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GRB 090313: X-shooter's first shot at a GRB*


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ABSTRACT

Context. X-shooter is the first second-generation instrument to become operative at the ESO Very Large Telescope (VLT). It is a broad-band medium-resolution spectrograph designed with gamma-ray burst (GRB) afterglow spectroscopy as one of its main science drivers.

Aims. During the first commissioning night on sky with the instrument fully assembled, X-shooter observed the afterglow of GRB 090313 as a demonstration of the instrument’s capabilities.

Methods. GRB 090313 was observed almost two days after the burst onset, when the object had already faded to R ~ 21.6. Furthermore, the 90% illuminated Moon was just 30 degrees away from the field. In spite of the adverse conditions, we obtained a spectrum that, for the first time in GRB research, covers simultaneously the range from 5700 to 23000 Å.

Results. The spectrum shows multiple absorption features at a redshift of 3.3736, which we identify as the redshift of the GRB. These features are composed of 3 components with different ionisation levels and velocities. Some of the features have never been observed before in a GRB at such a high redshift. Furthermore, we detect two intervening systems at redshifts of 1.8005 and 1.9597.

Conclusions. These results demonstrate the potential of X-shooter in the GRB field, as it was capable of observing a GRB down to a magnitude limit that would include 72% of long GRB afterglows 2 hours after the burst onset. Coupled with the rapid response mode available at VLT, allowing reaction times of just a few minutes, X-shooter constitutes an important leap forward on medium resolution spectroscopic studies of GRBs, their host galaxies and intervening systems, probing the early history of the Universe.

Key words. Gamma rays: bursts - Instrumentation: spectrographs

1. Introduction

During the first hours after the onset of long gamma-ray bursts (GRBs), for a short-long classification see Kouveliotou et al. 1993), their optical/near infrared (nIR) counterparts shine as the brightest beacons in the Universe (Kann et al. 2007; Racusin et al. 2008; Bloom et al. 2009). Being generally produced by the collapse of a massive star (Woosley & Bloom 2006, and references therein), they give us the opportunity to study the environment of massive star forming regions at cosmological distances (the average redshift of long GRBs observed by Swift is ~ 2.2; Fynbo et al. 2009) through the use of medium to high resolution spectroscopy. Time variability of absorption features corresponding to fine-structure and metastable level transitions has been sometimes identified (Dessauges-Zavadsky et al. 2006; Vreeswijk et al. 2007; D’Elia et al. 2009), which makes it possible to constrain the distance from the GRB to the absorbing gas, at typical scales of kpc. Only few such cases have been spotted up to now, due to the required spectral resolution and sensitivity. Furthermore, being bright sources that disappear over time, they allow us to study intervening systems through their absorption signatures in the afterglow spectrum, and to search for the associated galaxies when the afterglow has faded away (Jakobsson et al. 2004; Chen et al. 2009).

The family of short GRBs, although still poorly studied, presents on average fainter counterparts and has been suggested...
to be produced by the coalescence of compact objects (Nakar 2007, and references therein), although some of them could come from other progenitors, such as extragalactic magnetars (Hurley et al. 2005). Up to now, there have been few attempts to acquire a spectrum of a short GRB, most of them having been unsuccessful due to late observations or faint afterglows. There is still no medium or high resolution spectrum of a short GRB.

Within this context, X-shooter (D’Odorico et al. 2006) is presented to the GRB community. It is the first of the second-generation instruments at ESO’s Very Large Telescope (VLT), at Paranal Observatory (Chile). It is a single target spectrograph capable of obtaining a medium resolution spectrum (R=4 000 - 14 000, depending mainly on the slit width and wavelength) covering the complete range from 3 000 to 24 800 Å in a single exposure. It has been designed to maximise efficiency by splitting the light with dichroics into three arms: ultraviolet/blue (UVB), visible (VIS) and near-infrared (NIR). Each arm has an echelle spectrograph with optimised optics, coatings, dispersive elements and detectors. Since March 2009, it is installed in the Cassegrain focus of Kueyen, the second 8.2m Unit Telescope of the VLT, where it began routine scientific observations in October 2009.

One of the key science drivers of X-shooter is the study of optical and NIR afterglows of GRBs as cosmological probes of the circumstellar, interstellar and intergalactic medium back to the epoch of first star formation in the Universe. During its first commissioning night on sky with its full setup, X-shooter was used to observe the afterglow of GRB 090313, which had exploded two days before, as a test target. In this article we present the results of this observation of a GRB with X-shooter, giving a hint of the full potential that the instrument will have during regular observations.

The paper is organised as follows: Sect. 2 describes our observations in the context of the GRB evolution. In Sect. 3 we present our results, focusing on the spectral features local to the GRB and on the intervening systems. Finally, in Sect. 4 we discuss the results and present our conclusions.

2. Observations

At 09:06:27 UT on 13 March 2009, Swift’s Burst Alert Telescope (BAT) detected GRB 090313 (Mao et al. 2009), a long-duration burst with $T_{90} = 78 \pm 19$ s (Sakamoto et al. 2009). In response to the trigger, the 0.76m Katzman Automatic Imaging Telescope (KAIT) slewed to the position shortly after and detected a bright ($R$-16 magnitude) optical afterglow (Chornock et al. 2009a) at equatorial coordinates (J2000.0): R.A. = 13h13m36s.21, Dec. = +08°05'49.2" (Updike et al. 2009).

The afterglow evolved through a plateau phase (Perley et al. 2009b, de Ugarte Postigo et al. 2009b) during which it maintained a magnitude of $I \sim 17.7$ up to almost a day after the burst, when the light curve steepened (de Ugarte Postigo et al. 2009c) and decayed following a power law $F \propto t^{-1.77}$ (Perley et al. 2009a). Perley (2009) used multicolour photometry to study the spectral energy distribution of the afterglow, concluding that its intrinsic extinction followed a Small Magellanic Cloud profile with a V-band extinction $A_V \leq 0.4$. This value was later refined by Kann et al. (2009) to $A_V = 0.34 \pm 0.15$. They note that in the time interval between 0.02 and 0.5 days the afterglow of GRB 090313 was the optically brightest ever detected. A detailed multiwavelength study of the afterglow will be presented by Melandri et al. (in preparation).

Shortly after X-shooter came online for commissioning, it was aimed at the afterglow of GRB 090313. The observations consisted of a 900 s exposure and four additional exposures of 1500 s each, with a slit width of 0.9'' in the VIS and NIR arms and 1.0'' in UVB. The UVB and VIS detectors were used with 1x2 binning (binned in the spectral direction but not in the spatial one) and a slow readout of 100 kHz to minimise the noise. The NIR detector was used in the default unbailed sample-up-the-ramp (non-destructive) mode. The resolution of the final spectrum varies with wavelength from 35 to 60 km s$^{-1}$. All three spectral ranges were exposed during the first 900 s. Inspection of this first set of frames showed a negligible signal in the UVB arm due to strong contamination by the Moon, which was just 30 degrees away from the field and almost full (90%). Hence, for the subsequent exposures, only VIS and NIR frames were obtained. The mid-exposure time of the combined spectrum is 15.26 March 2009 UT, 45.1 hours after the onset of the burst, when the afterglow had already faded to $R \sim 21.6$ (Perley et al. 2009a; Cobb 2009). On a 2x2 s combination of observation frames obtained at a mean time of 43.82 hours after the burst we measure $I=20.63\pm0.06$ (see Fig. 1). This magnitude is based on Cousins magnitudes derived from the SDSS catalogue. The signal to noise ratio (S/N) per spectral bin of the spectrum varies with wavelength, reaching a maximum of $\sim 7$ around 8000 Å.

![Fig. 1.  $I$-band acquisition image. The GRB afterglow is indicated with an arrow. We have also marked the two galaxies identified by Berger (2009), mentioned in the discussion, as G1 and G2 (G2 is faintly visible ~ 2'' NW of the afterglow). The figure shows the complete field of view of the acquisition and guiding camera, 90'' x 90''. North and East are indicated in the figure.](http://www.sdss.org/DR7/algorithms/sdssUBVRITransform.html)
reported throughout the paper are in vacuum. The uncertainty in the wavelength calibration is of the order of 30 km s\(^{-1}\) when using the current pipeline, which is the dominant uncertainty when calculating the redshift. For the analysis of the spectral features we have used FITLYMAN (Fontana & Ballester 1995).

We caution that, being the first night of commissioning on sky, the instrument was not yet optimised. Thus, the results presented here must not be considered as representing the optimal performance of the instrument but as a preliminary view of the potential that will be delivered by the instrument in regular operation. The results presented here supersede those reported by de Ugarte Postigo et al. (2009a).

3. Results

Over the complete range of the spectrum we identify a main absorption system that is composed of several velocity components. In order to determine the central redshift of the absorption system, the spectra were rebinned such that the resulting absorption line centre represents the wavelength where the strongest absorption takes place. Excluding from our calculations the blended absorption lines C\(\text{II}\)\(\lambda\)1334 and C\(\text{II}\)^{+}\(\lambda\)1335.6, 1335.7 (see Sect. 3.1), we derive a redshift of 3.3736\(\pm\)0.0004 which we identify as the redshift of the GRB. This value is consistent with the one previously determined by Chornock et al. (2009b) using GMOS/Gemini-South and Thöne et al. (2009) using FORS2/VLT.

Furthermore, we identify two intervening systems in the spectrum, one of which can be again divided into several velocity components. We determine the redshift in the same way as for the host galaxy system and derive redshifts of 1.9597\(\pm\)0.0003 for the higher redshift system and 1.8005\(\pm\)0.0003 for the multi-component lower redshift system. Fig. 2 shows the complete normalized X-shooter spectrum, where the absorption features of both the GRB and the intervening absorption systems are marked. The rest frame equivalent widths (EW\(_{\text{rest}}\)) of all identified features are listed in Table 1, together with their observed and rest frame wavelengths and redshift.

### 3.1. The host galaxy system

Most of the absorption features detected at the redshift of the GRB can be separated into three different components that we name I, II and III, with I having the highest redshift. We fit line profiles to the different components in order to determine the column density of each species. Due to the limited resolution and S/N, we fix the thermal \(b\)-parameter to 5 km s\(^{-1}\) and the turbulent \(b\)-parameters to 20 km s\(^{-1}\). We also fixed the column density of the outer components I and II to the low S/N in the blue end of the spectrum. For weaker lines where we do not detect all three components, we give 3-\sigma upper limits for those components unless those regions are affected by skylines or other absorption transitions.

The central component II is the one with the highest column density and except for Fe II it could be fixed to 0 km s\(^{-1}\). The blueshifted component III is around \(-85\) km s\(^{-1}\) for Fe II and \(-47\) km s\(^{-1}\) for component I. For Mn II and Mg II we could derive lower limits of the column densities of these components. For Mn II we could not fit component I due to contamination by skylines. The absorption bluewards of component III in Si II\(\lambda\)1526 is due to Fe II\(\lambda\)2382 from the intervening system at redshift 1.80. We did not fit the O I \(\lambda\)1302 transition due to the low S/N in the blue end of the spectrum. For weaker lines where we do not detect all three components, we give 3-\sigma upper limits for those components unless those regions are affected by skylines or other absorption transitions.

The central component II is the one with the highest column density and except for Fe II it could be fixed to 0 km s\(^{-1}\). The blueshifted component III is around \(-85\) km s\(^{-1}\) for all elements where this component is present except for Fe II where it lies at \(-47\) km s\(^{-1}\). For component I, the situation is slightly more complex. All three components II and III are present in the multi-component lower redshift system at redshift 1.80. For component I, the situation is slightly more complex. All three components II and III are present in the multi-component lower redshift system at redshift 1.80.
Fig. 2. Normalised spectrum of the afterglow of GRB 090313, smoothed with a Gaussian filter (using a smoothing kernel with full width half maximum varying from 1 to 4 Å) for displaying purposes. The absorption features produced at the redshift of the GRB afterglow (z = 3.3736) are indicated in larger font size (red). The intervening systems at z = 1.8005 and z = 1.9597 are indicated in smaller case and using dark (blue) and light (green) traces respectively. The thick horizontal lines at the top of each panel indicate regions affected by strong telluric bands, which have been excluded from the analysis. The error spectrum is marked as a pale (blue) line. See the electronic edition for a color version of this figure.

components but at slightly different velocities than the other lines. We cannot confirm this behaviour securely by fitting other Fe II lines as the $\lambda$ 1608 Å line is the only one not severely affected by skylines. This behaviour of the different components might indicate that the absorbing material is not at the same place along the line-of-sight for different elements, which is expected if the absorption lines trace gas at different locations inside the host galaxy. Generally, we find that in component I the low ionization species are predominant over the higher ionization species, while for component III the opposite is true. This is also confirmed by the ratio of column densities of AlIII and AlII for which we get values of 0.03±0.03, 0.14±0.13 and 4.2±0.9 for components I, II and III respectively. A similar behaviour is observed for the ratio of column densities of Si IV and Si II with values of 0.02±0.01, 0.91±0.26 and 1.18±0.14 for components I to III.

We detect the fine structure transitions of CII*$\lambda$1334, CII*$\lambda$1335.6, 1335.7. The latter two have only a 0.1 Å difference in central wavelength, and therefore cannot be separated with the spectral resolution provided by X-shooter. However, the 1335.7 Å transition is 10 times stronger than the 1335.6 Å one and we therefore fit the absorption systems assuming that the stronger transition is responsible for most of the absorption. The resonant and fine structure transitions are separated well enough to allow a fit of all 3 components for both lines, only component III of the fine structure transition is rather close to component I of the resonant line, making the system blended. On the other hand we cannot identify any Si II* lines at the redshift of the GRB, which were reported for this GRB.
by Chornock et al. (2009b). However, our spectrum only covers the 1533.4 Å and the 1309.2 Å features and not that at 1264.7 Å which is significantly stronger. We determine a 3-σ upper limit for Si II* 1533.4 of EWrest < 0.21 Å and a limit for Si II* 1309.2 of EWrest < 0.58 Å, the first being more constraining due to both the higher oscillator strength and signal to noise ratio.

Combining the column density of all three components we find a value of [Si/Fe] > 0.65 for the GRB host galaxy (reference Solar composition obtained from Asplund et al. 2005). This large value of [Si/Fe] is in agreement with the work of Prochaska et al. (2007) for GRBs, being higher than those found for intervening absorbers in quasar spectra.

3.2. Intervening systems

An intervening system is identified at a redshift of 1.9597 through the detection of Fe II and Mg II in absorption (see Fig. 4 and Table 3).

At a redshift of 1.8005 we detect a further intervening system through several absorption features produced by low ionisation transitions (Fe II and Mg II) as well as neutral Mg I. This system is formed by three components with relative velocities of -286 km s⁻¹, 0 km s⁻¹ and +85 km s⁻¹ (see Fig. 5 and Table 4).

The absorber at z = 1.8 can be classified as a strong absorber (Mg II 2796 EWrest > 1 Å, see Table 1). Prochter et al. (2006) pointed out an excess (by a factor of ~ 4) in the frequency of strong Mg II 2796 absorbers in the line of sight of GRBs as compared to quasars. Recently, Vergani et al. (2009), using a sample of GRB afterglow spectra that doubles the redshift path of previous studies, confirmed this excess but only by a factor of ~ 2. The comparison is done using the SDSS QSO survey, with a redshift range 0.37 < z < 2.27 and a 6-σ detection limit of the Mg II 2796 line. Following these criteria the redshift path of the X-shooter spectrum of GRB 090313 for strong systems is Az = 1.13, giving a number density of 0.88. This number density is in agreement with that of 0.70±0.15 found by Vergani et al. (2009), whereas the number density of the strong Mg II systems found along QSO lines of sight is only 0.28±0.01 (Nestor et al. 2005).

4. Discussion and conclusions

In this paper we present the first spectrum of a GRB obtained with X-shooter, covering for the first time a range from optical to NIR simultaneously. Although observed during an early commissioning phase and under unfavourable conditions, the results allow us to have an optimistic view of X-shooter’s potential.

For the GRB, we determine a redshift of 3.3736, at which we detect absorption features with three velocity components. From the values in Table 2 and from Fig. 3 it is inferred that component II has the highest column densities, and we used it to calculate the redshift. Component I is the least ionised (high ionisation lines are only weakly detected) while in component III we detect mainly highly ionised species. Although not conclusive, this could indicate that component III is the closest to the GRB, while component I is the furthest. The relative velocities between the 3 different components are due to relative motion of the gas within the host galaxy, in principle unrelated to the GRB itself. The large values of [Si/Fe] measured in the GRB host galaxy may be indicative of enhanced abundance of Si (produced by extensive star formation) or a higher depletion level of Fe (evidence of dust). In fact, Kann et al. (2009) measured an extinction corresponding to $A_V = 0.34\pm0.15$ for this burst, which as they note, is atypically large for such a high redshift event. They also note that GRB 090313 is among the most intrinsically luminous optical afterglows detected. However, if we look at the
Table 2. List of features identified in the spectrum (detections $>3\sigma$). Most lines show three velocity components. Transitions in brackets are contaminated by skylines or blended and have not been used to fit the column densities. Upper limits are $3\sigma$ where the wavelengths were fixed to the corresponding components observed in other transitions. For saturated features we give lower limits for the column density.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Transitions</th>
<th>Component I</th>
<th>Component II</th>
<th>Component III</th>
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<td>(Å)</td>
<td>Velocity</td>
<td>log N</td>
<td>Velocity</td>
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<tr>
<td></td>
<td></td>
<td>(km s$^{-1}$)</td>
<td>(cm$^{-2}$)</td>
<td>(km s$^{-1}$)</td>
</tr>
<tr>
<td>SiIV</td>
<td>1393, 1402</td>
<td>+130</td>
<td>13.3±0.3</td>
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<tr>
<td>SiII</td>
<td>1526</td>
<td>+130</td>
<td>15.0±0.5</td>
<td>0</td>
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<tr>
<td>CIV</td>
<td>1548, 1550</td>
<td>+102</td>
<td>13.2±0.3</td>
<td>0</td>
</tr>
<tr>
<td>CII</td>
<td>1334</td>
<td>+102</td>
<td>14.1±0.4</td>
<td>0</td>
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<tr>
<td>CII*</td>
<td>1335</td>
<td>+102</td>
<td>15.3±0.8</td>
<td>0</td>
</tr>
<tr>
<td>FeII</td>
<td>1608, 2374</td>
<td>(2382, 2585, 2600)</td>
<td>+102</td>
<td>14.9±0.2</td>
</tr>
<tr>
<td>AlIII</td>
<td>1854, 1862</td>
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<td>12.8±0.1</td>
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</tr>
<tr>
<td>AlII</td>
<td>1670</td>
<td>+102</td>
<td>&gt;14.6</td>
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</tr>
<tr>
<td>CrII</td>
<td>2062</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MgII</td>
<td>2796, 2803</td>
<td>+130</td>
<td>&gt;14.8</td>
<td>—</td>
</tr>
<tr>
<td>MnII</td>
<td>2583</td>
<td>+130</td>
<td>12.2±0.3</td>
<td>0</td>
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<tr>
<td>CaII</td>
<td>(3933), 3969</td>
<td>(–85)</td>
<td>&lt;12.6</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3. List of column densities measured for the transitions identified in the $z=0.96$ intervening system.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Transitions</th>
<th>Component I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Å)</td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(km s$^{-1}$)</td>
</tr>
<tr>
<td>FeII</td>
<td>2344, 2382, 2600</td>
<td>0</td>
</tr>
<tr>
<td>MgII</td>
<td>2796, 2803</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4. List of column densities measured for the transitions identified in the $z=1.80$ intervening system. This system presents 3 different velocity components.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Transitions</th>
<th>Component I</th>
<th>Component II</th>
<th>Component III</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Å)</td>
<td>Velocity</td>
<td>log N</td>
<td>Velocity</td>
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<tr>
<td></td>
<td></td>
<td>(km s$^{-1}$)</td>
<td>(cm$^{-2}$)</td>
<td>(km s$^{-1}$)</td>
</tr>
<tr>
<td>FeII</td>
<td>2382, 2586, 2600</td>
<td>+85</td>
<td>13.3±0.1</td>
<td>0</td>
</tr>
<tr>
<td>MgII</td>
<td>2796, 2803</td>
<td>+85</td>
<td>13.4±0.1</td>
<td>0</td>
</tr>
<tr>
<td>MgI</td>
<td>2853</td>
<td>+85</td>
<td>12.3±0.2</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1), we find that they are consistent with the typical values found in the sample of Fynbo et al. (2009). We note that, to our knowledge, some features such as Mg II, Mg I and Ca II had not been observed before in GRB spectra at such high redshift.

The surveys of strong Mg II (EW$_{\text{rest}}>1\AA$) intervening absorbers along GRB lines of sight gave the surprising result of an excess of these systems compared to QSO lines of sight (Prochter et al. 2006; Vergani et al. 2009). We have measured the EW$_{\text{rest}}$ of the Mg II 2796 line of both intervening systems, finding a combined value (coadd of the three components) of $1.35±0.10\AA$ for the $z=1.80$ and $0.50±0.03\AA$ for the $z=0.96$. The number density of strong Mg II systems for this spectrum is $dn/dz = 0.88$, in agreement with the excess of a factor of ~2 compared to QSO lines of sight found by Vergani et al. (2009).

The same authors also considered the statistics of weak systems ($0.3\AA<\text{EW}_{\text{rest}}<1\AA$) and conclude that their number density is in agreement with what is found along QSO lines of sight, as confirmed by Tejos et al. (2009). The S/N of the GRB 090313 X-shooter spectrum is too low to cover a significant redshift path for a rest frame equivalent width limit of 0.3Å, on the other hand this limit will be normally reached for the guaranteed time programme for observations of GRB afterglows that will

![Fig. 4. Fit of Mg II and Fe II lines of the intervening system at $z=1.9597$.](image)

EW$_{\text{rest}}$ measured for the absorption features in this spectrum (see
be performed with X-shooter. This program will collect about 100 spectra within 3 years, hugely increasing the redshift path of the GRB surveys and therefore the significance of the statistics, and bringing useful information to explain the unexpected excess of strong absorbers. Moreover, X-shooter will cover simultaneously a larger redshift path compared to the instruments presently used for QSO and GRB afterglow spectroscopic observations, up to \( \Delta z \approx 5 \) (the total redshift path for strong Mg II systems for the spectrum presented here is \( \Delta z = 2.1 \)). Therefore X-shooter QSO and GRB surveys will be able to investigate systematically the presence and nature of Mg II systems up to a much higher redshift than currently done.

No significant emission lines have been detected at the redshift of the GRB or at any of the intervening systems. Berger (2009) pointed out the presence of two galaxies near the afterglow (G1 and G2, see Fig. 1). The brightest one (G1, \( r = 15.6 \)) has a known redshift of \( z = 0.0235 \) and is located at 17°8 from the afterglow, equivalent to 8.3 kpc projected at the redshift of the galaxy. We do not see any features at this redshift and, in particular, nothing is detected at the wavelength of the most prominent absorption features that can be seen in the SDSS spectrum of G1 (Abazajian et al. 2009), which are the Ca II 8500, 8544, 8664 and Na I 5891, 5897. Ca II features are not detected with 3-\( \sigma \) limits of \( EW_{\text{rest}} < 0.6 \) Å and Na I with limits of \( EW_{\text{rest}} < 1.2 \) Å. The closest galaxy, G2 at \( z = 2.3 \), with \( r = 21.6 \) does not have an identified redshift, so its relation with any of the observed absorption features will need further investigation.

To conclude, we point out some facts that show the potential that X-shooter has in the GRB field. Given a 10-\( \sigma \) limiting magnitude (per spectral bin) of \( R = 21.0 \) with 1 hr exposure, it will be able to study 33% (72%) of long bursts 12 (2) hours after the onset (using optical fluxes and decay indices from Nysewander et al. 2009). As an example, X-shooter would have been able to obtain a spectrum similar to or better than the one presented here of the \( z \approx 8.2 \) GRB 090423 (Tanvir et al. 2009; Salvaterra et al. 2009) during the first 24 hours and to follow the nearby GRB 030329 for over a month. If we consider short GRBs, we expect to be able to study 3% (17%) within 12 (2) hours of the burst onset. Together with the rapid response mode available at VLT, that allows reaction times of just a few minutes, the possibilities increase. With its intermediate resolution, we will distinguish components with differential velocities of \( \sim 30 \) km s\(^{-1}\).

As shown here, this resolution will allow to derive, through line fitting, abundances of the different element species, although with some limitations as compared to higher resolution spectrographs when fitting blended components or marginally saturated lines. Thanks to the wide wavelength coverage it will be capable of observing afterglows up to redshifts of \( \sim 18 \), assuming that they exist (at redshift 18, Ly-\( \alpha \) would lie at \( \lambda = 23000 \) Å). It will allow systematic studies of lines over wide redshift ranges (Mg II 2796, 2803 will be detectable from \( z = 0.1 \) up to \( z = 7.5 \)) as well as measurements of ratios with widely separated lines. Furthermore, through the wide spectral coverage we will have a larger amount of lines to determine metallicities with better accuracy. It will also allow the study of dust extinction profiles in GRB environments. Thanks to the increased sensitivity compared to other instruments of similar resolution, we will be able to study feature variability with higher time resolution and up to later times. All this places X-shooter in a position to lead breakthrough advances in GRB research in the next years.

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Fig. 5. Fit of Mg I, Mg II and Fe II lines of the intervening system at \( z = 1.8005 \), with three velocity components.
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