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UVES and FORS2 spectroscopy of the GRB081008 afterglow

V. D'Elia[1,2], S. Campana[3], S. Covino[3], P. D'Avanzo[3], S. Piranomonte[1], and G. Tagliaferri[3]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Roma, Via di Frascati 33, I-00040 Monte Porzio Catone (RM), Italy
[2] ASI Science Data Center – Via Galileo Galilei, I-00044 Frascati (RM), Italy
[3] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC), Italy e-mail: `delia@asdc.asi.it`

Abstract.
We study the GRB 081008 environment with simultaneous high- and low-resolution spectroscopy using UVES and FORS2 data acquired $\sim$ 5 hr after the *Swift* trigger. The interstellar medium (ISM) of the host galaxy at $z = 1.9683$ is constituted by at least three components which contribute to the line profiles. Component I is the redmost one, and is 20 km/s and 78 km/s redward component II and III, respectively. We detect several ground state and excited absorption features in components I and II. These features have been used to compute the distances between the GRB and the absorbers. Component I is found to be 52 ± 6 pc away from the GRB, while component II presents few excited transitions and its distance is 200^{+60}_{-80} pc. Component III only features a few, low ionization and saturated lines suggesting that it is even farther from the GRB. The hydrogen column density associated to GRB 081008 is $\log N_{\rm H}/{\rm cm}^{-2} = 21.11 \pm 0.10$, and the metallicity of the host galaxy is in the range [X/H] $= -1.29$ to -0.52. In particular, we found [Fe/H]$= -1.19 \pm 0.11$ and [Zn/H]$= -0.52 \pm 0.11$ with respect to solar values. This discrepancy can be explained by the presence of dust in the GRB ISM, given the opposite refractory properties of iron and zinc. By deriving the depletion pattern for GRB 081008, we find the optical extinction in the visual band to be $A_V \sim 0.19$ mag. The Curve of Growth analysis applied to the FORS2 spectra brings column densities consistent at the 3σ level to that evaluated from the UVES data using the line fitting procedure. This reflects the low saturation of the detected GRB 081008 absorption features.

Key words. gamma-rays: bursts – ISM: abundances – line: profiles – atomic data.

1. Introduction

For a few hours after their onset, Gamma Ray Bursts (GRBs) are the brightest beacons in the far Universe, offering a superb opportunity to investigate both GRB physics and high redshift galaxies. Early time spectroscopy of GRB afterglows can give us precious information on the kinematics, geometry, ionization and metallicity of the interstellar matter of GRB host galaxies up to a redshift $z \sim 5$,

Send offprint requests to: V. D'Elia

Table 1. Abundances computed from the UVES data

Element X	$\log N_X/\mathrm{cm}^{-2}$	$[X/\mathrm{H}]$
O	$> 15.12 \pm 0.06$	$> -2.68 \pm 0.11$
Al	$> 13.70 \pm 0.04$	$> -1.86 \pm 0.11$
Si	15.75 ± 0.04	-0.87 ± 0.10
Cr	13.83 ± 0.03	-0.92 ± 0.10
Fe	15.42 ± 0.04	-1.19 ± 0.11
Ni	13.74 ± 0.07	-1.29 ± 0.12
Zn	13.15 ± 0.04	-0.52 ± 0.11

and of intervening absorbers along the line of sight. Our dataset comprises nearly simultaneous UVES high resolution and FORS2 low resolution spectra of GRB081008. High resolution spectroscopy is important for many reasons: (i) absorption lines can be separated into several components belonging to the same system; (ii) the metal column densities can be measured through a fit to the line profile for each component; (iii) fine structure and other excited lines can be resolved. A comparison between high and low resolution data is important to define a range of line parameters (column density as a function of the oscillator strength and Doppler parameter) for which the saturation effect can be correctly accounted for when high resolution data are not available.

2. Observations and Analysis

The GRB081008 afterglow was observed with UVES ~ 4.30 hours after the trigger using dichroic 1, for a total exposure of 1800s. The wavelength coverage is 3300−3900 and 4800−6800Å, the spectral resolution is 40.000 and the S/N is ~ 5 and ~ 8 in the blue and red band, respectively. Three FORS2 spectra of 900s each, acquired starting 4.37 hours after the burst complete our dataset. The wavelength coverage is 3500 – 6300Å, the spectral resolution is 780, and the S/N of the combined FORS2 spectrum is 60 – 80. The derived redshift of the host galaxy is $z = 1.9683$. Just two faint intervening absorbers are identified along the GRB 081008 sightline: one featuring the MgII 2796/2803 doublet at $z = 1.286$ and one featuring the CIV 1548/1550 doublet at $z = 1.78$. UVES data were analyzed using FITLYMAN in the MIDAS environment, to compute column densities through Voigt fitting profile. Two components are necessary in order to obtain a satisfactory fit for most of the line profiles of the absorber at the redshift of GRB 081008. Actually, some strongly satu-

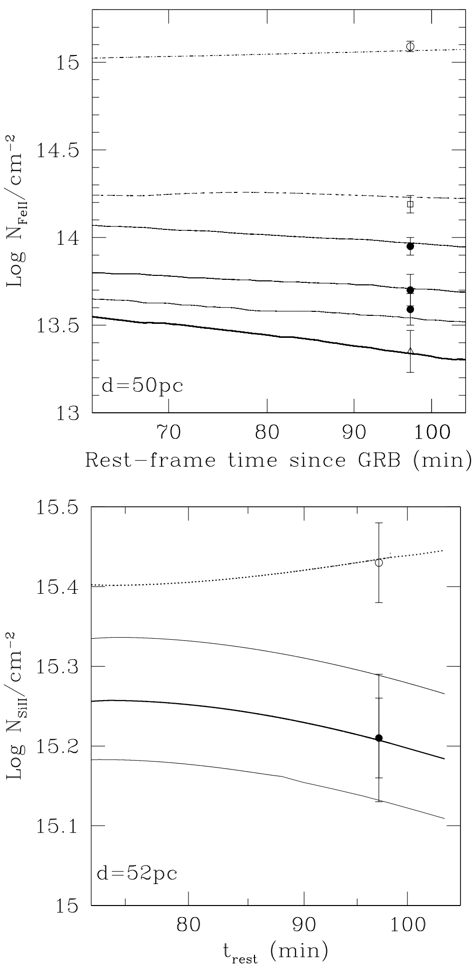

Fig. 1. Comparison between the observed column densities in the FeII and SiII levels for component I of GRB 081008 and that predicted by our photo-excitation code. A distance $of 51^{+21}_{-11}$ pc and 52 ± 6 pc from the GRB is predicted using FeII (top panel) and SiII (bottom panel), respectively.

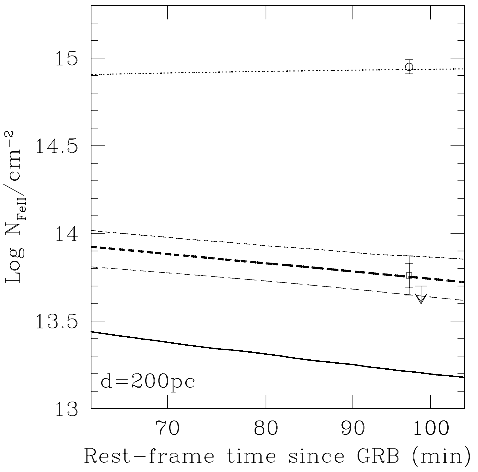

Fig. 2. Comparison between the observed column densities in the FeII levels for component II of GRB 081008 and that predicted by our photo-excitation code. A distance of 200^{+60}_{-80} pc is predicted.

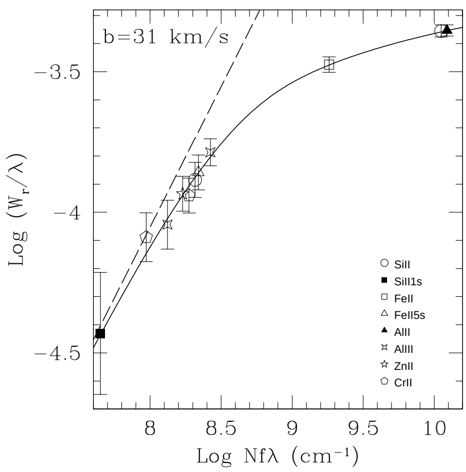

Fig. 3. COG analysis applied to the FORS2 features with measured W_r.

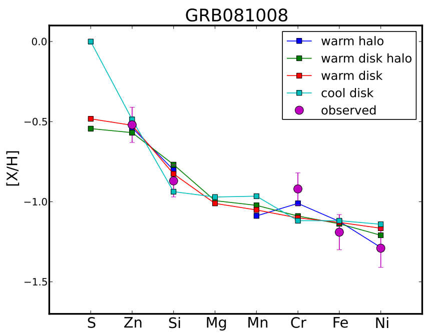

Fig. 4. Depletion patterns in the GRB 081008 absorbing gas.

rated features show absorption in a third, bluemost component.

3. Results

3.1. Metallicity

Fitting the FORS2 Lyα feature we measure the HI column density: $\log(N_{HI}/cm^{-2}) = 21.11 \pm 0.10$. Since the Ly absorption can not be resolved into components (as for metals), we computed just an overall metallicity, which is in the range 0.05 – 0.3 with respect to solar values (see table 1)

3.2. Excited features and GRB/absorbers distance

Excited features, belonging to the FeII, NiII and SiII levels have been identified in GRB 081008. Vreeswijk et al (2007) and DElia et al. (2009), using multi-epoch high resolution spectroscopy, observed variability in the excited FeII and NiII lines of GRB 060418 and 080319B, which is a clear signature of indirect UV pumping exciting such features. In other words, the decreasing UV flux coming from the GRB excites the higher atomic levels with lesser and lesser efficiency. The ratios between excited and ground state column densities exclude collisional processes as responsible for the production of excited features in GRB 081008, even if multi-epoch spectroscopy to search for variability is not available. In this scenario, the redmost component I is the closest to the GRB, since it shows high absorption from the excited states. In order to compute this distance we compare the observed columns with the results from a time dependent photo-excitation code. We built a code that computes the column densities of more than a hundred FeII and SiII levels as a function of an incoming UV flux decreasing with time. Once the lightcurve of GRB 081008 has been used as input for this code, we can estimate the GRB/absorber distance. We find that the gas of component I is 52 ± 6 pc away from the source (Fig. 1), while that of component II is at 200^{+60}_{-80} pc (Fig.2). All errors are given at the 90% confidence level.

3.3. FORS2 spectroscopy

It is extremely interesting to compare low and high resolution spectroscopic data in order to study the saturation problem. A line that is saturated in a high resolution spectrum, may not appear saturated in low resolution because its absorption is diluted in a higher wavelength range. To compare UVES and FORS2 data, we used the Curve of Growth analysis (COG, see Spitzer 1978) to compute the column densities and b parameter from the equivalent widths (W_r) of the FORS2 data (Fig. 3). Since FORS2 can not separate the absorption into components, we summed up all the UVES contribution coming from components I and II before comparing them with the FORS2 ones. The two sets of measurements are consistent at the 3σ level in the worst case. This is not surprising, since UVES data are mostly not saturated. However, this analysis provides a good set of column density ranges for which the COG method applied to low resolution data can provide reliable results.

3.4. Dust depletion pattern

Table 1 shows that FeII and ZnII abundances are significantly different. This can be ascribed to the different refractory properties of the two elements, with the former that preferentially tends to produce dust grains while the latter prefers the gas phase. The comparison between these opposite elements can thus provide information on the dust content in the GRB environments. In order to be more quantitative, we derive the dust depletion pattern for the GRB 081008 environment, following the method described in Savaglio (2000). We consider the four depletion patterns observed in the Milky Way, namely, those in the warm halo (WH), warm disk + halo (WHD), warm disk (WD) and cool disk (CD) clouds. We find that the best fit to our data is given by the WH cloud pattern, with a metallicity of $Z_{GRB}/Z_{\odot} \sim 0.3$ (Fig. 4). This metallicity value is consistent with our [Zn/H] measurement (Table 1). Since the latter quantity is linked to the extinction (see e.g., Savglio, Fall & Fiore 2003) we derive $A_V \sim 0.19$ mag along the GRB 081008 line of sight.

4. Conclusions

UVES spectroscopy of GRB 081008 reveals a clumpy host galaxy gas with at least three components. The host metallicity is in the range 0.05 – 0.3 (with respect to solar).

Excited lines detection and analysis set the GRB/absorber distance to ∼ 50 pc and ∼ 200 pc for component I and II, respectively.

FORS2 spectroscopy complements high resolution data and provides a set of column densities for which the COG method applied to low resolution data is reliable.

The study of the dust depletion patterns enables to determine the metallicity including dust. We estimate $Z_{GRB}/Z_{\odot} \sim 0.3$ and $A_V \sim 0.19$.

More details can be found in D'Elia et al. 2011, MNRAS, in press).

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