Statistics and characteristics of Mg II absorbers along GRB lines of sight

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Summary

We analyse the properties of MgII absorption systems detected along the sightlines toward GRBs using a sample of 10 GRB afterglow spectra obtained with VLT-UVES over the past six years. The signal-to-noise ratio is sufficiently high that we can extend previous studies to smaller equivalent widths. We find that the number of weak absorbers is similar along GRB and QSO lines of sight, while the number of strong systems is a factor of 2 larger along GRB lines of sight, about twice smaller however than previously reported. Adding intermediate and low resolution observations reported in the literature to our sample, we increase the absorption length for strong systems to Δz = 31.5 (about twice the path length of previous studies) and confirm the strong MgII systems excess at 3σ significance. We find also that the number density of strong MgII is larger low redshift and that the number densityof (sub)-DLAs per unit redshift in the UVES sample is probably twice larger than what is expected from QSO sightlines which confirms the peculiarity of GRB lines of sight. Our results support the idea that the current sample of GRB lines of sight could be biased by a subtle gravitational lensing effect.

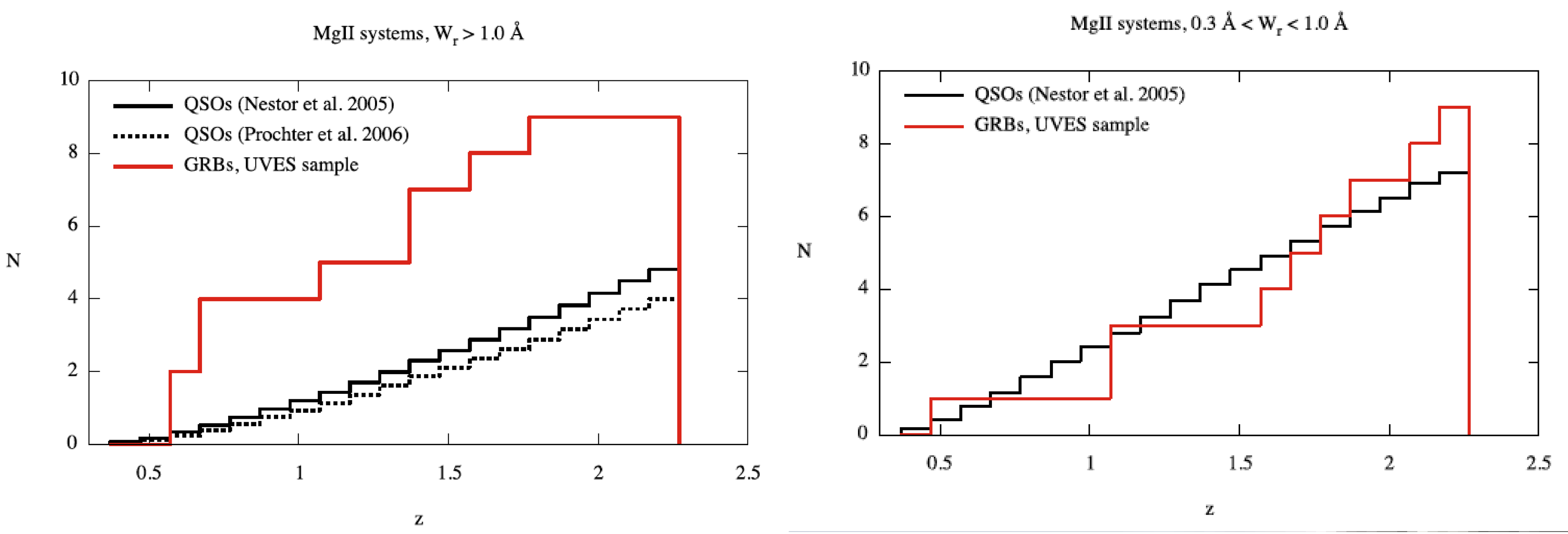

Fig. 1. Comparison between the cumulative distribution of MgII systems detected along the UVES GRB lines of sight (red) and the one expected along QSO lines of sight following Nestor et al. (2005) (black solid) or Prochter et al. (2006a) (black dashed), for strong (left panel) and weak (rigth panel) systems.

$W_r(\lambda 2796)$	>0.3 Å	>1 Å	> 0.3 and <1 Å
$\langle z_{abs} \rangle$	1.34	1.11	1.57
Redshift path	13.79	13.94	13.79
N_{obs}^{MgII} (UVES sample)	18	9	9
N_{exp}^{MgII} (Nestor et al., 2005)	11.98 (±3.46)	4.83 (±2.20)	7.21 (±2.68)
N_{exp}^{MgII} (Prochter et al., 2006)		4.00 (±2.00)	

Table 1. Number of MgII systems and redshift paths.

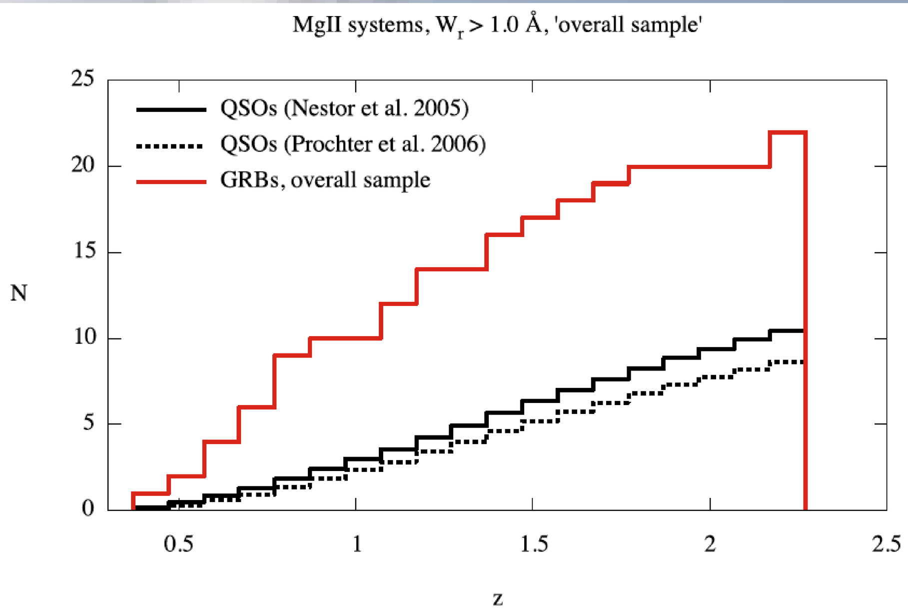

Fig. 2. Comparison between the cumulative distribution of strong MgII systems in the overall sample of GRB lines of sight (same legend as Fig.2).

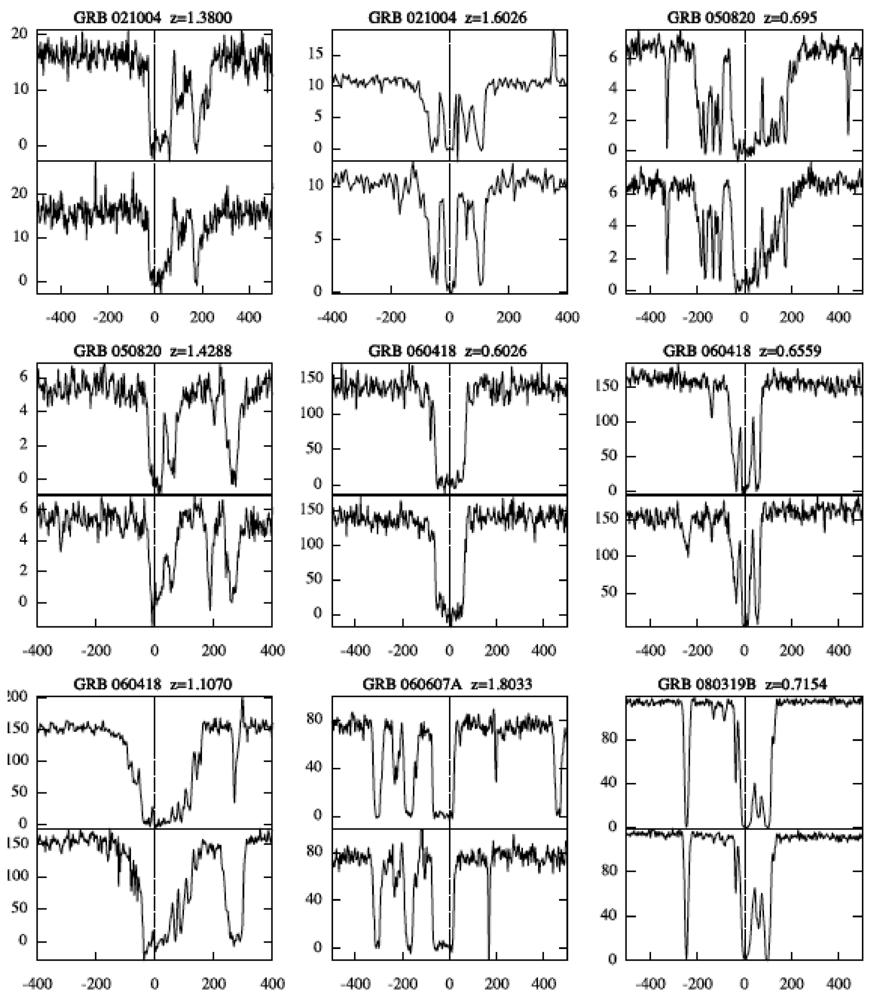

Fig. 3. The strong MgII absorption systems detected in the UVES spectra displayed in the velocity space.

Introduction

Prochter et al. (2006b, ApJL 648, 93) found that the incidence of strong MgII intervening systems along GRB sightlines is ~ 4 times higher (number density dN/dz = 0.90 ± 0.24) than what is seen in the SDSS along QSO lines of sight . Several processes have been pointed out to explain these excess (Porciani et al. 2007, ApJ 659, 218) : obscuration of QSOs by dust in the absorber, different size of the source beam, gravitational lensing and magnification bias. All these possibilities are still debated and none is in itself to explain the discrepancy. The properties of the systems do not favor the idea that part of the systems are actually caused by ejected material local to the GRBs (see also Cucchiara et al. 2009, ApJ, in press, arXiv:0811.1382).

Our analysis

We searched for MgII absorbers present in new a sample of 10 GRB afterglow spectra obtained with VLT-UVES. The signal-to-noise ratio is sufficiently high that we can extend previous studies to smaller equivalent widths (typically Wr > 0.3 Å). We use the SDSS QSO survey redshift limits zstart = 0.366 and zend = 2.27 and we exclude the redshift range within 3000km/s from the GRB redshift. We consider all MgII components within 500km/s as a single system.

The 9 strong systems detected are displayed in Fig. 3. In Fig. 1 the cumulative number distribution of MgII systems detected along UVES GRB lines of sight is shown and compared to those expected along QSO lines of sight following Prochter et al. (2006a, Apj, 639, 766) and Nestor et al. (2005, ApJ, 628, 637). Results are summarized in Table 1.

We confirm the excess of *strong* MgII systems along GRB lines of sigth BUT only of a factor of about 2. The number of *weak* systems is consistent with QSO lines of sight.

Adding intermediate and low resolution observations reported in the literature to our sample, we increase the absorption length for strong systems to Δz = 31.5 (about twice the path length of previous studies). The cumulative number distribution of the strong MgII systems is shown in Fig. 2. The factor of 2 excess of strong MgII systems along GRB lines of sight is confirmed at 3 sigma.

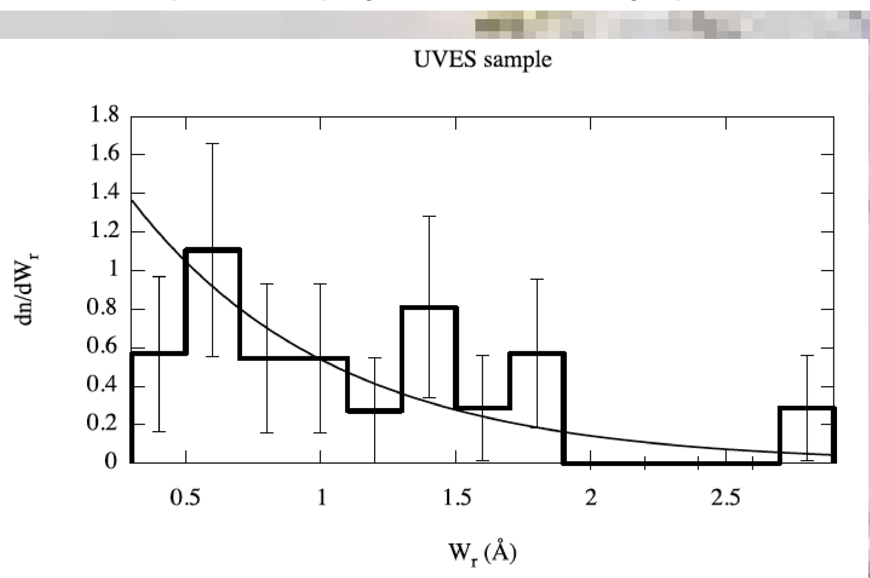

Fig. 4. Normalized Wr distribution of the MgII systems with Wr > 0.3 Å detected in the UVES sample. The solid curve represents the same function for QSO absorbers (Nestor et al. 2005).

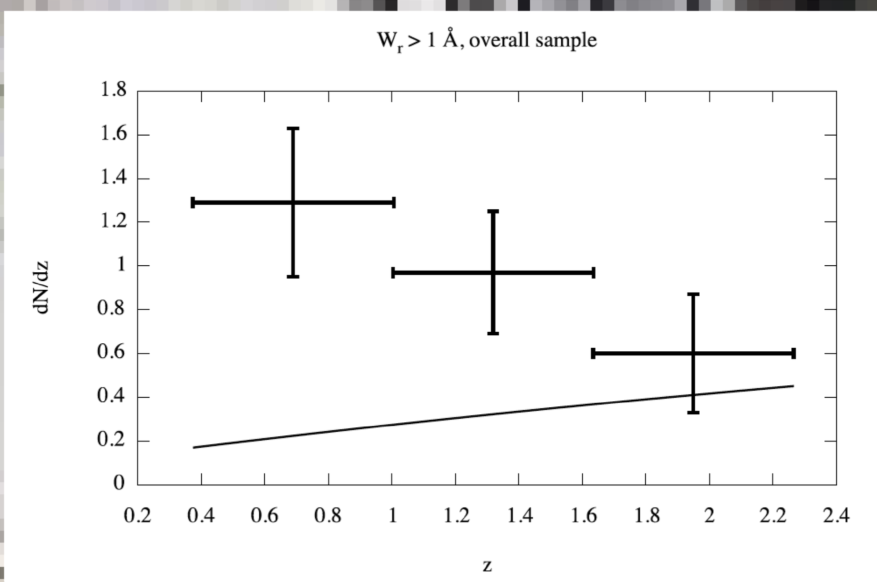

Fig. 5. Number density evolution of strong MgII systems detected along GRB lines of sight. The solid line represents thecorresponding function for QSO lines of sight.

The equivalent width and redshift distributions

We show in Fig. 4 the comparison between the normalized Wr distribution of all MgII systems with Wr > 0.3 Å detected in the UVES sample and the one reported by Nestor et al. (2005) for the MgII systems along the QSO lines of sight in the SDSS survey. The KS tests give a 27% chance that the GRB and QSO distributions are drawn from the same population for the UVES sample. This result argues against the idea that the excess of MgII systems could be related to the internal structure of the intervening clouds.

While the total number of systems and the number of weak systems have a comparable redshift evolution in GRB and QSO lines of sight, the excess of strong systems is seen in GRBs especially at low redshift (see Fig. 5). This apparent excess of strong systems in the low-redshift bins could be an argument in favor of some lensing amplification bias affecting the GRB lines of sight as the effect of lensing should be larger in case the deflecting mass is at smaller redshift. GRB lines of sight could be preferentially chosen for follow-up when the GRB afterglow is brighter due to lensing by the presence of an excess of galaxies along the line of sight.

The dust bias hypothesis

It has been proposed that a dust bias could affect the statistics of strong MgII systems. Indeed, if part of the population of strong MgII systems contains a substantial amount of dust, then the corresponding lines of sight could be missed in QSO surveys because of the attenuation of the quasar whereas GRBs being intrinsically brighter, the same lines of sight are not missed when observing GRBs. We estimate the dust content of strong MgII systems UVES los from the depletion of iron compared to other non-depleted species as is usually done in DLAs. Results are reported in Table 2. Although depletion of iron can be significant, the corresponding attenuation is modest because the column densities of metallic species are relatively small owing to low metallicities. We note that for GRB021004 and GRB060607A we could estimate the attenuation for ALL strong MgII systems identified along their line of sight. Therefore our results do not support the idea that a bias due to the presence of dust in strong Mg ii systems could be an explanation for the overabundance of the strong Mg ii absorbers.

Table 2. Iron to Zinc or Siloicon ratio and extinction estimate for 4 strong MgII systems.

	z	N(FeII) (cm^{-2})	N(ZnII) (cm^{-2})	N(SiII) (cm^{-2})	[Fe/Zn]	[Fe/Si]	N_{Fe}^{dust} (cm^{-2})	A_V
GRB021004	1.3800	15.09 ± 0.05		15.19 ± 0.09		−0.05 ± 0.10	14.18 ± 0.23	~ 0
GRB021004	1.6026	14.60 ± 0.03	12.78 ± 0.02		−1.03 ± 0.04		15.59 ± 0.02	< 0.2
GRB060418	1.1070	14.69 ± 0.01	12.87 ± 0.03		−1.05 ± 0.03		15.68 ± 0.03	< 0.2
GRB060607A	1.8033	14.07 ± 0.03		14.36 ± 0.10		−0.24 ± 0.10	13.94 ± 0.17	~ 0

Estimating the HI column density of the strong MgII systems

A key parameter to characterize an absorber is the corresponding HI column density. Unfortunately, the HI Lyman-α absorption line of most of the systems is located below the atmospheric cut-off and is unobservable from the ground. We will assume that the strong systems seen in front of GRBs and QSOs are cosmological and drawn from the same population. We believe that the results discussed previously legitimate this assumption. We use the velocity-metallicity correlation found by Ledoux et al. (2006, A&A, 457, 71) to estimate the expected metallicity of the strong systems in the UVES sample. We infer the hydrogen column densities dividing the zinc, silicon or iron column densities measured in the UVES spectrum by the metallicity. Another method to infer the presence of DLAs among MgII absorbers is to use the 'D-index' (Ellison et al. 2009). The results are shown in Table 3 (columns 3 and 4).

We can compare the number of DLAs per unit redshift, n_{DLA}, found for the QSO lines of sight by Rao et al. (2006, ApJ, 636, 610) to that of our GRB sample. Rao et al. (2006) found n_{DLA}=0.1 (with errors of the order of 0.02). If we assume that three to five systems in our sample are DLAs(see Table 6) we find n_{DLA}=0.22-0.36 . This means that the number of DLAs is at least twice larger along GRB lines of sight as compared to QSO lines of sight. This further supports the idea that the current sample of GRB lines of sight could be biased by a subtle gravitational lensing effect.

GRB	z_{abs}	[X/H][a]	N_{HI}(cm^{-2})[b]	D-index[c]
021004	1.380	−0.63	20.3	8.32 ± 0.22
021004	1.603	−0.65	20.8	9.99 ± 0.47
050820A	0.692			9.0 ± 0.03[d]
050820A	1.429	−0.34	> 19.2	8.13 ± 0.22
060418	0.603	−1.13	> 22.0	10.39 ± 0.09[e]
060418	0.656	−0.77	> 19.2	7.51 ± 0.05
060418	1.107	−0.85	21.1	8.17 ± 0.06
060607A	1.803	−0.21	19.0	9.12 ± 0.06
080319B	0.715	−0.17	> 18.7	8.06 ± 0.01

Table 3. Inferred metallicity, N_{HI} and D-index of strong MgII systems in the UVES sample.

Observed sub-DLA absorbers

We searched the Lyman-α forest probed by the UVES spectra for the presence of damped Lyman-α absorption lines. We found four sub-DLAs over a redshift range of Δz = 4.3. This is again twice larger than what is expected in QSOs. However the statistics is poor. It is intriguing that these systems are all located in the half redshift range of the Lyman- forest closest to the GRB. It is therefore not excluded that part of this gas is somehow associated with the GRBs. In that case, ejection velocities of the order of 10 to 25 000 km/s are required.