GRB Host Studies (GHostS)

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Abstract. The GRB Host Studies (GHostS) is a public archive collecting observed quantities of GRB host galaxies. At this time (January 2006) it contains information on 32 GRB hosts, i.e. about half of the total number of GRBs with known redshift. Here we present some preliminary statistical analysis of the sample, e.g. the total stellar mass, metallicity and star formation rate for the hosts. We found that these are generally low-mass objects, with 79% having $M_* < 10^{10}$ $M_\odot$. The total stellar mass and the metallicity for a subsample of 7 hosts at $0.4 < z < 1$ are consistent with the mass-metallicity relation recently found for normal star-forming galaxies in the same redshift interval. At least 56% of the total sample are bursty galaxies: their growth time-scale (the time required to form the observed stellar mass assuming that the observed SFR is constant over the entire life of the galaxy) is shorter than 400 Myr.

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INTRODUCTION

Although the typical nature of GRB hosts is still heavily under discussion, it is clear that they differ from normal high-z galaxies, as they are generally low-luminosity and young objects [1, 2]. We still cannot tell whether they form a galaxy population by themselves, or they are just much easier to detect than normal low-luminosity galaxies because they are associated with transient, but very luminous events.

To help investigate this issue, we have initiated a database dedicated to GRB host galaxies, called GRB Host Studies[1] (GHostS). Thanks to the advent of the Swift mission, the amount of results related to GRB hosts is in rapid ascent. The goal of GHostS is to gather, classify and synthesize GRB host information, and derive meangful parameters for a new statistically significant sample. At the present, it is the largest public archive of its kind. For each host, the optical-NIR photometry is provided, together with emission line fluxes, originating in the star-forming regions. So far, GHostS uses results coming from more than 70 different publications.

In this first work, we focus on the determination of the total stellar mass of the host galaxies, a parameter that has been hardly investigated in the past, for a number of good reasons [3]. We relate stellar masses to SFRs and metallicities.

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[1] GHostS can be accessed at the URL http://www.pha.jhu.edu/∼savaglio/ghosts

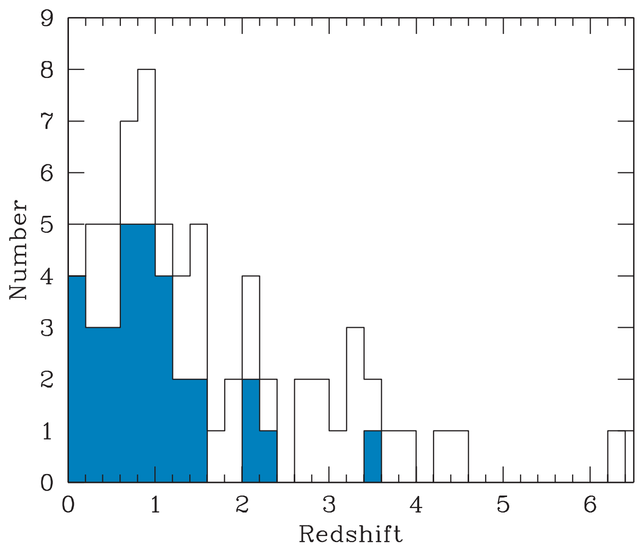

FIGURE 1. Redshift histogram of all GRBs with known redshift (67 in total - *open histogram*) and of the 32 GRBs with detected host, currently included in the GHostS archive (*filled histogram*). The median redshift of the two samples is $z \simeq 1.12$ and $z \simeq 0.84$, respectively.

THE GRB HOST SAMPLE

The median redshift of our 32 GRB hosts is $z \simeq 0.84$ (Figure 1), i.e. lower than the present median redshift for all GRBs with measured redshift ($z \simeq 1.12$). A couple of them are associated with a short-duration GRB, the remaining are long-duration GRBs. The objects are selected according to the requirement that optical-NIR photometry (necessary to estimate the total stellar mass) is available. Optical-NIR photometry is hard to measure for $z > 2$ galaxies in general. Our sample contains 4 objects with $z > 2$.

Among the 32 hosts, fluxes of [OII], [OIII] and Hβ emission lines are available for 19, 10 and 9 of them, respectively. These are used to derive metallicities and SFRs.

Total stellar masses

The stellar mass of the hosts is derived using a procedure which will be described in detail in a future paper (Le Borgne, Glazebrook & Savaglio, in preparation). Briefly, our technique uses SED fitting to the multi-band optical-NIR photometry. The observed NIR light, which in high-z galaxies samples rest-frame light above the 4000Å break, is closely related to the galaxy's total stellar mass and provides good stellar mass estimates up to $z = 2 - 3$ [4]. It is also insensitive to dust because most stars in a galaxy are not in birth clouds, and because the redder bands are less affected by extinction. The stellar mass derived this way is a much more meaningful physical variable than the luminosity,

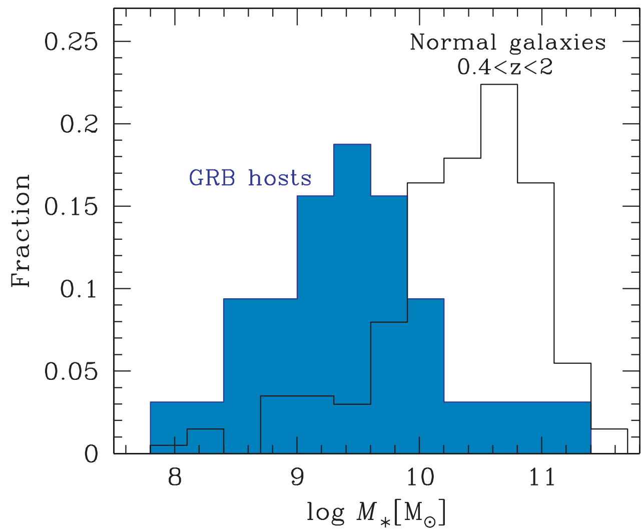

FIGURE 2. Fraction of GRB hosts per stellar-mass bins (*filled histogram*) and the comparison with 201 normal $0.4 < z < 2$ galaxies (*open histogram*) from the $K < 20.6$ Gemini Deep Deep Survey (see also [4]). In the GRB host sample, 79% have stellar masses below $M_* = 10^{10.0}$ M$_\odot$. The GDDS is complete for stellar masses below $M_* = 10^{10.8}$ M$_\odot$ and $M_* = 10^{10.1}$ M$_\odot$, for all galaxies and star-forming galaxies, respectively.

because it represents the integral of the past star-formation and merger history, and, in contrast for instance to UV light, can only increase with time.

In Figure 2 we show the stellar mass histogram for the 32 GRB hosts. The median/average mass and 1σ dispersion are $M_* = 10^{9.5}$ M$_\odot$ and 0.9 dex, respectively. This is compared to the same histogram obtained for normal $0.4 < z < 2$ galaxies from the Gemini Deep Deep Survey (GDDS; [5]). The GDDS is a deep optical-NIR ($K < 20.6$) survey and is complete at $0.4 < z < 2$ for all galaxies and for star-forming galaxies down to stellar masses $M_* = 10^{10.8}$ M$_\odot$ and $M_* = 10^{10.1}$ M$_\odot$, respectively. The comparison shows that GRB observations are much more efficient in detecting low-mass galaxies at high redshift than traditional high-z surveys.

Metallicities and SFRs

Metallicities are derived with the R_{23} calibrator, which uses [OII], [OIII] and Hβ line fluxes [6]. We adopted the formulation recently proposed by Kobulnicky & Kewley (2004) [7]. This set of emission lines allows the metallicity measurement for the largest possible number of GRB hosts. The $12 + \log(\mathrm{O/H})$ value is derived for 9 hosts, 7 of which are in the redshift interval $0.4 < z < 1$ (Figure 3). Figure 3 also shows the same

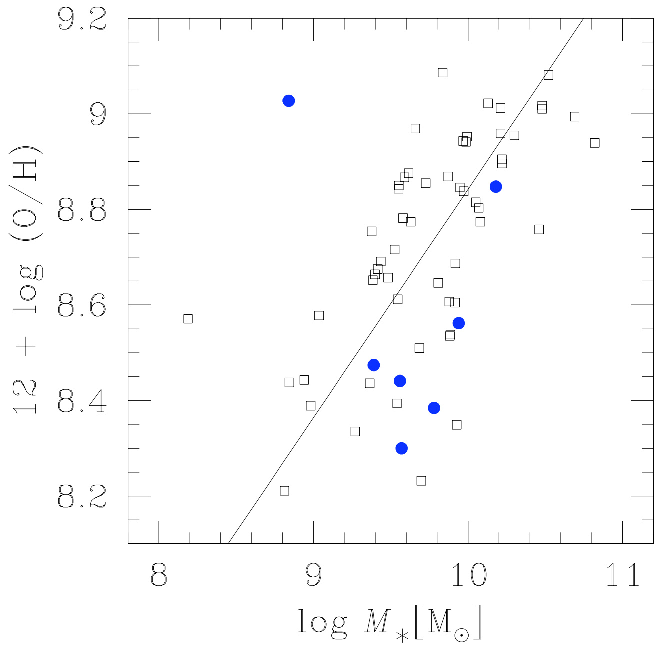

FIGURE 3. Total stellar mass and metallicity for $0.4 < z < 1$ GRB hosts (*filled circles*). Metallicities are derived assuming a modest (10%) Balmer stellar absorption correction and $A_V = 1$ dust extinction (Milky Way extinction law). The outlier at $\log M_* = 8.8$ is the GRB 991208 host galaxy at $z = 0.706$ [9]. *Open squares*: results for $0.4 < z < 1$ galaxies from GDDS and CFRS [10]. The straight line is the bisector fit for this sample.

parameters derived for GDDS and Canada-France Redshift Survey[2] (CFRS) galaxies, in the same redshift interval [10].

We estimate SFRs using the [OII] emission, the most common line measured in GRB hosts. The Hα emission flux provides a more robust SFR estimate, however this is measured in 5 GRB hosts only. Moustakas et al. (2006) [11] have shown that the dust-corrected [OII]-to-Hα flux ratio in local galaxies is on average one (0.12 dex dispersion) over a large range of B luminosities (from 10^7 to 10^{11} $\mathrm{L}_\odot$). We adopt this relation to derive SFRs, after assuming a Milky Way extinction law with $A_V = 1$. The median SFR and the range spanned by the 19 GRB hosts are SFR $= 12$ $\mathrm{M}_\odot$ yr^{-1} and $1 - 100$ $\mathrm{M}_\odot$ yr^{-1}, respectively (we also apply a correction of a factor of 2 for slit-aperture loss).

Another indicative parameter is the SFR per mass unit, or the inverse of this, also called growth time-scale. This is defined as $\rho_* \equiv M_*/\mathrm{SFR}$ [12], and is the time that a galaxy needs to build the observed stellar mass, if the SFR is assumed to be constant and is given by the observed value. The result as a function of redshift is shown in Figure 4, together with the comparison with normal star-forming $0.4 < z < 1$ galaxies from GDDS and CFRS [10].

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[2] Emission line fluxes for the CFRS galaxies are taken from Lilly et al. (2003) [8]

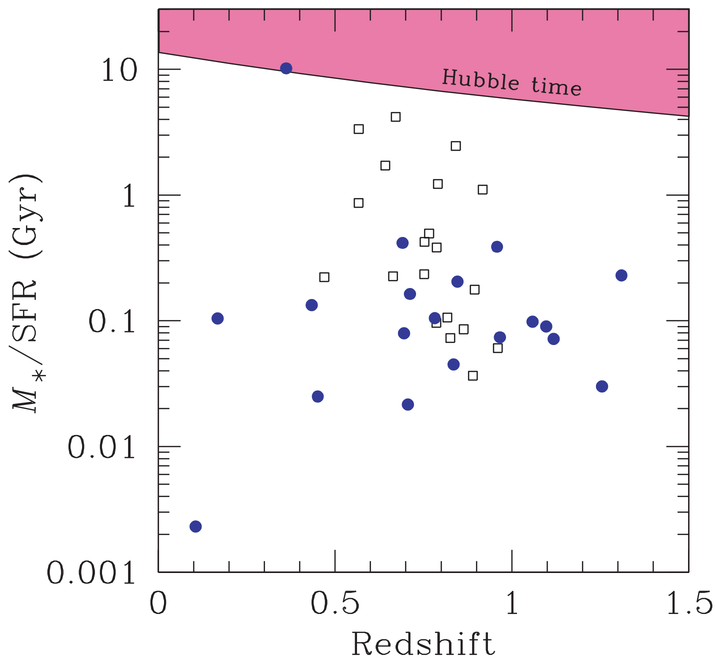

FIGURE 4. Growth time-scale (total stellar mass divided by observed SFR) as a function of redshift for 19 GRB hosts (*filled dots*). These are compared to the $0.4 < z < 1$ star-forming galaxies of GDDS and CFRS of Figure 3 (*open squares*). The curve marks the age of the universe (Hubble time) as a function of redshift, and indicates the transition from the quiescent star-formation mode to the bursty star-formation mode.

RESULTS

We presented the first results of the GHostS project. We focused on the stellar mass of 32 GRB hosts, SFRs for a subsample of 19, and metallicities for a subsample of 9, and compared these to normal high-z galaxies. We found that the total stellar mass is $< 10^{10.0}$ $M_\odot$ for 79% of the GRB hosts (Figure 2). At this mass, most of the high-z deep spectroscopic surveys are highly incomplete. The median stellar mass of the sample is $M_* = 10^{9.5}$ $M_\odot$, i.e. comparable to the stellar mass content of the Large Magellanic Cloud. Recently, Chary et al. (2002) [3] have derived stellar masses for 7 hosts and found a similar median value.

The median observed and dust-corrected (for $A_V = 1$) SFR in 19 hosts are 3 and 12 $M_\odot$ yr^{-1}, respectively. Given the generally low stellar masses for these GRB hosts, we conclude that a large fraction are bursty galaxies, with growth time-scales that are shorter than 400 Myr, and on average 100 Myr (Figure 4). If we consider the whole GRB population with measured redshift (67 in total), the host is a bursty galaxy in at least 1/4 of the cases.

The median metallicity in 9 GRB hosts is 0.6 solar, with values ranging from half to twice solar. These values are not far from expectations, given the stellar masses and redshifts of the galaxies. Moreover, they behave as predicted by the mass-metallicity relation observed at high redshifts in normal star-forming galaxies (Figure 3).

In summary, we quantified some of the known statements regarding GRB hosts, according to which a large fraction of them are low-mass starbursts. Although low-mass starbursts at high redshifts are hard to identify if no GRB event occurs, there is no evidence that GRB hosts represent a different population of galaxies that existed in the young universe.

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