IL NUOVO CIMENTO Vol. 28 C, N. 4-5 Luglio-Ottobre 2005
DOI 10.1393/ncc/i2005-10127-0

The GRB 030328 host: Another case of a blue starburst galaxy(*)(**)

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(ricevuto il 23 Maggio 2005; pubblicato online il 13 Ottobre 2005)

Summary. — We present for the first time the detection of the GRB 030328 host galaxy in four optical bands equivalent to $UBRI$. The host galaxy spectral energy distribution is consistent with a low extinction ($E(B-V) < 0.21$) starburst galaxy. The restframe B-band magnitude of host is $M_B \sim -20.4$.

PACS 95.75.De – Photography and photometry.
PACS 98.70.Rz – γ-ray sources; γ-ray bursts.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

A long gamma-ray burst (GRB) was detected on 2003 March 28 at 11:20:58.34 UT by the HETE-2 spacecraft [1]. The gamma-ray event showed a duration of approximately 100 seconds in the 30–400 keV energy band, so it belongs to the category of "long-duration" GRBs [2]. The GRB peak flux over 5.2 seconds was $7.3 \times 10^{-7}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, and the fluence was $3.0 \times 10^{-5}\,\mathrm{erg\,cm^{-2}}$ in the mentioned energy band. Optical images taken $\sim$ 1.3 hours after the GRB revealed the associated optical afterglow (OA) [3]. Subsequent low resolution spectroscopy determined a redshift value of $z = 1.52$ for the OA [4, 5]. Nevertheless no host galaxy detection has been reported to date.

Throughout, we assume a cosmology where $\Omega_\Lambda = 0.7$, $\Omega_M = 0.3$ and $H_0 = 72\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. Under these assumptions, the luminosity distance of GRB 030328 is $d_l = 10.8\,\mathrm{Gpc}$ and the look-back time is 9.05 Gyr ($\sim$ 69.2 % of the present Universe age).

(*) Based on data taken at the 2.2-m and 3.5-m telescopes of the Centro Astronómico Hispano Alemán de Calar Alto, operated by the Max Planck institute of Heidelberg and Centro Superior de Investigaciones Científicas.
(**) Paper presented at the "4th Workshop on Gamma-Ray Burst in the Afterglow Era", Rome, October 18-22, 2004.

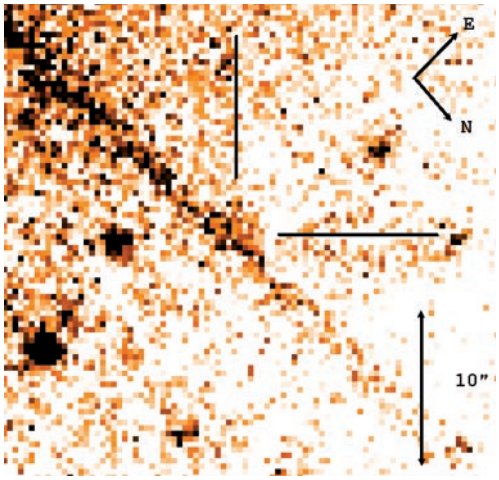

Fig. 1. – The tick-marks indicate the GRB 030328 host galaxy. The image have been created co-adding the images of the four channels. As can been seen, a spike originated at a bright $R \sim 8$ mag field star (out of the FOV toward the left upper corner) goes through the host galaxy.

2. – Observations

In the present paper we report optical multicolour imaging of the GRB 030328 host galaxy. The observations were carried out with the Calar Alto (CAHA) 2.2-m telescope $\sim$1 year after the GRB, when the contribution of the OA was negligible. The data were collected with the BUSCA camera [6], which allows simultaneous imaging in four optical bands. The four channels (named $C1$, $C2$, $C3$ and $C4$) are not standard filters, so they were calibrated by observing the spectro-photometric standard star GD153 [7] at the same airmass to that of the GRB field (information on the four BUSCA channels are described in [8]). $C1$ is similar the Johnson U-band, $C2$ is a transition between Johnson's B and V filters. $C3$ is very close to the R_c-band and $C4$ is identical to the I_c filter. The covered field of view (FOV) was $12.0' \times 12.0'$, and the resulting pixel scale $0.35''$/pix.

The photometric and astrometric analysis of the field was complicated by the presence of two bright field stars ($R \sim 8$) located $\sim 3'$ south from the OA position. In order to mitigate the high background they generated, the BUSCA camera was rotated 45 degrees and the telescope pointing was shifted that both stars were out of the FOV. Even with this configuration some degree of contamination was unavoidable, and a spike coming from the star crossed the OA position (see fig. 1).

Reduction was based on standard procedures running under IRAF([1]) and the photometry on PHOT. To account for the spike contamination three apertures were used; two positioned along on the spike bracketing the OA equidistantly, and the third one on the OA. The fluxes of the two apertures were averaged and subtracted from the central one at the OA. This procedure only integrated the OA flux. The process was repeated moving the two apertures along the spike, giving the magnitude errors of table I.

([1]) IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

TABLE I. – *Optical observations carried out for the GRB 030328 host galaxy. The host galaxy AB Magnitudes have been corrected for Galactic reddening* [9].

Date (UT) March 2004	Filter	$T_{\rm exp}$ (s)	Seeing (arcsec)	Magnitude (AB)
23.9549–24.1641	$C1$	24×600	1.7[a]	24.98±0.30
25.0366–25.1513		14×600		
23.9549–24.1641	$C2$	24×600	1.5[a]	24.72±0.35
25.0366–25.1513		14×600		
23.9549–24.1641	$C3$	24×600	1.4[a]	24.39±0.35
25.0366–25.1513		14×600		
23.9549–24.1641	$C4$	24×600	1.2[a]	24.42±0.40
25.0366–25.1513		14×600		

([a]) Full width at half maximum (FWHM) of the co-added image.

3. – Results

The astrometric solution for each of the four co-added images was based on ~ 60 USNO-A2.0 stars. The final host coordinates, obtained averaging the four channels, are; $\alpha_{J2000} = 12^h10^m48.37''$, $\delta_{J2000} = -09°20'51.0''$.The astrometric error for each coordinate is $0.7''$, not accounting for the systematic error of the USNO-A2.0 catalogue ($\sim 0.25''$, see [10]). The main source of error comes from the uncertainty on the centroid position

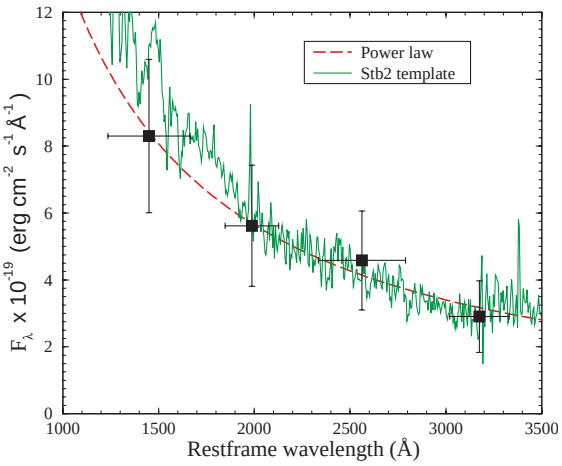

Fig. 2. – The restframe SED of the GRB 030328 host galaxy once the flux densities have been corrected for Galactic reddening [9]. The squares show the host flux densities corresponding to the four BUSCA channels. The horizontal error bars represent the FWHM of the BUSCA filters (measured in the host restframe). The long dashed line shows the satisfactory power law fit obtained with $\beta = -1.25$. The spiky line displays the best fit obtained with the K96 templates, corresponding to a starburst galaxy with $0.11 < E(B-V) < 0.21$ (template Stb2).

due to the bright spike contamination. The inferred position is consistent with the one reported for the OA [3].

Figure 2 shows the SED of the GRB 030328 host galaxy once the observed flux densities have been corrected for Galactic reddening ($E(B-V) = 0.047$, [9]). As can be seen a power law fit provides a satisfactory fit to the SED (χ^2/d.o.f = 0.08) yielding a spectral index value of $\beta = -1.25 \pm 0.54$ ($F_\lambda \sim \lambda^\beta$).

In order to infer information on the host extinction the SED was fitted with the empirical galaxy templates described in [11] (K96 hereafter). The observed K96 templates can be grouped into seven sets: Bulge (B), E, S0, Sa, Sb, Sc and Stb galaxies. Additionally, the Stb K96 templates are subdivided into six classes depending on their extinction by increasing $E(B-V)$ in steps of 0.1 (from Stb1 to Stb6; see more details in K96). The extinction for the B, E, S0, Sa, Sb, and Sc templates is a free parameter.

The best fit is obtained with the blue Stb1 and Stb2 SEDs (χ^2/d.o.f ~ 0.1), which are defined to have the lowest extinctions among the K96 starburst templates ($0 < E(B-V) < 0.21$). The rest of redder templates yield worse results. Thus, we conclude that the GRB 030328 host is likely a blue low extinction starburst galaxy. This result agrees with the conclusion by [12], who found that GRB hosts are similar to the blue starburst galaxies of the Hubble Deep field. For the Stb1 and Stb2 SED fits the absolute B-band magnitude of the host is $M_B \sim -20.4$. No information can be obtained on the stellar population age since the 4000 Å jump is beyond our restframe wavelength range.

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This research is partially supported by the Spanish Ministry of Science and Education through programmes ESP2002-04124-C03-01 and AYA2004-01515 (including FEDER funds). JG acknowledges the support of a Ramón y Cajal Fellowship from the Spanish Ministry of Education and Science.

REFERENCES

[1] Villasenor J., Crew G., Vanderspek R. *et al.*, *GCN Circ.*, **1978** (2003).
[2] Kouveliotou C., Meegan C. A., Fishman G. J. *et al.*, *ApJL*, **413** (1993) 101.
[3] Peterson B. A. and Price P. A., *GCN Circ.*, **1974** (2003).
[4] Martini P., Garnavich P. and Stanek K. Z., *GCN Circ.*, **1979** (2003).
[5] Rol E., Vreeswijk P. and Jaunsen A., *GCN Circ.*, **1981** (2003).
[6] Reif K., Poschmann H., Bagschik H. *et al.*, in *Optical Detectors for Astronomy: State-of-the-Art at the Turn of the Millenium. 4th ESO CCD Workshop, 1999, held in Garching, Germany*, edited by Amico P. and Beletic J.W. (Kluwer Academic Publisher) 2000, pp. 143.
[7] Bohlin R. C., Colina L. and Finley D. S., *AJ*, **110** (1995) 1316.
[8] Gorosabel J., Pérez-Ramírez M.D., Sollerman J. *et al.*, to be published in *A&A* (2005).
[9] Schlegel D. J., Finkbeiner D. P. and David M., *ApJ*, **500** (1998) 525.
[10] Assafin M., Andrei A. H., Vieira Martins R. *et al.*, *ApJ*, **552** (2001) 380.
[11] Kinney A. L., Calzetti D., Bohlin R. C. *et al.*, *ApJ*, **467** (1996) 38.
[12] Christensen L., Hjorth J. and Gorosabel J., *ApJ*, **425** (2004) 913.