Probing Galaxies through Quasar Absorption Lines
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Evidence for a magnitude-dependent bias in the Hamburg/ESO survey for damped Lyman–α systems

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Abstract. We present preliminary results from the Hamburg/ESO survey for damped Ly-α (hereafter, DLA) systems. This survey is characterised by (i) good knowledge of the biases affecting the parent QSO survey, and (ii) the brightness and (iii) relatively wide magnitude distribution of the background QSOs. Therefore, it is well–suited to study possible magnitude–dependent biases in DLA surveys, such as the one expected from dust obscuration.

We have systematically searched for damped Lyman-α line candidates in 5 Å resolution spectra of the 188 QSOs that constitute our statistical sample. These candidates have later been re-observed with UVES at the ESO–Very Large Telescope (VLT) for confirmation and accurate $N(HI)$ measurements. In the redshift range covered by the survey, 19 DLA systems have been discovered. Over the whole survey, we find that the number density $n(z)$ and cosmological density of gas $\Omega_{\rm gas}$ have comparable values to the ones obtained by CORALS (Ellison *et al.* 2001).

However, the number densities of DLA systems $n(z)$ in two sub–samples of equal absorption distance path defined by the magnitude of the background QSOs differ by a factor of ≈ 5. We estimate that the probability that $n(z)$ is equal in the two sub–samples is < 0.003. A similar, only slightly less significant difference is found for $\Omega_{\rm gas}$.

1. Introduction

The possibility that dust in intervening DLA absorbers could obscure the background QSOs has been considered for more than 20 years (see e.g. Ostriker & Heisler 1984). Fall & Pei (1989) estimated that 30% of the $z_{\rm em} = 3$ QSOs could have been missed by optical surveys and, conversely, that dust could significantly bias surveys from DLA systems in the spectra of optically-selected QSOs. Pei, Fall & Bechtold (1991) found that spectra of QSOs showing DLA absorption lines are significantly redder than those without DLA systems, in an unfortunately small sample. Recently, Murphy & Liske (2004) have failed to confirm this finding in a much larger sample of QSOs from the SDSS survey.

Direct evidence that dust may strongly affect the statistics of DLA systems is crucially missing for different reasons: (i) the QSOs from the LBQS survey (Wolfe *et al.* 1995) show

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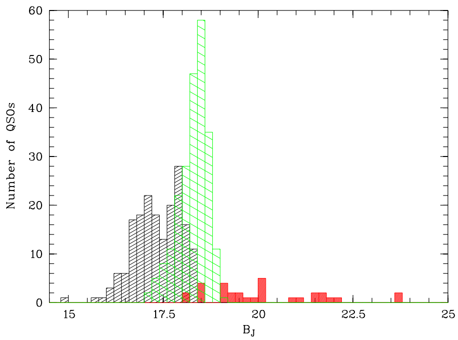

Figure 1. Distribution of QSO magnitudes in the three major surveys for DLA systems at $z_{\rm abs} \approx 2$: in *black, small hashing spacing:* , the recently completed Hamburg/ESO survey, in *red, filled histograms:* the CORALS survey (Ellison *et al.* 2001), and in *green, large hashing spacing:* the LBQS survey, whose results are part of the study of Wolfe *et al.* (1995). Note the strong difference in $B_{\rm J}$ magnitude coverage between the three surveys.

a narrow magnitude range (cf. Fig. 1); and (ii) a comparison between optically- and radio-selected DLA samples (Ellison *et al.* 2001) does not provide strong constraints because of the small size of the radio-selected sample. Instead, the evidence for dust in DLA systems is mostly indirect (Pettini *et al.* 1997; Boissé *et al.* 1998; Ledoux *et al.* 2003).

2. A magnitude dependent bias in the Hamburg/ESO DLA survey

Between 1996 and 2001, we have observed 243 QSOs or QSO candidates from the Hamburg/ESO QSO survey at a spectral resolution of $\simeq 5$ Å, FWHM with the ESO – 1.5m and Danish – 1.54m telescopes at the ESO La Silla observatory. After eliminating non-QSOs, $z < 1.6$ QSOs, BAL QSOs, or spectra with a too low S/N, we built a statistically well-defined sample of 188 QSOs. The distribution of these QSOs in the $z - B_{\rm J}$ plane is statistically indistinguishable from the parent H/ESO QSO survey, indicating that we have not involuntarily biased our surveys while selecting our spectroscopic targets.

The spectra of these objects were systematically searched for absorption lines in a redshift range limited, in the blue, by the wavelength for which the S/N per pixel is 5 and, in the red, by the wavelength corresponding to a receding velocity of 5000 km/s from the QSO redshift. The QSOs whose spectra show absorption lines detected at the 5σ level with rest equivalent width larger than 7.5Å (corresponding to $\log N_{\rm HI} = 20$) were re-observed with UVES at the ESO VLT. Results for the whole survey are given in the 2nd column of Table 1 ($\Omega_{\rm M} = 1.0$, $\Omega_\Lambda = 0$ for easy comparison with previous results). In other words, our mean number density for the whole survey is extremely similar to the one of CORALS (Ellison *et al.* 2001), if we take the redshift dependence of $n(z)$ into account, and is 50 % larger than that found from the relation $n(z) = 0.055\,(1+z)^{1.11}$ (Storrie–Lombardi & Wolfe 2000). We also find the cosmological density of neutral gas comparable to previous results.

Our QSO sample has the particular characteristics of including bright QSOs. We have therefore constituted 2 sub–samples of equal total absorption distance path $\Delta\chi$. These sub–samples are based on the magnitude $B_{\rm J}$ of the background QSOs. The critical magnitude to define the 2 samples is $B_{\rm J} = 17.40$. From Poisson statistics, we estimate that the probability to obtain the observed number of DLA systems in the 2 sub–samples from the same (mean) number density is less than 0.003. Figs. 2 show a comparison of the values of $n(z)$ and $\Omega_{\rm gas}$ for the 2 H/ESO sub–samples with 2 sub–samples of the CORALS survey defined in a similar way.

Both the H/ESO and CORALS surveys indicate that $n(z)$ and $\Omega_{\rm gas}$ are correlated with the magnitude of the background QSOs. The steep increase seen in both surveys does not take place at the same $B_{\rm J}$ though. A possible reason is that the CORALS QSOs have larger redshifts than the H/ESO ones. Indeed, (a) for (nearly) all H/ESO QSOs, the

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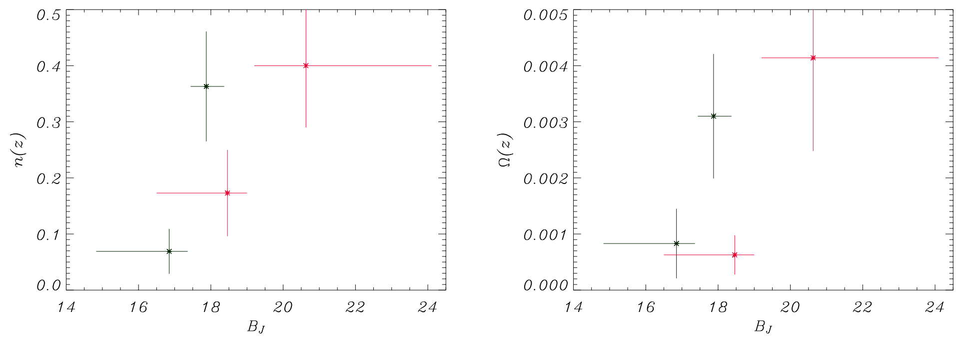

Figure 2. *Left:* number densities of DLA systems in the bright and faint sub–samples of the H/ESO survey (black, left–most points) and CORALS (red, right–most points). *Right:* idem for the cosmological density. The 2 CORALS sub–samples have identical $\Delta\chi$: the bright sample correspond to a coverage towards $B_{\rm J} < 19.2$ QSOs and include 5 DLA systems, while the faint sample corresponds to fainter QSOs and include 12 systems. The horizontal bars represent the $B_{\rm J}$ coverage of each sub–sample. The position of the vertical bar along the $B_{\rm J}$ axis represents the mean magnitude of the sub–sample. The extent of the vertical bar represents the $\pm 1\sigma$ error.

Table 1. Preliminary results from the H/ESO DLA survey

	Whole Sample	Bright Sub–Sample	Faint Sub–Sample
QSOs	188	93	95
Δz	87.7	43.6	44.0
$\Delta\chi$	154.1	76.4	77.8
$< B_{\rm J} >$	17.37	16.85	17.87
DLAs	19	3	16
$n(z)$	0.22 ± 0.05	0.069 ± 0.040	0.36 ± 0.09
$10^3\,\Omega_{\rm gas}$	1.98 ± 0.64	0.83 ± 0.62	3.10 ± 1.12

Ly–α emission line falls within the $B_{\rm J}$ passband, and this is not the case for a significant fraction of the CORALS QSOs; (b) the flux decrement caused by the Ly-α forest is larger for the CORALS QSOs than for the H/ESO ones; and (c) as the mean redshift of the CORALS survey is larger, any reddening effect caused by the DLA systems would be larger in the CORALS survey than in the H/ESO one. We are currently testing this possibility.

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