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LGRB hosts in emission and in absorption

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Abstract. Long-duration gamma-ray bursts (LGRBs) provide a unique way of selecting a sample of actively star-forming galaxies independent of their brightness and at practically any redshift. I will review what we know about the hosts and more immediate environments of LGRBs from two different perspectives: ultraviolet absorption-line spectroscopy of the bright early afterglow, and observations of their hosts in emission once the afterglow has faded away.

Keywords. Gamma rays: bursts – ISM: abundances – Galaxies: high-redshift

1. Introduction

There is strong evidence that long-duration gamma-ray bursts (LGRBs) originate from the explosion of a massive star (see Hjorth & Bloom 2011, and references therein). LGRBs are extremely bright in gamma-rays, X-rays and the optical/near-infrared, making them observable at practically any redshift (so far up to $z = 8.2$; Tanvir *et al.* 2009). This makes them excellent probes of massive star-forming regions at any redshift, independent of the amount of dust surrounding the explosion (at least in gamma- and X-rays) and independent of the host-galaxy brightness. The bright - but quickly fading - LGRB afterglow allows extraction of detailed information of the host-galaxy interstellar medium through ultraviolet (UV) absorption-line spectroscopy (see Sect. 2). After the afterglow has faded away, the host galaxy can be studied at leasure in emission (see Sect. 3). Through these two complementary perspectives, LGRBs can provide unique insight into the chemical evolution of (LGRB-selected) star-forming regions, the star-formation history of the universe, the distribution of H I gas, metals and dust surrounding the explosions and the gas kinematics, e.g. inflows and outflows, in actively star-forming galaxies.

2. LGRB host galaxies in absorption

Prompt UV absorption-line spectroscopy of LGRB afterglows show their host-galaxy interstellar medium to harbour large column densities of H I gas (e.g. Vreeswijk *et al.* 2004) and metals (e.g. Savaglio *et al.* 2003). The LGRB host metallicity as a function of redshift does not appear to evolve much (e.g. Savaglio *et al.* 2012); in any case its evolution is weaker than that inferred from quasar aborption-line studies. Only a very small fraction of LGRB sightlines show the presence of molecules in the host ISM (see Prochaska *et al.* 2009), but observations so far have been biased against their detection (see Krühler *et al.* 2013). The relatively simple broken power-law spectra of LGRB afterglows, from the optical to the X-ray regime, make them very suitable to probe dust extinction properties of the absorbing medium (e.g. Schady *et al.* 2007), even allowing the inference of an absolute extinction curve (Elíasdóttir *et al.* 2009). Most LGRB host extinction curves are consistent with an LMC type exctinction, but a non-negligible fraction shows the 2175 Å extinction bump prevalent along Milky Way sightlines (Zafar *et al.* 2011). Finally, detection of variable absorption of fine-structure lines of Fe II and Ni II have shown the

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absorbing neutral gas to be at least 100 pc and up to kiloparsecs away from the LGRB explosion (e.g. Vreeswijk *et al.* 2007; D'Elia *et al.* 2009), even in the case where clear on-going ionisation is detected (Vreeswijk *et al.* 2013).

3. LGRB host galaxies in emission

In emission, the typical LGRB host is a faint, blue, low-mass galaxy (see Savaglio *et al.* 2009) with an irregular morphology (Fruchter *et al.* 2006) that is very actively forming stars and hence displaying prominent emission lines (e.g. Krühler *et al.* 2015). For a sample of low-redshift LGRBs, several different studies have found LGRBs to prefer low-metallicity environments (Modjaz *et al.* 2008). The metallicities of LGRB hosts fall below the local (SDSS) mass-metallicity relation (see Levesque *et al.* 2010), but they are consistent with the general population of galaxies when considering a more fundamental relation between mass, metallicty and star-formation rate (Mannucci *et al.* 2011).

The studies mentioned above are based on biased samples of LGRBs, whereas a signficant fraction (∼25%) is "dark", i.e. not detected at optical wavelengths where most follow-up studies are being performed. It is important to include this missing population when making general inferences on the LGRB host-galaxy population. For example, Perley *et al.* (2013) find the hosts of a sample of dust-obscured LGRB afterglows to be much more massive, up to an order of magnitude, and to have higher star-formation rates than the hosts of non-obscured LGRBs. The very successful *Swift* mission has allowed the construction of such unbiased, complete samples, such as the following: TOUGH (Hjorth *et al.* 2012), GROND (Greiner *et al.* 2011), BAT6 (Vergani *et al.* 2015) and SHOALS (Perley *et al.* 2015). These are providing a more complete picture of LGRB hosts and are starting to addresss whether LGRBs are unbiased tracers of star formation.

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