UVES - VLT High Resolution Spectroscopy of GRB Afterglows

S. Piranomonte(1)(*) V. D’Elia(1), P. Ward(2), F. Fiore(1), E.J.A. Meurs(2)

INAF - Osservatorio Astronomico di Roma, Italy
Dunsink Observatory, Castelknock, Dublin, Ireland

Summary. —
We present early time, high resolution spectroscopy of three GRB afterglows: GRB050730, 050922C and 060418. These data give us precious information on the kinematics, ionization and metallicity of the interstellar matter of GRB host galaxies up to a redshift \( z \sim 4 \), and of intervening absorbers along the line of sight.

1. – Observations
The GRB050730 afterglow was observed 4.0 hours after the trigger. We find seven main absorption systems at \( z = 3.968, 3.564, 2.2536, 2.2526, 2.2618, 1.7729 \) and 1.7723.

The GRB050922C afterglow was observed 3.5 hours after the trigger. We find four main absorption systems at \( z = 2.199, 2.077, 2.008 \) and 1.9985.

The GRB060418 afterglow was observed 10 minutes after the trigger. We find four main absorption systems at \( z = 1.489, 1.106, 0.655 \) and 0.602.

The resolution of all spectra is R 40,000 (7.5 km/s in the observer frame). Data sets were reduced using UVES pipeline for MIDAS. All afterglows are clearly detected in the range 3300 - 10000 Å.

2. – Fine Structure Lines
Fine structure lines for CII, OI, FeII and SiII have been identified in all the GRBs. Such lines convey information on the temperature and electron density of the absorbing medium, provided that they are excited by collisional processes (J. N. Bahcall, R. A. Wolf et al. ApJ, 152, 701, 1968).

To constrain these parameters we need to estimate the fine structure column densities for two different ions and compare them. For GRB050730, two out of five components show fine structure lines (Fig. 1). Reliable values for temperature and electron density
Fig. 1. – The low ionization lines CII, OI and SiII together with their fine structure excited levels in GRB050730. Low ionization states and fine structure levels do not appear in all components. High ionization lines CIV and SiIV have been taken as reference lines in the fitting procedure.

are T a few $10^3$ K and $n > 10^4$ cm$^{-3}$ (second component; the components are numbered according to decreasing z) and $n \sim 10 \div 100$ cm$^{-3}$ (third component). The other components do not show fine structure features: this is an indication that they refer to a clumpy environment.

3. – Metallicity

Metallicity in GRBs can be measured comparing the column densities of heavy elements to that obtained for hydrogen by fitting the Ly$-\alpha$, $\beta$ and $\gamma$ profiles. Both for GRB050730 and GRB050922C, we find metallicities between $10^{-3}$ and $10^{-2}$ with respect to the solar values.

Since metals tend to form dust, that then does not contribute to the absorption lines, this result is affected by some uncertainties. In GRB060418 we identify CrII and ZnII lines. Such elements tend to stay in the gas state, minimizing the uncertainty when estimating the metallicity. No H features are present in this GRB spectrum, so we derive the $N_H$ column from the X-ray data, leading to: $Z($Cr$) = -1.8 \pm 0.3$ and $Z($Zn$) = -1.3 \pm 0.2$, a bit higher than for the other two GRBs, but still below the solar values.

4. – Conclusions

The absorption spectra of GRB afterglows are extremely complex, featuring several systems at different redshifts. Both high and low ionization lines are observed in the circumburst environment, but their relative abundances vary from component to component, indicating a clumpy environment consisting of multiple shells.

Fine structure lines give information on the temperature and electron density of the absorbing medium, provided that they are excited by collisional effects. Different components have different densities, suggesting a variable density profile. Metallicity can be derived from the metal column densities; CrII and ZnII are the best indicators, since they do not form dust. Metallicity values around $10^{-2}$ with respect to the solar ones have been found. More details can be found in V. D’Elia, F. Fiore, E.J.A Meurs et al. 2006 (submitted to A&A, astro-ph/0609825, 2006).