Populations of High Energy Sources in Galaxies
Proceedings IAU Symposium No. 230, 2005
E. J. A. Meurs & G. Fabbiano, eds.

doi:10.1017/S1743921306008386

INTEGRAL and *XMM-Newton* observations of GRB 040223

S. McBreen[1] and S. McGlynn[2]

[1]Astrophysics Mission Division, RSSD of ESA, ESTEC, Noordwijk, the Netherlands
email: smcbreen@rssd.esa.int
[2]Department of Experimental Physics, University College Dublin, Dublin 4, Ireland
email: smcglynn@bermuda.ucd.ie

Abstract. We present gamma–ray and X-ray analysis of GRB040223 observed by *INTEGRAL* and *XMM-Newton*. GRB 040223 has a peak flux of $(1.6 \pm 0.1) \times 10^{-8}$ ergs cm^{-2} s^{-1}, a fluence of $(4.4 \pm 0.4) \times 10^{-7}$ ergs cm^{-2} and a steep photon power law index of -2.3 ± 0.2, in the energy range 20–200 keV. The steep spectrum implies that it is an X-ray rich GRB with emission up to 200 keV and $E_{\rm peak} < 20$ keV. The luminosity-lag relationship was used to obtain a redshift $z = 0.10^{+0.04}_{-0.02}$. The isotropic energy radiated in γ-rays and X-ray luminosity after 10 hours are both orders of magnitude less than classical GRBs.

Keywords. gamma rays: bursts, gamma rays: observations.

1. Introduction

The prompt emission from GRBs and the afterglow give valuable information on the radiation processes and the environment. There seems to be a continuum of spectral properties for X-ray flashes (XRF), X-ray rich GRBs and classical GRBs and it is probable that they have a similar origin (Sakamoto *et al.* 2004).

ESA's International Gamma-Ray Astrophysics Laboratory *INTEGRAL* (Winkler *et al.* 2003) is composed of two main coded-mask telescopes; an imager IBIS (Ubertini *et al.* 2003) and a spectrometer SPI (Vedrenne *et al.* 2003) with a combined energy range of 15 keV to 8 MeV. *INTEGRAL* has detected and localised 30 GRBs so far. The EPIC cameras on *XMM-Newton* (Turner *et al.* 2001) have been used to obtain X-ray afterglows of 6 of those GRBs. We report here observations of the prompt and afterglow emission of GRB 040223 and a detailed account is given elsewhere (McGlynn *et al.* 2005).

2. Data Analysis & Results

GRB 040223 was detected by the INTEGRAL burst alert system IBAS (Mereghetti *et al.* 2003). The IBIS light curve is given in Fig. 1a. GRB 040223 is in the long duration class with a well resolved pulse. The IBIS light curve was denoised with a wavelet analysis (Quilligan *et al.* 2002) and the risetime, fall time and FWHM of the pulse are 19 s, 22 s, and 13 s respectively. The IBIS data was divided into two energy channels i.e. 25–50 keV and 100–300 keV. The cross-correlation analysis (Norris 2002, Schaefer 2004) was performed between the two channels and the lag was determined to be 2.2 ± 0.3 s.

The IBIS spectral analysis was performed using the standard method (Moran *et al.* 2005). The IBIS data (20–200 keV) is well fit by a single power law with photon index -2.3 ± 0.2 with a reduced χ^2 of 1.01 for 20 degrees of freedom (dof) with errors at the 90% confidence level (Fig. 1b). The peak flux is $(1.6 \pm 0.1) \times 10^{-8}$ ergs cm^{-2} s^{-1} over the brightest second and the fluence is $(4.4 \pm 0.4) \times 10^{-7}$ ergs cm^{-2}.

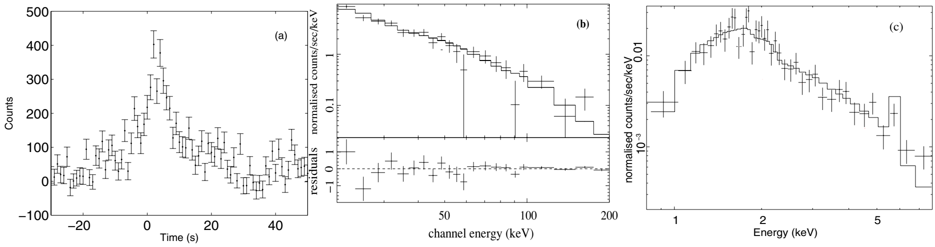

Figure 1. a) IBIS lightcurve of GRB 040223 in the energy range 15–200 keV; zero time is the IBAS trigger at 13:28:10 UTC. **b)** IBIS spectrum of GRB 040223 fit by a power law model from 20–200 keV. **c)** EPIC-PN spectrum of the GRB 040223 afterglow and its best fit absorbed power law model.

XMM-Newton observed the location of the GRB for 42 ks starting 18 ks after the burst where a fading X-ray source was detected. The temporal decay of the X-ray afterglow ($F_\nu(t) \propto t^{-\delta}$) was fit by a power law with index $\delta = -0.7 \pm 0.25$ by Gendre *et al.* (2004). Our analysis is consistent with this result. We obtained 3 afterglow spectra from the PN and MOS Cameras (0.2–10 keV) after standard data screening. The spectra were well fit by a power law $F_\nu \propto \nu^{-\beta_x}$ where the spectral index $\beta_x = 1.7 \pm 0.2$ with reduced χ^2 of 1.29 for 111 dof (Fig. 1c). The absorption column density has a high value of $N_H = 1.8 \times 10^{22}$ cm^{-2}, exceeding the high galactic value in this direction of 6×10^{21} cm^{-2}.

There are no direct measurements of the redshift to GRB 040223 so model dependent distance indicators were used. The luminosity-lag relationship (Norris 2002) was used to calculate the peak luminosity of $3.8^{+3.8}_{-1.7} \times 10^{47}$ ergs s^{-1} (McGlynn *et al.* 2005). The redshift to the source is $z = 0.10^{+0.04}_{-0.02}$ when the peak flux of $1.6 \pm 0.1 \times 10^{-8}$ ergs cm^{-2} s^{-1} is combined with the peak luminosity. The fluence gives a total isotropic γ–ray luminosity ($E_{\rm ISO}$) of approximately 10^{49} ergs which is about three orders of magnitude less than classical GRBs. GRB 040223 is sub-luminous in γ–rays by a large factor.

The X-ray flux after 10 hours is $2.4 \pm 0.4 \times 10^{-13}$ ergs cm^{-2} s^{-1} in the 2–10 keV region. The X-ray luminosity of GRB 040223 is 6×10^{42} ergs s^{-1} and is orders of magnitude fainter than observed from classical GRBs (Bloom *et al.* 2003). The X-ray and γ-ray luminosities of GRB 040223 and XRF 030723 are very comparable.

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