GRB 100316A: an explosion at a High Redshift Galaxy

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Abstract

We report the results of the target of opportunity (ToO) observations done hours after the GRB 100316A with the GTC (+OSIRIS). These observations represent the first successful spectroscopic ToO executed at GTC (GTC67-10A) for a GRB. The spectral observations, performed with the low resolution R300B and R300R grisms of OSIRIS, shows a smooth continuum truncated by a Damped Ly-α Absorption. A careful analysis of the trace reveals a faint Ly-α emission slightly offset from the afterglow trace. We interpret this line as the Ly-α emission coming from the GRB host galaxy at redshift z=3.155.

Introduction

A γ-ray burst (GRB) is a brief and intense emission of very high energy photons occuring in any direction of the sky (Klebesadel et al. 1973, ApJ 182, L85). GRBs are followed by a long-lasting emission called afterglow. Afterglows emit in all the electromagnetic spectrum, from X-rays to radio wavelengths. In the optical range, the flux of afterglows decay approximately as a power law ($F_\nu \sim t^{-\alpha}$; Sari et al. 1998, ApJ 497, L17) shining for hours-weeks after the γ-ray emission.

On 2010 March 16, the Burst Alert Telescope (BAT) on board the *Swift* satellite was triggered by GRB 100316A at T_0=02:23:00 UT (Baumgartner et al. 2010, GCN Circ 10501). The mask-weighted light curve shows a FRED-like (Fast Raise and Exponential Decay) pulse starting at T_0-1 s, peaking at T_0+2 s and ending at T_0+20 s.

Due to an Earth-limb constraint, Swift performed a delayed slew to the GRB, so the X-Ray Telescope (XRT) on board *Swift* began to observe 3.2 ks after the BAT trigger (Beardmore et al 2010, GCN Circ 10485). The optical emission of the afterglow was discovered by Gorosabel et al. (2010, GCN Circ 10488) with the 1.23m CAHA telescope.

Photometric Observations

The photometric observations were carried out with 1.23m CAHA telescope, Liverpool Telescope (LT) and Gran Telescopio de Canarias (GTC). We present a log in table 1 and an optical light curve in the Fig 1. We also attach the Swift XRT data. This X-ray light curve shows a rebrightening at $T - T_0 \sim 0.06$ days. Our third optical observation, taken approximately at the time of the X-ray flare, is clearly brighter than the flux predicted by a power-law decay (see black line of Fig 1). Thus, the flare seems to be also present in the optical light curve.

Table 1: Observing log of photometric observations.

T-T_0 (days)	Telescope	Exposure (s)	Filter	Magnitude
0.02654	1.23mCAHA	3×200s	Johnson R	20.76±0.07
0.04425	1.23mCAHA	3×200s	Johnson R	21.23±0.07
0.07615	1.23mCAHA	3×200s	Johnson R	21.35±0.08
0.09199	10.4mGTC	1×70s	Sloan r'	22.43±0.07
0.09977	10.4mGTC	3×40s	Sloan r'	22.49±0.06
0.94281	10.4mGTC	4×120s	Sloan g'	$>$ 24.5
0.95854	10.4mGTC	3×90s	Sloan r'	$>$ 23.3
0.96565	10.4mGTC	5×60s	Sloan i'	$>$ 23.1
0.97312	10.4mGTC	5×60s	Sloan z'	$>$ 23.5
2.13729	10.4mGTC	8×80s	Sloan i'	24.05±0.07
2.14777	10.4mGTC	3×180s	Sloan r'	24.12±0.08
2.16652	10.4mGTC	3×240s	Sloan g'	26.71±0.08
2.16786	10.4mGTC	8×90s	Sloan z'	23.83±0.09
123.07184	10.4mGTC	7×300s	Sloan r'	25.25±0.04

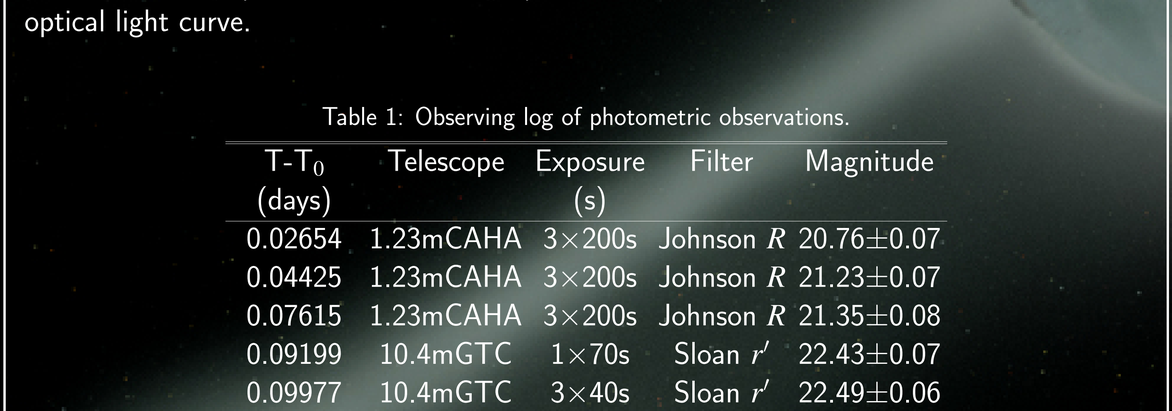

Figure 1: We represent on the left the optical light curve of the afterglow + host system and its theoretical behavior (black line) in the AB system (r' and R filters). The red line shows the power-law fit to the afterglow itself and the blue line represents the host galaxy flux level. A smooth power-law decay can not reproduce the optical light curve, providing an unacceptable χ^2 / dof = 17.9 value. The presence of a flare in both the X-ray (right) and optical light curves, and the large χ^2 / dof could indicate that the optical light curve shows a rich flaring structure superimposed on a smooth power-law decay.

Spectroscopic Observations

The spectroscopic observations were performed with GTC (+OSIRIS). The log of these observations is shown in table 2 and the R300B spectrum in the Fig 2. Due to the large slit width, we do not detect any absorption line except the Damped Lyman-α Absorption (DLA). Fortunately the wide slit width allowed to include an intense Ly-α emitter, most likely located in the GRB host galaxy. This explain the offset of the emission line from the afterglow trace.

Table 2: Observing log of spectroscopic observations.

T-T_0 (days)	Telescope	Exposure (s)	Grating	Slit width ($''$)
0.12101	10.4mGTC	3×900s	R300R	2.52
0.15942	10.4mGTC	2×900s	R300B	2.52

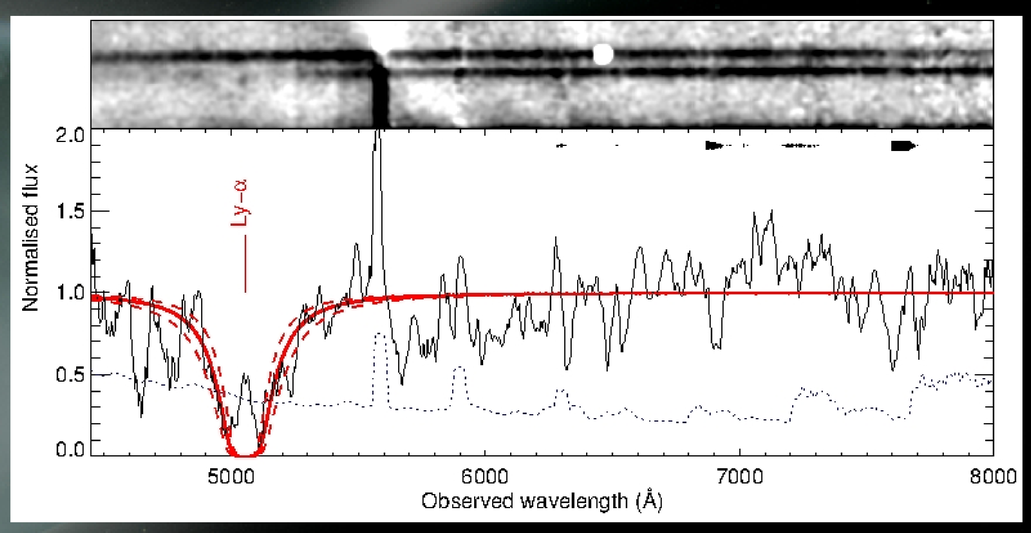

Figure 2: R300B long-slit spectrum of the GRB 100316A afterglow. As seen, the Ly-α emission is slightly off from the afterglow trace in the 2D image and partialy present in the extracted trace. The red line represents the DLA fit. Using the emission line we estimate a redshift of z=3.155. Instead, making use of the absorption line we derive a $\log N_H$=22.1±0.2 cm^{-2}. We measured a Ly-α line flux of 7.56±1.06 × 10^{17} erg s^{-1} cm^{-2}.

First Results

1. We detected a GRB afterglow with an optical decay that does not fits with a power-law (χ^2 / dof = 17.9). It seems there is flaring activity contribution superposed to the power-law decay with an index α=0.84±0.03. We also see a possible flare in the X-ray light curve.
2. Spectroscopy of the afterglow revealed a smooth continuum truncated by a DLA. The line fit suggests a $\log N_H$=22.1±0.2 cm^{-2}. This column density value is located in the mid-high region inside the interval found for the sample of galaxies analysed by Fynbo et al. (2009)
3. We detect a host galaxy (r'=25.25') that is a Ly-α emitter (LAE). Using this emission line we derived a redshift of z=3.155
4. The Ly-α emission line is slightly off from the afterglow trace. Mesuring this shift and assuming the standard cosmological parameters h=0.71, Ω_m=0.27 and Ω_Λ=0.73, we estimate an impact parameter of d = 9.0 ± 2.5 kpc (show figure 3).

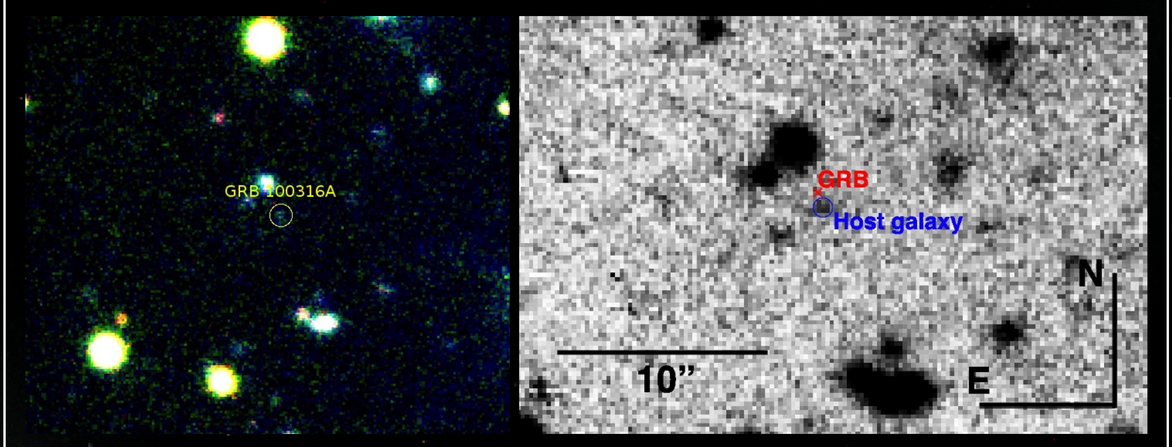

Figure 3: We present a colour composition of the GRB afterglow using Sloan r', i' and z' filters (left) and an image showing the position shift between the afterglow and the host galaxy (right).