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Preliminary Results on VLT K-band Imaging Observations of GRB Host Galaxies

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Abstract. We have obtained K-band imaging observations of Gamma-Ray Burst (GRB) host galaxies with the near-infrared spectro-imager ISAAC installed on the Very Large Telescope at Paranal (Chile). The derived K magnitudes, combined with other photometric data taken from the literature, are used to investigate the R–K colors of GRB hosts. We do not find any extremely reddened starbursts in our sample, despite the capability of GRBs to trace star formation even in dusty regions. The observed R–K colors are on the contrary typical of irregular and spiral blue galaxies at high redshift.

Key words. Galaxies: evolution, high-redshift, dust—Gamma-ray Bursts.

1. Introduction

A major timely event in astrophysics has been the dramatic transformation in our understanding of gamma-ray bursts (GRBs). There is indeed increasing evidence that the most common GRBs, those with durations longer than a few seconds, are associated with sites of massive star formation at cosmological distances. The physical properties of the afterglows, their locations at a few kpc from the center of host galaxies (e.g., Djorgovski 1999), and the statistics from the several thousands of GRBs detected so far with BATSE (Fishman *et al.* 1998), give strong support to the idea that the majority of GRBs are linked to the cataclysmic collapse of massive stars into black holes (MacFayden & Woosley 1999). Thus they can be used to sample massive star formation sites in distant galaxies. One of the great advantages of this approach is that GRBs, because they are beamed in relativistic jets (Mészáros 1999), are bright enough to be detected at lookback times up to redshifts of 20 (Lamb & Reichart 2000). Moreover, they are not attenuated by intervening columns of dust and gas, thus making the selection of star forming regions less affected by the biases associated with optical and UV surveys (e.g., Lyman- and UV-dropout techniques).

Up to 25 GRB hosts have already been discovered. These sources are not over-luminous (Schaefer 2000), and high resolution images have shown that they exhibit morphologies typical of spiral, compact or irregular galaxies (e.g., Bloom *et al.* 2002). Spectra of northern targets obtained by the Keck telescopes had first provided evidence that these galaxies are actively forming stars, but not at a rate especially high (e.g., Bloom *et al.* 2001). Nevertheless, Sokolov *et al.* (2001) have shown that a significant internal extinction by dust in several GRB hosts has probably led to under-estimated star forming rates (SFR) based either on emission lines (Balmer lines, [OII],...) or the UV continuum. Using broad-band photometry obtained with the 6m telescope of SAO

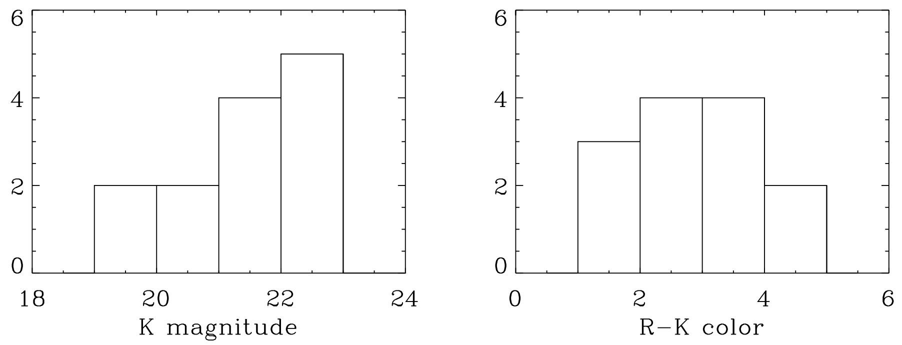

Figure 1. **Left:** K magnitude histogram of GRB host galaxies. Data were obtained as part of our on-going K-band imaging program on the VLT for 40%, the other photometric data points are quoted from Fruchter *et al.* (1999), Djorgovski *et al.* (2000), Vreeswijk *et al.* (1999), Bloom *et al.* (1999), Klose *et al.* (2000), Chary *et al.* (2002). **Right:** histogram of the observed R–K colors, for the similar sample of GRB hosts. The R magnitudes were taken from the literature, see Djorgovski *et al.* 2001 for references.

RAS, they measured the amount of dust absorption in a sub-sample of GRB hosts and revised their SFR to higher values, suggesting that some of them could harbor star formation rates greater than a few tens or even hundreds of solar masses per year. We finally note that the possibility to find powerful starbursts probed by Gamma-ray Bursts has been recently illustrated by the discovery of three Ultraluminous Infrared Galaxies among the GRB host sample (GRB 980703 host, Berger *et al.* 2001a – GRB 010222 host, Frail *et al.* 2002 – GRB 000418 host, Berger *et al.* 2001b) with SFR greater than 500 $M_{\odot}$ yr^{-1}.

2. Observations and results

Here we report on K-band imaging of several GRB hosts obtained with the VLT. Near-infrared (NIR) observations, which are less affected by extinction than those performed at optical wavelengths, not only provide a better view on the evolved stellar populations of galaxies, but may also reveal whether an additional component from hot dust emission significantly contributes to the optical/near-infrared spectral energy distribution (SED). Reddened optical-to-NIR colors can indeed be used as a telltale indicator for dust enshrouded star formation (e.g. HR10, Dey *et al.* 1999), such as in the case of a high fraction of EROs (Extremely Red Objects, defined with e.g., $R - K \geq 5$). We have therefore compared the K-band photometry of the GRB hosts that we have observed, with their R-band magnitudes taken from the literature.

The histograms showing the distributions of the K photometry as well as the R-K colors are presented in Fig. 1. Since the current sample of sources probed by GRBs is rather small (less than 30 galaxies), we have also included the photometric data points of other GRB hosts obtained by various groups (see figure caption for references). This allowed us to gather a total of 13 sources, and derive a more representative statistical analysis of their NIR magnitudes and colors.

First, as it can be seen in the K magnitude histogram, it is yet naïve but important to note that GRB host galaxies are rather faint objects as expected for field sources at high redshifts. An important fraction of the sample has indeed K magnitudes greater than 22, showing that long exposure times on the largest 8-to-10 m diameter ground-based telescopes are required to detect those sources. Similarly, we note that numerous GRB hosts have R mag higher than 25 (see e.g., Djorgovski *et al.* 2001). Second, it is quite interesting to mention that we do not find any reddened objects among the current sample of GRB hosts. Rather, we have taken account of their redshift and their morphology as shown by the high resolution images obtained with the HST (e.g., Bloom *et al.* 2002) to calculate the k-corrections to their R and K magnitudes, and found that the R–K colors are simply typical of irregular and spiral galaxies at high redshift.

3. A brief discussion

It is now widely believed that the extremely reddened objects denote dusty starbursts reddened by dust as well as old stellar populations in distant elliptical galaxies whose dominant emission is redshifted to the near-infrared. Yet, the respective fractions of these two classes among the full ERO population still remain unclear, and the association of the embedded star forming activity pointed by the starburst-EROs with the dusty high-z galaxies luminous in the far-infrared and submillimeter (e.g., SCUBA galaxies, Hughes *et al.* 1998) is still a matter of debate. By no means GRB host observations alone will help in enlightening such key issues for our understanding of star formation and galaxy evolution in the distant universe. Yet, the fact that no ERO is currently detected among GRB hosts is rather puzzling, since GRBs are thought to trace star formation without being affected by dust extinction and could be used therefore to probe cosmic star forming sites even in dusty environments.

A rather natural explanation for such a non-detection of ERO could be simply due to the very poor statistics currently available regarding GRB hosts. Moreover, one must keep in mind that the GRBs for which host galaxies have been studied so far only represent a small fraction of the full sample of detected GRBs, mainly those which were localized with a position better than 1” thanks to their afterglows observed either at optical, near-infrared and/or radio wavelengths[1]. Even though gamma-rays are not attenuated by dust and gas, their optical transients could still be affected by extinction, meaning that a fraction of our sample would be biased toward unobscured star forming regions. On the other hand, one may note that Ultraluminous Infrared galaxies (ULIRGs) have already been detected among GRB hosts. Two of them are reported in our sample, and therefore do not harbor particularly red colors. Moreover, the optical transients of the GRBs discovered in some of these ULIRGs did not exhibit any signature of significant dust absorption. This may be linked to the fact that gamma and hard-X rays can sublimate the dust particules along the burst line of sight (Fruchter *et al.* 2001).

A better characterization of the properties of GRB transients from X-ray to radio wavelengths is therefore required, to allow a clear understanding of the biases affecting our current sample of GRB host galaxies. The recent and successful commissioning of the HETE-2 mission will help in detecting numerous new GRBs, and will likely lead to significant progress in this area.

[1]Note that arcsec positions may also be obtained in the X-rays with Chandra, which however has been successful in discovering X-ray GRB afterglows only in very few cases so far (e.g. GRB000210).

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