INTEGRAL AND *XMM-NEWTON* OBSERVATIONS OF THE LOW-LUMINOSITY AND X–RAY RICH BURST GRB 040223

S. McBreen[1], S. McGlynn[2], S. Foley[2], B. McBreen[2], and L. Hanlon[2]

[1]Astrophysics Mission Division, RSSD of ESA, ESTEC, Noordwijk, the Netherlands
[2]School of Physics, University College Dublin, Dublin 4, Ireland

ABSTRACT

We present gamma–ray and X–ray analysis of GRB 040223, which was observed by *INTEGRAL* and *XMM-Newton*. GRB 040223 has a peak flux of (1.60 $\pm$0.13) $\times$ 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 $\pm$ 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. If $E_{\rm peak} < 10$ keV, it would qualify as an X-ray flash with high energy emission. The X-ray afterglow has a spectral index β_x = -1.7 $\pm$ 0.2, a temporal decay of t$^{-0.75\pm0.25}$ and a large column density of 1.8 $\times 10^{22}$ cm^{-2}. 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 the X–ray luminosity after 10 hours are both orders of magnitude less than classical GRBs. GRB 040223 is consistent with the extrapolation of the Amati relation into the region that includes XRF 030723 and XRF 020903.

Key words: gamma rays: bursts, gamma rays: observations, X–rays.

1. INTRODUCTION

The prompt emission from GRBs and their afterglows give valuable information on the radiation processes and the environment. In addition to GRBs, X–ray flashes (XRF) have been identified as a class of soft bursts that are very similar to GRBs. There seems to be a continuum of spectral properties for XRFs, 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 32 GRBs so far. The EPIC cameras on *XMM-Newton* (Turner et al., 2001) have been used to obtain X–ray afterglows of 6 of the GRBs. We report here observations of the prompt and afterglow emission from 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 and does not include two very weak pulses at about -80 s and -180 s. 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 $\pm$ 0.3 s which is longer than observed from most GRBs.

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 $\pm$ 0.2 with a reduced χ^2 of 1.01 for 20 degrees of freedom (dof). Errors are at the 90% confidence level (Fig. 1b). The peak flux is (1.60 $\pm$0.13) $\times$ 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}. The spectral results obtained with SPI are consistent with IBIS and γ-ray emission was significantly detected up to 200 keV.

XMM-Newton observed the location of the GRB for 42 ks starting 18 ks after the burst and a fading X–ray source was detected within the IBAS error circle. The temporal decay of the X–ray afterglow ($F_\nu(t) \propto t^{-\delta}$) was fit by a power law with index δ = -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 $\times 10^{21}$cm^{-2}.

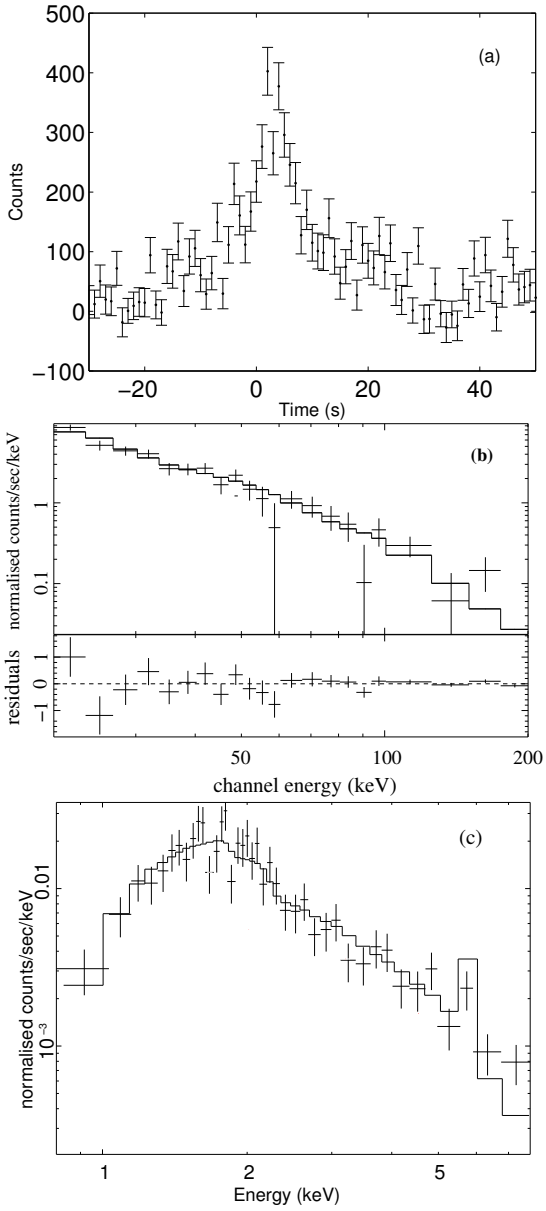

Figure 1. **a)** *IBIS lightcurve of GRB 040223 in the energy range 15–200 keV (zero time is the IBAS trigger at 13:28:10 UTC).* **b)** *IBIS spectrum of GRB 040223 fit by a power law model from 20–200 keV.* **c)** *EPIC spectrum of the GRB 040223 afterglow and its best fit absorbed power law model. The data points shown refer to the PN detector and agree with the MOS data.*

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 (1.60 ± 0.13) $\times 10^{-8}$ ergs cm^{-2} s^{-1} is combined with the peak luminosity. The fluence gives a total isotropic γ–ray luminosity (E_{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. Using the Amati relation (Ghirlanda et al., 2004), the value of E_{ISO} is $< 2 \times 10^{50}$ ergs assuming that the rest frame value of E_{peak} is < 20 keV. GRB 040223 lies on or near the extrapolation of the Amati relation from classical GRBs to include XRF 030723 and XRF 020903.

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.

REFERENCES

Barraud, C., Olive, J.-F., Lestrade, J. P., et al. 2003, A&A, 400, 1021

Bloom, J. S., Frail, D. A., & Kulkarni, S. R. 2003, ApJ, 594, 674

Gendre B., Piro L., De Pasquale M.[astro-ph/0412302]

Ghirlanda, G., Ghisellini, G., & Lazzati, D. 2004, ApJ, 616, 331

McGlynn, S., McBreen, S., Hanlon, L., et al. 2005, [astro-ph/0505349]

Mereghetti, S., Götz, D., Borkowski, J., Walter, R., & Pedersen, H. 2003, A&A, 411, L291

Moran, L., Mereghetti, S., Götz, D., et al. 2005, A&A, 432, 467

Norris, J. P. 2002, ApJ, 579, 386

Quilligan, F., McBreen, B., Hanlon, L., et al. 2002, A&A, 385, 377

Sakamoto, T., Lamb, D. Q., Graziani, C., et al. 2004, ApJ, 602, 875

Schaefer, B. E. 2004, ApJ, 602, 306

Turner, M. J. L., Abbey, A., Arnaud, M., et al. 2001, A&A, 365, L27

Ubertini, P., Lebrun, F., Di Cocco, G., et al. 2003, A&A, 411, L131

Vedrenne, G., Roques J. P., Schönfelder V. et al. A&A, 441, L63

Winkler, C., Courvoisier, T. J.-L., Di Cocco, G., et al. 2003, A&A, 411, L1