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GRB host galaxy studies with VLT/X-shooter*

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Abstract. We present the Italian-French GTO program dedicated to optical-NIR spectroscopy of long gamma-ray bursts (LGRB) host galaxies with VLT/X-shooter. To date most of the spectroscopical studies of GRB hosts are limited to $z < 1$. At the end of the GTO period we will have collected the slit spectra of $\sim$ 30 GRB hosts: about a half at $0.8 < z < 1.5$ and the remaining at $z > 1.5$. Thanks to the unique capability of the X-shooter spectrograph we will be able to determine the properties of these objects (star formation rate, metallicity, extinction...) and compare them to those observed in absorption through the afterglow spectroscopy and to those of the galaxy samples studied in current galaxy surveys. Using the IFU X-shooter setup we will also perform the first IFU survey of GRB hosts, collecting the IFU spectra for a sample of $\sim$ 15 hosts at $z < 0.5$. Here we will show some example of the studies we are carrying on with some preliminary results.

Key words. Gamma-rays bursts – Galaxies: ISM – Galaxies: evolution

1. Introduction

The study of LGRB hosts can bring useful information to galaxy evolution studies. LGRB hosts form unique sample of galaxies which cover a wide range of redshift and are not selected by luminosity (the possibility of studying their properties is of course observationally partially biased towards brighter hosts though). This sample can be complementary to those of current surveys of galaxies. It has been recently shown that they are systematically offset to lower metallicities with respect to the mass-metallicity (M-Z) relation found from the surveys of emission line galaxies (Han et al. 2010; Levesque et al. 2010; Mannucci et al. 2011). In order to explain this behaviour and to build a complete picture of galaxy evolution, it is important to increase the LGRB host sample to confirm this result and to determine if and how it evolves at higher redshift. To date most of the spectroscopical studies of GRB hosts are limited to $z < 1$.

The study of LGRB host galaxies can be a source of information also on the LGRB progenitors and on the physical properties of LGRB regions. The association of long gamma-ray bursts (LGRBs) with broad-lined

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type Ic supernovae (SNe) is now well established (e.g. Hjorth & Bloom 2011 and references therein; see however GRB 060614: Della Valle et al. 2006; Fynbo et al. 2006; Gal-Yam et al. 2006). However, it is still not clear which are the peculiar conditions that lead a massive star to have the special kind of core collapse that triggers the formation of a jet and a LGRBs. Metallicity is one of the fundamental parameters predicted to impact the evolution of massive stars as well as their explosive deaths and, together with rapid rotation, is expected to play a fundamental role in the formation of LGRBs (e.g. Heger et al. 2003; Yoon et al. 2010 and references therein). Modjaz et al. (2008) show that the SNe associated with LGRB seem to prefer lower metallicity environments than broad-lined Ic SNe without a LGRB association. Detailed investigations can be performed for nearby galaxies for which, through multi-slit and/or integral field unit (IFU) spectroscopy, we can build metallicity, SFR, density and velocity maps. It is therefore possible to look for peculiarities of the LGRB region and to study the kinematics of the gas in the galaxy.

Form October 2009 a new spectrograph is available on the ESO/VLT: the X-shooter spectrograph. This instrument has the unique capability to produce intermediate resolution (R ∼ 6000) spectra covering simultaneously a spectral range from 3000 to 24000Å. Thanks to the unique spectral range coverage and sensitivity of the X-shooter spectrograph we can now extend GRB host studies to high redshift and, thanks to the GTO time, determine the properties (star formation rate, metallicity, extinction...) of a larger sample of these objects. Moreover using the IFU X-shooter setup we can perform the first IFU survey of GRB hosts.

The following sections are dedicated to the presentation and firsts results of the slit and IFU programs.

2. Host GTO program: slit observations

At the end of the GTO period we will have collected the slit spectra of ∼ 30 LGRB hosts: about a half at $0.8 < z < 1.5$ and the remaining at $z > 1.5$. Our main objectives are: (i) to enlarge the sample of LGRB host spectra; (ii) to extend the LGRB host studies to higher redshift; (iii) to compare the LGRB host galaxy population properties with those of the galaxies studied in current surveys; (iv) to compare the properties of LGRB host galaxies studied through emission lines spectroscopy with those determined by the absorption spectra of GRB afterglows; (v) to search for the emission counterparts of the strong absorbers present along the GRB lines of sight. To date the spectra of 20 LGRB host have been reduced and the data analysis is on going.

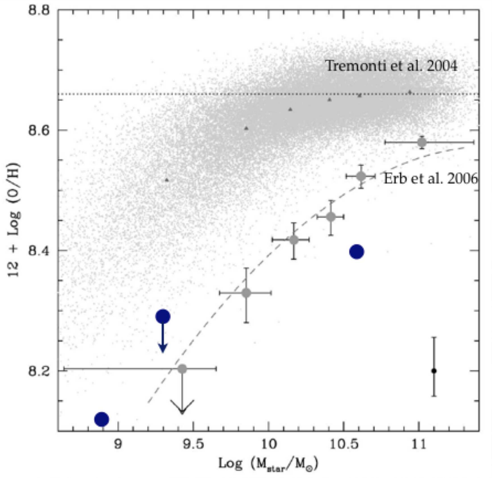

Fig. 1. The M-Z relation. Blue dots represent the preliminary results for our X-shooter LGRB host sample at $z \geq 1.5$. Grey dots with error bars represent the values found by Erb et al. (2006) for their sample of galaxies at an average redshift of $z \sim 2.2$. Small grey dots represent the M-Z found for the sample of SDSS galaxies studied by Tremonti et al. (2004) at $\langle z \rangle \sim 0.1$.

In Fig. 1 we show some preliminary results on the M-Z plot for LGRB hosts at $z \geq 1.5$. Contrary to the local and $0.3 < z < 1.0$ sample. Our aim is to determine with our whole sample if there is an offset also at these high redshift between the M-Z determined for LGRB hosts and that of the galaxies studied in the high z survey.

An example of the possibility of combining the study of the absorption features present in the afterglow spectrum and the emission lines of the host galaxy spectrum, making it possible to build a more complete picture of the properties of the host and potentially also to retrieve some spatial information on the host gas distribution, can be given by the study of the host galaxy of GRB 021004. Moreover, using different slit positions, we can also look for emission lines coming from the galaxies in the field of GRB 021004 and determine if they are the counterparts of the foreground absorbers found in the afterglow spectra.

For this GRB host we identified strong Lyα, [OIII]$\lambda\lambda$4959, 5007Å doublet and Hα emission lines (see Fig. 2) associated to the GRB 021004 host galaxy at $z = 2.33102$. The highest redshift absorbing cloud identified in the UVES afterglow spectra (e.g. Fiore et al. 2005) is blueshifted by $v \sim 180$ km s^{-1} relative to this value. The Lyα line is more extended than the [OIII] doublet lines and shows an asymmetric profile (with a peak redshifted by $v \sim 70$ km s^{-1} relative to the host galaxy redshift), and a red wing of more than 300 km s^{-1}. These features are typical of LAE and Lyman break galaxies.

Fig. 2. Section of the NIR 2D spectrum of the host galaxy of GRB 021004 showing the [OIII] doublet emission lines from the host galaxy.

We do not detect any emission line at the redshift of the 2 strong intervening MgII systems identified in the afterglow absorption spectra (Vergani et al. 2011). On the other hand we detect the [OIII] doublet and possibly the Lyα emission lines at $z = 2.33184$ from a close-by galaxy 'A' (see Fig. 3), at a distance of about 15 kpc from the GRB host galaxy. This detection together with the profile shape and spatial extension of the host Lyα emission line suggests a possible interaction between these two galaxies.

To date the sample of LGRB host is biased against dark GRB. Within our program we are observing also some dark GRB host galaxies, such as the one of GRB 070306. The afterglow of this GRB showed an extinction corresponding to $A_V = 5.4 \pm 0.5$ (SMC; Pei 1992). In our X-shooter spectrum with detected many emission lines, from the [OII] doublet to the [SII] one (see Fig 4). Our preliminary results indicates that the host galaxy has an $A_V = 1.3 \pm 0.2$ and a metallicity of 12+log(O/H) ~ 8.4.

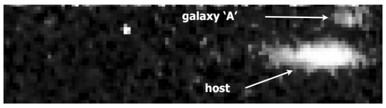

Fig. 3. Section of the NIR 2D spectrum of the GRB 021004 host, at a different slit position angle than the one presented in Fig. 2, showing the [OIII]λ5007Å lines of the GRB host and the close-by galaxy 'A'.

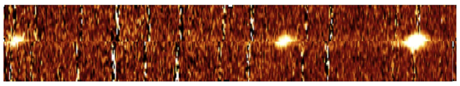

Fig. 4. Section of the NIR 2D spectrum of the host galaxy of GRB 070603 showing, from left to right, the Hβ and [OIII] doublet emission lines from the host.

3. Host GTO program: IFU observations

For much nearby galaxies ($z < 0.5$), more detailed investigations can be performed through IFU spectroscopy. The metallicity, SFR, density and velocity maps can be built to look for peculiarities of the LGRB regions and to study the kine- matics of the gas in the galaxy.

IFU surveys of intermediate redshift galaxies performed in the past (e.g. Flores et al. 2006; Puech et al. 2006) show the power of this technique in determining the dynamical properties of the galaxies demonstrating the presence of several galaxies with perturbed kinematics due to mergers or outflows and therefore adding important pieces to the galaxy evolution scenario. With IFU observations of LGRB host galaxies it will be possible to extend these studies to lower mass and lower metallicity objects.

Some preliminary maps of the firsts reduced spectra are shown in Figs 5 and 6.

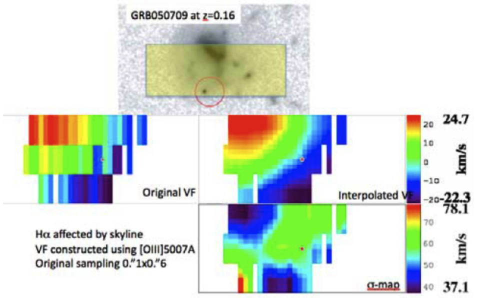

Fig. 5. *Upper panel*: HST/ACS image of the GRB 090302 at $z = 0.16$, overleaped the position of the IFU observations. *Middle-left panel*: velocity field of the galaxy constructed using the [OIII]5007Å emission line (with spaxels of 0.″6 × 0.″1). *Middle-right and lower panel*: interpolated VF and σ-map for visual ease (spaxels of 0.″1 × 0.″1). From Flores et al. (2011).

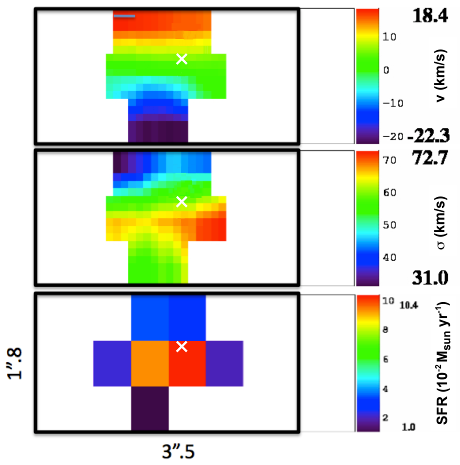

Fig. 6. *From top to bottom*: IFU velocity, velocity dispersion and SFR maps (1″ = 6.018 kpc) of the host galaxy of GRB 091127. The afterglow position is indicated by the white cross. The velocity and velocity dispersion maps are interpolated to spaxels of 0″.1 × 0″.1 for better viewing. From Vergani et al. (2011)

4. Conclusions

We presented the Italian-French VLT/X-shooter GTO program dedicated to the spectroscopy of GRB host galaxies. LGRB host galaxy studies are important to obtain information on galaxy evolution complementary to that found from galaxy surveys and can also be useful to understand which are the environmental factors that play a role in the formation of a GRB. With the study of the LGRB host sample in both slit and IFU mode we will be able to retrieve important information on the properties of LGRB host galaxy also at $z > 1$ and of the GRB region. At the end of the GTO period we will have collected the slit spectra of ~ 30 GRB hosts (about a half at $0.8 < z < 1.5$ and the remaining at $z > 1.5$) and the IFU spectra of ~ 15 hosts.

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