X	–	X	X	–
PSS J1432+3940	14 32 24.9	39 40 24	4.28	3.272	21.0^{61}	18.6	X	$<0.0009^{F,N}$	–	–	–
PSS J1435+3057	14 35 23.6	30 57 22	4.297	3.710	20.0^{53*}	19.3	0.03^{we}	$<0.001^{F,N}$	X	$<0.0001^{w}$	$<0.002(250)^{M}$
…	…	…	…	3.510	20.0^{53*}	…	…	…	…	…	…
…	…	…	…	3.260	20.0^{53}	…	…	…	…	…	…
PSS J1443+2724	14 43 31.2	27 24 37	4.407	4.216	20.8^{53*}	19.3	X	$<0.001^{F,N}$	X	$<0.0001^{w}$	$<0.0005(250)^{M}$
[HB89] 1451−375	14 54 27.4	−37 47 33	0.314	0.270	20.1^{27*}	16.7	2.9^{P}	$1.6^{P}, 0.9^{N}$	1.51^{P}	1.84^{P}	$1.51(8.4)^{P}$
[HB89] 1451+123	14 54 18.6	12 10 55	3.246	3.173	$19.9^{11,13,14,15*}$	18.6	X	$<0.0009^{F,N}$	–	–	–
…	…	…	…	2.477	$20.3^{13,15*}$	…	…	…	…	…	…
…	…	…	…	2.254	$19.9^{13,15*}$	…	…	…	…	…	…
PSS J1456+2007	14 56 28.9	20 07 26	4.249	3.43	19.8^{58}	19.5	X	$<0.001^{F,N}$	–	0.001^{w}	–
…	…	…	…	4.16	19.9^{58}	…	…	…	…	…	…

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	$\log N_{HI}$	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
BRI 1500+0824	15 02 45.4	08 13 05	3.943	2.797	20.8[37,53]	18.8	X	<0.001[F,N]	X	X	–
QSO 1503+118	Not published		2.792	2.131	19.8[13*]	–	X	–	–	–	–
HS 1543+5921	15 44 20.2	59 12 27	0.807	0.009	20.4[54]	17.0	X	0.06[y]	X	X	–
[HB89] 1548+092	15 51 03.4	09 08 50	2.749	2.321	19.8[11,14,15*]	18.0	X	<0.0009[F,N]	X	X	–
PSS J1618+4125	16 18 22.7	41 25 59	4.213	3.92	20.5[58]	19.6	X	<0.001[F,N]	X	<0.0001[w]	<0.001(250)[M]
3C 336	16 24 39.4	23 45 12	0.927	0.656	20.4[52]	17.5	7.83[T]	2.50[P,N]	1.40[P]	0.76[P]	–
PSS J1633+1411	16 33 19.7	14 11 43	4.351	3.90	19.8[58]	18.7	X	<0.001[F,N]	X	X	–
PC 1643+4631A	16 45 00.7	46 26 13	3.790	3.137	20.7[16]	20.3	X	<0.001[F,N]	X	X	–
RX J1759.4+6638	17 59 27.9	66 38 53	4.32	3.40	20.4[58]	21.9	X	0.003[N]	–	–	≈0(240)[l]
PSS J1802+5616	18 02 48.9	56 16 51	4.158	3.39	20.1[58]	18.3	X	<0.003[N]	X	X	–
…	…	…	…	3.56	20.2[58]	…	…	…	…	…	…
…	…	…	…	3.76	20.4[58]	…	…	…	…	…	…
…	…	…	…	3.80	20.1[58]	…	…	…	…	…	…
[HB89] 1836+511	18 37 19.2	51 11 34	2.827	2.248	19.8[15*]	19.9	X	<0.003[N]	–	–	–
HS 1946+7658	19 44 54.9	77 05 52	3.051	2.84	21.3[26]	16.2	–	<0.003[N]	–	0.001[V]	–
PC 2047+0123	20 50 23.3	01 35 11	3.799	2.730	20.4[53]	19.7	X	<0.003[N]	X	X	0.002(240)[o]
[WHO91] 2059−360	21 02 44.6	−35 53 07	3.090	3.0825	20.9[47]	19.2	–	<0.003[N]	X	X	–
[HB89] 2112+059 NED02	21 15 18.0	06 08 33	0.398	0.204	20.5[27*]	18.9	X	<0.003[N]	–	0.001[V]	–
PSS J2122−0014	21 22 07.5	−00 14 45	4.114	3.20	20.3[58]	19.1	X	<0.0009[F,N]	X	<0.0002[w]	–
…	…	…	…	4.00	20.1[58]	…	…	…	…	…	…
[MWA91] 2126−4618	21 30 09.6	−46 05 49	1.888	1.795	20.1[29*]	18.9	–	–	X	X	–
PMN J2130−4515	21 30 52.4	−45 15 43	2.713	2.051	19.9[29*]	18.6	–	–	–	0.30[V,pmn]	–
LBQS 2132−4321	21 36 06.0	−43 08 18	2.420	1.916	20.6[29]	17.9	–	–	X	X	–
PMN J2134−0419	21 34 12.1	−04 19 10	4.334	3.27	20.0[58]	20.0	0.62[T]	0.29[e,N]	–	0.24[pmn]	–
[HB89] 2136+141	21 39 01.3	14 23 36	2.427	2.134	19.8[13*]	18.9	0.72[T,P]	1.13[N]	1.15[P]	1.11[P]	≈1.7(8.4)[P,K]/ 1.6(11)/1.2(22)[K]
…	…	…	…	2.118	19.8[13*]	…	…	…	…	…	…

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
[MWA91] 2138−4427	21 41 59.5	−44 13 26	3.17	2.851	20.9[29]	18.2	–	–	X	X	–
[MWA91] 2139−4434	21 42 25.9	−44 20 18	3.230	2.380	19.8[29*]	17.7	–	–	X	X	–
PSS J2154+0335	21 54 06.9	03 35 40	4.363	3.61	20.4[58]	19.0	X	<0.003[N]	X	X	–
…	…	…	…	3.79	19.7[58]	…	…	…	…	…	…
LBQS 2206−1958	22 08 52.1	−19 44 00	2.56	2.0763	20.7[13,29]	17.3	X	<0.003[N]	X	X	<0.0003(8.4)[h]
…	…	…	…	1.927	20.5[13,29]	…	…	…	…	…	…
BR J2216−6714	22 16 52.0	−67 14 44	4.469	3.37	20.0[58]	18.1	–	–	X	X	–
…	…	…	…	4.28	20.0[58]	…	…	…	…	…	…
…	…	…	…	4.32	20.1[58]	…	…	…	…	…	…
3C 446	22 25 47.3	−04 57 02	1.4040	0.493	20.9[27*]	17.2	≈11[P]	6.2[P]	4.7[P]	4.3[P]	5.9(8.4)[P,x]/3.7(22)[P,r]/ 4.0(90)/1.5(230)[x]
LBQS 2230+0232	22 32 35.3	02 47 55	2.147	1.858	20.8[29]	17.8	X	<0.003[N]	X	X	–
LBQS 2231−0015	22 34 09.0	00 00 02	3.020	2.070	20.2[15,29*]	17.4	X	<0.001[F,N]	–	–	–
[HB89] 2233+131	22 36 19.2	13 26 20	3.274	3.150	20.2[12,15,41*]	18.8	X	<0.003[N]	–	–	–
…	…	…	…	2.551	20.0[15*]	…	…	…	…	…	…
[VCV96] Q 2239−386	22 42 21.7	−38 20 17	3.554	3.2810	20.8[15,29]	20.3	–	<0.003[N]	X	X	–
…	…	…	…	3.240	19.6[15*]	…	…	…	…	…	…
2MASSi J2239536−055219	22 39 53.6	−05 52 19	4.558	4.069	20.5[37,53]	18.3	X	<0.003[N]	X	X	–
PSS J2241+1352	22 41 47.9	13 52 03	4.441	3.65	20.0[58]	19.1	X	<0.003[N]	X	X	–
…	…	…	…	4.28	20.7[58]	…	…	…	…	…	…
LBQS 2248+0127	22 50 39.9	01 43 45	2.559	1.902	20.6[29]	18.2	X	<0.003[N]	X	X	–
QSO 2311−373	23 13 59.7	−37 04 46	2.476	2.182	20.5[60]	–	–	0.24[N]	0.27[P]	0.39[P]	–
BR J2317−4345	23 17 26.8	−43 45 28	3.943	3.49	20.9[58]	19.1	–	–	X	X	–
[HB89] 2314−409	23 16 46.9	−40 41 21	2.448	1.857	20.6[60]	18.0	–	0.62[P]	0.50[P]	0.42[P]	0.18(8.4)[P]
…	…	…	…	1.875	20.3[60]	…	…	…	…	…	…
BR J2328−4513	23 28 48.6	−45 13 46	4.359	3.04	20.1[58]	19.2	–	–	X	X	–

(Continued)

Table 1. (Continued)

Quasar	Coordinates (J2000)		z_{em}	z_{abs}	log N_{HI}	V	Radio flux densities (Jy)				
	h m s	d ′ ″					$S_{0.4}$	$S_{1.4}$	$S_{2.7}$	$S_{5.0}$	S_{higher}
PSS J2344+0342	23 44 30.0	03 42 30	4.239	2.68	21.0^{58}	18.2	X	$<0.003^{N}$	X	X	–
…	…	…	…	3.21	20.9^{58}	…	…	…	…	…	…
MG3 J234456+3433	23 44 51.3	34 33 50	3.053	2.9084	21.2^{23,31}	18.4	$0.37^{we}/0.26^{T}$	$\approx 0.15^{23,N}$	–	$0.15^{c,V,23}$	–
[HB89] 2348−011	23 50 57.8	−00 52 10	3.014	2.610	21.3^{13,15}	18.0	X	$<0.0009^{F,N}$	–	–	–
…	…	…	…	2.426	20.5^{13,15,29}	…	…	…	…	…	…
BR J2349−3712	23 49 13.9	−37 12 59	4.208	3.69	20.2^{58}	18.7	–	$<0.003^{N}$	X	X	–
QSO 2351−1154	Not published			2.063	19.8^{15*}						
…	…	…	…	1.837	19.8^{15*}	…	…	…	…	…	…
QSO 2351+0217	Not published		2.03	1.766	20.9^{29}						
[WB92] 2358+1857	00 01 08.6	19 14 34	3.10	3.081	20.0^{23}	20.5	0.24^{23}	$0.27^{23,N}$	–	0.20^{23}	–
[HB89] 2359−022	00 01 50.0	−01 59 40	2.817	2.1537	20.3^{13,15,29}	18.7	X	$0.037^{m,F,N}$	–	–	–
…	…	…	…	2.0951	20.7^{13,15,29}	…	…	…	…	…	…
QSO 2359+0023	Not published		–	2.219	19.9^{15*}						
…	…	…	…	2.116	19.9^{15*}	…	…	…	…	…	…
[HB89] 2359+068	00 01 40.6	07 09 54	3.234	1.751	19.6^{15*}	18.4	X	$<0.003^{N}$	X	X	–

Note that several of the DLA citations do not give the background quasar's coordinates, although we did manage to get some (but not all) of these from the authors. For the remaining few we obtained the coordinates from elsewhere (e.g. NED, SIMBAD, Véron-Cetty & Véron 2001). However, note that when checking the coordinates for the DLAs without published magnitudes against optical images (Digitized Sky and APM Surveys)*, we found no optical counterparts at the limiting APM magnitudes of 21.5 (north) and 22.5 (south) for QSOs 0112–30, 0115–30, 1052+04, 1159+01 (C. Hazard & R.G. McMahon, unpublished) nor QSO 1338+101 (C. Hazard & W.L.W. Sargent, unpublished) and so we have no knowledge of where these coordinates originally came from. Where we have failed to find optical coordinates for any of these sources, '*Not published*' is inserted into the table. We have kept these sources in the catalogue for the sake of providing a full comprehensive list and, for the sake of consistency, we do not include the best radio positions as this could prove misleading.

2.2 The Radio References

The radio parameters of the background quasar supplying the continuum emission are compiled from Wardle & Miley (1971)[a], Condon et al. (1981)[b], Gregory & Condon (1991)[c], Visnovsky et al. (1992)[d], White & Becker (1992)[e], Lonsdale, Barthel & Miley (1993)[f], Zhang et al. (1994)[g], Hooper et al. (1995)[h], Kameno et al. (1995)[i], Barvainis, Lonsdale & Antonucci (1996)[j], Falcke, Sherwood & Patnaik (1996)[k], Omont et al. (1996)[l], Bischof & Becker (1997)[m], de Vries, Barthel & O'Dea (1997)[n], Hughes, Dunlop & Rawlings (1997)[o], Kukula et al. (1998)[p], Lonsdale, Doeleman & Phillips (1998)[q], Teräsranta et al. (1998)[r], Bloom et al. (1999)[s], McMahon et al. (1999)[t], Wadadekar & Kembhavi (1999)[u], Peng et al. (2000)[v], Stern et al. (2000)[w], Tornikoski, Lainela & Valtaoja (2000)[x], Bowen et al. (2001, and references therein)[y], Carilli et al. (2001)[z] and current versions of the Parkes (Wright & Otrupcek 1990, incorporating the 408 MHz flux densities from the MRC catalogue; Large, Cram & Burgess 1991)[P], Green Bank (White & Becker 1992)[G], FIRST (Becker, White & Helfand 1995)[F], Texas (Douglas et al. 1996)[T], PMN (Griffith et al. 1994; Wright et al. 1994; Griffith et al. 1995; Wright et al. 1996)[pmn], WENSS (Rengelink et al. 1997)[we], NVSS (Condon et al. 1998)[N], Kovalev et al. (1999)[K] and Véron-Cetty & Véron (2001)[V] catalogues, and most recently, the MAMBO survey of the highest redshift PSS quasars (Omont et al. 2001)[M]. Finally, the results of White et al. (2000)[W] give new DLAs as well as the FIRST radio luminosities of the quasars illuminating these.

Note that no radio information for the quasars in Table 1 was found in the 5 GHz catalogue of Becker, White & Edwards (1991), the optically quiet quasar search of Kollgaard et al. (1995) nor the S5 radio source catalogue of Stickel & Kühr (1996).

3 Discussion

As mentioned in the introduction, we have compiled this catalogue since the comparison between optical and radio absorption lines can provide a considerably more precise determination of $\Delta\alpha/\alpha$: to a first approximation, the ratio of two optical transition frequencies used in the many-multiplet method (Dzuba, Flambaum & Webb 1999; Webb et al. 1999) is $\frac{\omega_1}{\omega_2} \propto 1 + 0.1\alpha^2$. However, the ratio of the hyperfine neutral hydrogen (21 cm) to an optical resonance transition frequency is directly proportional to α^2, i.e. about 10 times larger. Thus, a substantial improvement in the determination of any variation of α could be made by obtaining further statistics from optical *and* 21 cm lines in cosmological absorbers. The limit on the variation of α can be obtained by the comparison of the H I 21 cm line with any other optical or radio line (Section 3.2). However, by using redshifted 21 cm H I together with α-sensitive species such as iron, zinc, chromium and nickel (Dzuba et al. 1999), frequently seen in DLAs, we simultaneously maximise sensitivity and take advantage of the different signs of the frequency shifts due to α variation to help minimise systematic effects (Murphy et al. 2001a; Webb et al. 2001).

A new systematic effect which applies to tests for $\Delta\alpha/\alpha$ involving an H I and optical comparison involves the possible different spatial characteristics of the radio and optical quasar emission. Large differences can result in the radio and optical light probing slightly different lines-of-sight. However, we note that there are examples where the radio and optical emission is known to coincide spatially, and those cases are clearly of particular interest (Section 3.1). In order to minimise the spatial segregation problem, the most reliable tests will come from comparing H I lines with neutral atomic or molecular species, or singly ionised species where the ionisation potential is smaller than that for neutral hydrogen.

3.1 Radio-loud Quasars illuminating DLAs

Of the known radio-loud (Sradio $\gtrsim 0.1$ Jy) systems, we summarise the current state of searches for atomic and molecular hydrogen (Section 3.2) absorption features. Note that with regard to the spatial distribution of the optical and radio emission, from the NVSS catalogue (Condon et al. 1998), *unless otherwise stated, the 1.4 GHz emission extends to a radius of* $\approx 1'$ *and the peak emission coincides with the given optical position* (Table 1).

PKS 0118−272: A BL Lac object where Kanekar & Chengalur (2001) failed to detect H I absorption at $z = 0.5579$.

[HB89] 0149+336: A gravitational lens candidate for which we could find no reference to radio absorption features.

PKS 0201+113: A gravitational lens where de Bruyn et al. (1996) and Briggs, Brinks & Wolfe (1997) have detected H I absorption at $z = 3.388$.

*These can be found at http://archive.stsci.edu/dss/ and http://www. ast.cam.ac.uk/~apmcat/, respectively.

[HB89] 0201+365: No reference to radio absorption features found.
[HB89] 0215+015: A BL Lac object where Briggs & Wolfe (1983) failed to detect H I absorption.
[HB89] 0235+164: A BL Lac object where H I absorption at $z = 0.524$ has been detected (Wolfe, Briggs & Davis 1982; Briggs & Wolfe 1983). Douglas et al. (1992); Wiklind & Combes (1995) failed to detect CO at the absorption redshift.
[HB89] 0248+430: Lane & Briggs (2001) have detected the H I absorption at the DLA redshift.
[HB89] 0329−255: No reference to radio absorption features found.
[HB89] 0335−122: No H I absorption detected (N. Kanekar & J.N. Chengalur, in preparation).
PKS 0336−017: N. Kanekar & J.N. Chengalur (in preparation) failed to detect H I absorption at $z = 3.0619$.
QSO 0347−211: No reference to radio absorption features found.
PKS 0405−331: As above.
QSO 0432−440: As above. *No NVSS data available.*
[HB89] 0438−436: Drinkwater, Combes & Wiklind (1996) failed to detect CO in the torus of this AGN ($z = 2.852$). *No NVSS data available.*
[HB89] 0439−4319: Tentative H I absorption detected by Kanekar et al. (2001) in this low redshift source. *No NVSS data available.*
PKS 0454+039: No H I (Briggs & Wolfe 1983) or H_2 (Ge & Bechtold 1999) absorption has been detected. *No optical/radio offset, but there is a second* 30″ *radius radio source centered at 5 s to the west.*
[HB89] 0458−020: In this blazar, Wolfe et al. (1985); Briggs et al. (1989) have detected H I absorption at $z = 2.03945$. No H_2 or CO (i.e. molecular) absorption has been detected (Wiklind & Combes 1994b, Ge & Bechtold 1999).
PKS 0528−250: Carilli et al. (1996) failed to detect H I absorption at $z = 2.8110$, although H_2 absorption in this DLA (Foltz, Chaffee & Black 1988, Srianand & Petitjean 1998, Ge & Bechtold 1999) and CO emission in the $z = 2.14$ DLA (Brown & vanden Bout 1993) have been detected. Note that no H_2 or CO absorption in either DLA was detected by Wiklind & Combes (1994b); Lu Sargent & Barlow (1999).
[HB89] 0537−286: No reference to radio absorption features found.
[HB89] 0552+398: Although Galactic H I (Dickey et al. 1983) and HCO^+ (Lucas & Liszt 1996) absorption has been observed towards this quasar, no reference to absorption at the DLA (or any cosmological) redshift could be found.
J074110.6+311200: In this optically variable quasar, Lane et al. (1998); Kanekar, Ghosh & Chengalur (2001) have detected H I absorption at $z = 0.2212$.
FBQS J083052.0+241059: In this blazar, Kanekar & Chengalur (2001) have detected H I absorption at $z = 0.5247$.
IRAS F08279+5255: A gravitational lens in which Combes, Maoli & Omont (1999) have detected CO 4→3 emission at $z = 3.911$, the redshift of the source. *There is a weak central radio source at optical position with two stronger diagonally opposing sources near* 08h31m50s/52d43′30″ *and* 08h31m 25s/52d46′30″.
[HB89] 0834−201: No reference to radio absorption features found for this blazar.
QSO 0913+003: No reference to radio absorption features found.
QSO 0933−333: As above. *Offset from optical position at* 09h35m08.6s/-33d32′34″.
[HB89] 0938+119: No reference to radio absorption features found. *No offset but there is a second source to the south east near* 09h41m20.5s/11d45″00′.
[HB89] 0952+179: Kanekar & Chengalur (2001) have detected H I absorption at $z = 0.2378$.
[HB89] 0957+561: A gravitational lens where no H I absorption has been detected (N. Kanekar & J.N. Chengalur, in preparation).
[HB89] 1017+109: No reference to radio absorption features found. *Radio position offset* ≈20″ *to the west of the optical centre.*
[HB89] 1021−006: No reference to radio absorption features found for this optically variable quasar.
RX J1028.6−0844: No H I absorption detected (N. Kanekar & J.N. Chengalur, in preparation).
PKS 1055−301: No reference to radio absorption features found. *Radio position offset* ≈1′ *to the west of the optical centre.*
2MASSi J1124428−170517: No reference to radio absorption features found. *Offset slightly from optical position at* 11h24m41.5s/-17d05′10″.
[HB89] 1127−145: Lane et al. (1998); Chengalur & Kanekar (2000) have detected variable H I absorption at $z = 0.3127$ towards this blazar.
[HB89] 1157+014: Wolfe et al. (1981) and Briggs & Wolfe (1983) have detected H I absorption at $z = 1.94362$.
LBQS 1213+0922: No reference to radio absorption features found.
FBQS J121732.5+330538: Wiklind & Combes (1994b) failed to detect CO absorption at $z = 1.9984$.
FBQS J122824.9+312837: Briggs & Wolfe (1983) failed to detect H I absorption at $z = 1.7945$.
PKS B1228−113: No reference to radio absorption features found.
QSO 1230−101: As above.
PKS 1251−407: As above. *No NVSS data available.*
3C 286: H I at $z = 0.69215$ by Brown & Roberts (1973) but no H_2 absorption has yet been detected (Ge & Bechtold 1999).
[HB89] 1331+170: A blazar where Wolfe & Davis (1979); Briggs & Wolfe (1983) have detected H I absorption at $z = 1.7764$, but Lu et al. (1999) failed to detect CO absorption.
PKS B1354−107: No H I absorption detected (N. Kanekar & J.N. Chengalur, in preparation) in the

Table 2. The radio-loud DLAs in which H I absorption has been searched

τ is the optical depth of the H I line, with 3σ upper limits quoted, as given by the references in Section 3.1. For PKS 0201+113 the values are from de Bruyn et al. (1996) and Briggs et al. (1997), respectively. PKS 0336−017 and MG3 J234456+3433 — these are results from N. Kanekar & J.N. Chengalur (in preparation); Carilli et al. (1996) obtained $\tau < 0.02$ and 0.1, respectively. S is the approximate flux density in janskys at $z_{\rm abs}$ and S.I. is the spectral index (both are estimated from the flux density values in Table 1 and $S \propto \nu^{-\rm S.I.}$). In the last column, GPS designates a GHz peaked source with the approximate turnover frequency given in parenthesis. In the case of the 'U-shaped' SEDs, [HB89] 0215+015 is known to exhibit radio outbursts (e.g. Ledden & Odell 1985) and so the flux densities quoted will be variable. For PKS 0454+039 and [HB89] 1331+170, these could be due to an anomalous flux density measurement and both are considered flat spectrum sources (e.g. Wampler et al. 1984; Mattox et al. 1997).

Quasar	τ	$\log N_{\rm HI}$	S	S.I.	Notes
PKS 0118−272	<0.007	20.3	1.2	0.1	
PKS 0201+113	0.09, 0.04	21.3	0.3	–	GPS (2.6)
[HB89] 0215+015	<0.04	19.9	0.9	–	See caption
[HB89] 0235+164	0.05–0.5	21.6	1.8	−0.2	Inverted
[HB89] 0248+430	0.20	21.6	1.2	–	GPS (2.5)
[HB89] 0335−122	<0.008	20.8	0.8	0.3	
PKS 0336−017	<0.005	21.2	1.3	0.6	
[HB89] 0439−4319	<0.007	20.0	0.4	0.2	
PKS 0454+039	<0.01	20.7	0.4	–	See caption
[HB89] 0458−020	0.3	21.7	2.5	0.3	
PKS 0528−250	<0.2	21.2	1.9	0.5	For $z_{\rm abs} = 2.811$ DLA
J074110.6+311200	0.07	21.2	1.9	–	GPS (2.9) $z_{\rm abs} = 0.221$ DLA
FBQS J083052.0+241059	0.007	20.3	0.8	−0.2	Inverted
[HB89] 0952+179	0.013	21.3	1.2	0.3	
[HB89] 0957+561	<0.004	20.3	0.9	1.3	
RX J1028.6-0844	<0.03	20.1	1.7	0.9	$z_{\rm abs} = 3.42$ DLA
[HB89] 1127−145	0.06	21.7	6.2	–	GPS (1.4)
[HB89] 1157+014	0.05	21.8	1.0	0.8	
FBQS J122824.9+312837	<0.05	19.1	0.3	0	
3C 286	0.11	21.3	19.0	0.6	
[HB89] 1331+170	0.020	21.4	0.6	–	See caption
PKS B1354−107	<0.05	20.8	0.2	0	$z_{\rm abs} = 2.996$ DLA
[HB89] 1451−375	<0.006	20.1	1.8	0.2	
3C 446	<0.02	20.9	7.4	0.5	
MG3 J234456+3433	<0.04	21.2	0.3	0.2	

$z_{\rm abs} = 2.966$ DLA. *Radio position offset* $\approx 15''$ *to the west of the optical centre.*

[HB89] 1354+258: No reference to radio absorption features found.

[HB89] 1402+044: No reference to radio absorption features found for this BL Lac.

PKS B1418−064: No reference to radio absorption features found.

[HB89] 1451−375: Chengalur & Kanekar (2000) failed to detect H I absorption in this HST source.

3C 336: No reference to radio absorption features found for this optically variable quasar.

PMN J2130−4515: No reference to radio absorption features found. *No NVSS data available.*

PMN J2134−0419: No reference to radio absorption features found.

[HB89] 2136+141: No reference to radio absorption features found.

3C 446: A blazar not detected in H I absorption at the DLA (Chengalur & Kanekar 2000) nor CO absorption at the quasar redshift (Drinkwater et al. 1996).

QSO 2311−373: No reference to radio absorption features found.

[HB89] 2314−409: As above. *No NVSS data available.*

MG3 J234456+3433: Carilli et al. (1996) and N. Kanekar & J.N. Chengalur (in preparation) failed to detect H I absorption at $z = 2.9084$.

Finally, note that H I absorption has been observed in the inferred (from metal lines) DLAs **3 C196**, **LBQS 1229−0207** (Wolfe et al. 1995) and **[HB89] 1243−072** (Lane & Briggs 2001).

3.2 Searching for New Radio Absorbers

If we summarise the current H I absorption results for the DLAs (Table 2), we see that although many of the positive results have very high column densities, this does not appear to be a prerequisite for H I absorption (i.e. FBQS J083052.0+241059). Perhaps also of relevance is the spectral energy distributions (SEDs): note that all of the GHz peaked sources have high column densities and have all been detected in H I. Of the two inverted SEDs, one DLA has a high column density whereas the other is relatively low and both of the flat SED detections have high column densities. Finally, the two steep spectrum quasars which illuminate DLAs detected in H I absorption

([HB89] 1157+014 and 3C 286) also have high column densities.

Because of the relation between turnover frequency and source size (Fanti et al. 1990; O'Dea & Baum 1997), we may expect a higher H I absorption detection rate from flat and inverted SED sources, since these result from similar optical and radio lines-of-sight. However, as it stands, the statistics are too small (Table 2) and so in order to maximise our sample, it appears that the way to proceed is an unbiased search for H I in the DLAs occulting the remaining radio-loud quasars.

As mentioned in Section 1, as well as optical and H I comparisons, the inter-comparison of atomic and molecular lines will also give a ten-fold increase in accuracy for $\Delta\alpha/\alpha$: due to its zero dipole moment and small moment of inertia, molecular hydrogen cannot be directly observed at radio frequencies* and so it is the usual practice to infer the presence of this from the millimetre rotational lines of such molecules as CO. In order to also take advantage of this, we have applied for time to search for molecular absorption lines in the DLAs occulting mm-loud quasars with the IRAM 30 metre and Swedish ESO Sub-millimetre telescopes. Recently (April 2002), we have been awarded time on the Australia Telescope Compact Array in order to obtain 90 GHz flux measurements for the whole radio-loud sample, as a means of selecting new sources in which to search for millimetre absorption. The results will be published in forthcoming papers.

Also, with regard to finding new systems in which there may be absorption (in all three frequency regimes), we see that 13 of the quasars are known to be BL Lac/optically variable/blazars† and that 3 of the sources are known gravitational lenses. This may be of interest as of the four known high redshift millimetre (i.e. molecular) absorbers, two are BL Lac objects: B 0218+357 (Wiklind & Combes 1995) and PKS 1413+135 (Wiklind & Combes 1994a)‡. This may suggest several strategies for finding similar new absorbers (Stocke & Rector 1999) which could prove useful in appending to this catalogue.

4 Summary

We have performed an exhaustive search of the literature in order to produce a list of all known damped Lyman alpha systems and their associated radio properties. It is the 57 radio-loud systems in which we are interested as many of these have the potential to show H I absorption in each DLA. Of the sources searched, it is seen that several exhibit such absorption and we are involved in an ongoing project to search for this in the remaining systems. Not only will this give us radio lines for comparison with optical data in order to constrain any temporal variations in the fine structure constant, but we will have a significant sample from which we could consider why some DLAs absorb in H I whereas others do not. For example, Chengalur & Kanekar (2000) suggest that low redshift DLAs may arise from a multitude of absorbers, and hence do not have sufficient path length for H I absorption, while those of higher redshift are due to more compact systems. Finally, as well as finding new H I absorbers, we hope that this catalogue will prove useful to those using damped Lyman alpha systems as part of their research.

Final note: In order to retain its usefulness to the astronomical community, we have now produced an on-line version of this catalogue which will be continually updated. This is available from http://www.phys.unsw.edu.au/~sjc/dla.

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*In the case of $z > 1.8$ sources, however, the ultraviolet lines of H_2 are redshifted into the optical window, making molecular hydrogen readily observable at these frequencies. As well as for PKS 0528−250 (Section 3.1) molecular hydrogen has also been detected in the DLAs occulting the radio-quiet quasars [HB89] 0000-263 (Levshakov et al. 2000), LBQS 0013−0029 (Ge & Bechtold 1997; Petitjean, Srianand, & Ledoux 2002), [HB89] 0347−383 (Levshakov et al. 2002), LBQS 1232+0815 (Ge & Bechtold 1997; Srianand et al. 2000) and the inferred (Wolfe et al. 1995) DLA [HB89] 0551−366 (Ledoux, Srianand, & Petitjean 2002).

†BL Lacs and Optically Violent Variables are known collectively as blazars. In these radio-loud active galactic nuclei the radio jet is relativistically beamed close to the line-of-sight (e.g. Peterson 1997).

‡The former, as well as PKS 1830−211, is also a gravitational lens (Wiklind & Combes 1996).

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¶http://vizir.u-strasbg.fr/local/cgi-bin/vizHelp?faq.htx

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