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Spectro-photometric study of the GRB 030329 host galaxy(*)

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(*) Based on observations carried out with the Nordic Optical Telescope, operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway, and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. 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. The spectral observations were obtained at the European Southern Observatory, Cerro Paranal (Chile), under the Director's Discretionary Time programme 271.D-5006(A).

Summary. — In this study optical/near-infrared(NIR) broad band photometry and optical spectroscopic observations of the GRB 030329 host galaxy are presented. The Spectral Energy Distribution (SED) of the host is consistent with a starburst galaxy template with a dominant stellar population age of ~ 150 Myr and an extinction $A_{\rm v} \sim 0.6$. Analysis of the spectral emission lines shows that the host is likely a low metallicity galaxy. Two independent diagnostics, based on the restframe UV continuum and the [OII] line flux, provide a consistent unextincted star formation rate of SFR$\sim 0.6 M_{\odot}$ yr^{-1}. The low absolute magnitude of the host ($M_B \sim -16.5$) implies a high specific star formation rate value, SSFR=$\sim 34 M_{\odot}$ yr$^{-1}(L/L^{\star})^{-1}$.

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PACS 95.75.Fg – Spectroscopy and spectrophotometry.
PACS 98.70.Rz – gamma-ray sources; gamma-ray bursts.

1. – Introduction

GRB 030329 was detected on 2003 March 29 at 11:37:14.67 UT by the HETE-2 spacecraft [1]. The GRB showed a duration of approximately 30 seconds in the 30–400 keV energy range. Thus, GRB 030329 falls into the "long-duration" category of GRBs [2]. The spectroscopic observations performed for GRB 030329 [3, 4, 5, 6] strongly confirmed previous evidences [7, 8] that long GRBs are related to Ic supernova (SN) explosions. The redshift of GRB 030329 was determined to be $z = 0.168$ from early spectroscopy with the Very Large Telescope (VLT, [9]). This makes GRB 030329 the third nearest burst overall (GRB 980425 is the nearest at $z = 0.0085$ [10], and GRB 031203 had $z = 0.1055$ [11]). HST observations showed that the host is a dwarf compact (full width half maximum, FWHM$\sim 0.5''$; [12]). However, to date there are no studies on the host galaxy SED, which gives relevant information on the extinction, dominant stellar population age, star formation rate (SFR) and galaxy type.

2. – Observations

In the present paper we report imaging and spectroscopic observations of the GRB 030329 host galaxy.

The photometric observations are based on a number of optical/NIR facilities in order to compile a well sampled SED. The $UBVR$-band observations where performed with the 2.56-m Nordic Optical Telescope (NOT) equipped with MOSCA. Additional optical observations were obtained with the BUSCA camera [13] at the 2.2-m telescope of Calar Alto (CAHA). BUSCA allows simultaneous imaging in four broad optical bands. The four channels (hereafter named $C1$, $C2$, $C3$ and $C4$) resemble Johnson's $UBRI$ bands, however they do not correspond to standard filters so they need to be calibrated by observing spectro-photometric standard stars [14]. Additionally JHK'-band data were acquired with the 3.5-m CAHA telescope equipped with Omega-Prime. All these optical/NIR imaging data were collected $\sim$1 year after the GRB event when the optical afterglow (OA) contribution to the total flux was negligible.

The optical spectroscopic data were acquired using VLT equipped with FORS2. The observations were conducted with the 300V grism and an order sorting filter GG375, covering the $\sim 3800 - 8800$ Å wavelength range. A $1.3''$ wide slit yielded a spectral resolution of ~ 10.5 Å. The VLT observations were performed ∼82 days after the GRB, when the OA was still contributing substantially to the measured flux ($\sim 50\%$ according to [15]). Hence, the spectral measurements overestimated the host galaxy continuum emission, so the uncontaminated photometric points had to be used to estimate the continuum level. A more extended description can be found in [16]

3. – Results

Based on the VLT spectroscopic data and using the R_{23} diagnostic method [17], we show that the GRB 030329 host is likely a low metallicity galaxy ($Z = 0.004$, see also [18]). From fitting synthetic and empirical SED templates, we infer that the host galaxy of GRB 030329 is most probably a starburst galaxy. This result is in agreement with the conclusions reported by [19] based on an independent host sample, who found that GRB hosts correspond to starburst galaxies in $\sim 90\%$ of the cases.

Based on the HyperZ public code [20], we derived a dominant stellar population age of 150 ± 80 years for a instantaneous starburst episode. However, an ideal starburst where all the star formation occurs simultaneously is not realistic. Thus, in a real starburst, like the GRB 030329 host, although the majority of the star formation occurred ~ 150 Myr ago, the star formation can not stop sharply. Thus, the inferred age of ~ 150 Myr should be considered as an upper limit of the actual GRB progenitor age.

The SED fitting (using either synthetic or empirical templates) and the spectroscopic data yield a consistent extinction value of $A_{\rm v} = 0.6$. Two independent diagnostic techniques, namely the UV continuum and the [OII] emission line flux, provide consistently a SFR value of $\sim 0.6 M_{\odot}$ yr^{-1} once it is corrected for the host galaxy reddening.

The host restframe B-band absolute magnitude is $M_B \sim -16.5$ ($L \sim 0.016 L^{\star}$, assuming $M_B^{\star} = -21$, [21]), confirming its subluminous nature [12]. The GRB 030329 host SFR is the lowest among the sample of [19]. However, the associated unextincted specific SFR is the highest (SSFR = $\sim 34 M_{\odot}$ yr$^{-1}(L/L^{\star})^{-1}$). All the findings present in this paper are consistent with the host galaxy being an active star forming galaxy.

A GRB 030329 field galaxy accidentally placed on the FORS2 slit, showed a redshift very similar to the host galaxy ($z = 0.1710 \pm 0.0003$), which may be indicative of a possible galaxy clustering. Multi-object spectroscopy of the GRB 030329 field might clarify the potential existence of a galaxy association around $z \sim$0.17

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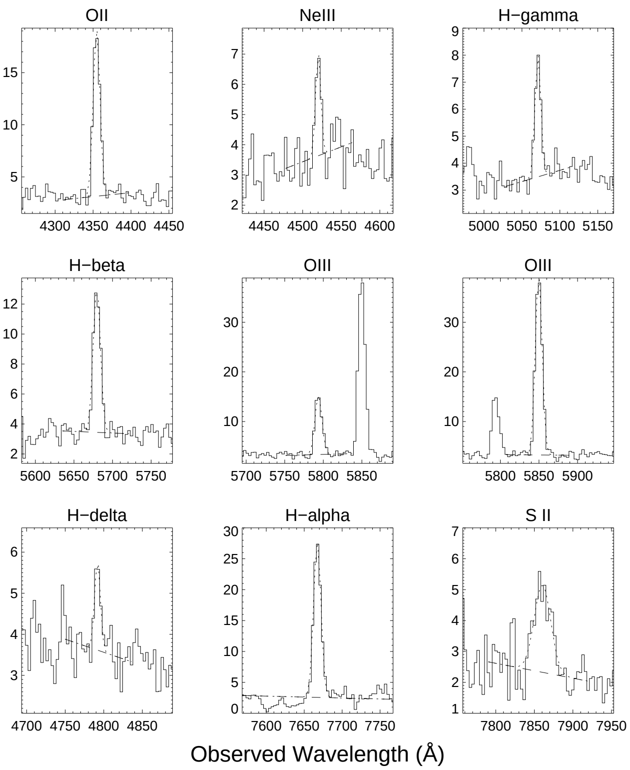

Fig. 1. – The figure shows the nine lines detected in our VLT spectrum. The vertical axes represent the flux densities in units of 10^{-18} erg s^{-1} cm^{-2} Å^{-1}. The values of the lines' integrated fluxes can be seen in [16].

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