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What did ASCA see in the GRB 970828 afterglow?

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Abstract. The ASCA satellite made a quick followup observation of GRB 970828 and detected its fading X-ray afterglow at the position localized by the All-Sky Monitor on the Rossi XTE satellite. Because of the quickness, the afterglow was still rather bright ($\sim 4\ 10^{-13}$ ergs cm^{-2} s^{-1}: $2-10$ keV), and ASCA obtained the data of good quality. We found the spectral features of the absorption which implies a column density of $4.1\ 10^{21}$ cm^{-2} at $z = 0$, together with an emission line at ~ 5 keV. The line could be red shifted Fe K_α line. Hence, it suggests a *relatively small* red shift $z \approx 0.33$ for this GRB.

Key words: gamma-rays: bursts

1. Introduction

Among nine GRB afterglows which displayed optical counterparts, the red-shift of the source is found from the optical spectroscopy for three GRBs, 970508, 971214 and 980703 (Metzger et al. 1997; Kulkarni et al. 1998; Djorgovski et al. 1998), and one, GRB 980329, was implied to be $z \sim 5$ by Fruchter (1998) from its fluxes in $K - R$ band. Another noteworthy GRB is GRB 980425 which is suggested to be associated with a SN Ic, SN1998bw, at $z = 0.0085$ (Galama et al. 1998).

In contrast to these events, the burst of 28 August 1997 (GRB 970828) displayed an afterglow only in an X-ray band and accompanied no optical transient down to $R = 23.8$ (Groot et al. 1998). This GRB was detected by ASM/RXTE on August 28.73931, 1997 UT and localized into a small region with $2' \times 5'$ accuracy (Remillard et al. 1997; Smith et al. 1997). A subsequent scan by the PCA/RXTE (Proportional Counter Array) found an X-ray afterglow of 0.5 mCrab ($2-10$ keV) about four hours after the burst detection (Marshall et al. 1997). Here we report the detection of an afterglow of GRB 970828, and its X-ray properties obtained with ASCA.

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2. Observation and analysis

An ASCA observation of GRB 970828 in the $0.5-10$ keV range as a Target of Opportunity Observation (TOO) was conducted soon after the alerts from the RXTE team based on the ASM/RXTE detection. The observation with net exposure time of ~ 36 ksec was performed during a period of August 29.91 - August 30.85 UT beginning at 1.17 days after the GRB. Both two scientific instruments on ASCA, the SIS and the GIS detector, saw an X-ray source of an average $2-10$ keV flux of $F_X \sim 4\ 10^{-13}$ erg s^{-1} cm^{-2} within the combined source error region given by ASM/RXTE and IPN (Smith et al. 1997; Hurley et al. 1997; Murakami et al. 1997). The position of the X-ray source was determined at R.A. = $18^h08^m32\overset{s}{.}2$ and Decl. = $+59°18'54''$ (J2000) with a 90% error radius of $0\overset{'}{.}5$ by an image analysis on the datasets.

2.1. X-ray flux variability

The X-ray source clearly displayed a fading behavior during the observation. The flux in $2-10$ keV range estimated assuming a power-law spectrum with the photon index of -2 decayed from $\sim 1\ 10^{-11}$ ergs cm^{-2} s^{-1} (the PCA observation at $t \sim 1.4\ 10^4$ s) to $\sim 3\ 10^{-13}$ ergs cm^{-2} s^{-1} (at the end of the ASCA observation at $t \sim 1.7\ 10^5$ s) where t is an elapsed time since the burst. However,the ASCA data indicate a variability of the source rather than a simple power-law like decay. Figure 1 shows the SIS count rate together with the "best-fit" power-law fading model: $t^{-1.44\pm0.07}$ (solid line) based on the PCA/RXTE (Marshall et al. 1997) and the ASCA observation. A peak structure appears around $t = 1.25\ 10^5$ s.

2.2. Afterglow spectra

Spectra of the source were made for three periods during the observation indicated by dashed lines labeled "A", "B" and "C" in Fig. 1. We made fittings with a model "absorbed power-law" ($\exp(-N_H\sigma(E)) * E^{-\alpha}$), and found a large absorption column density, N_H in the best fit

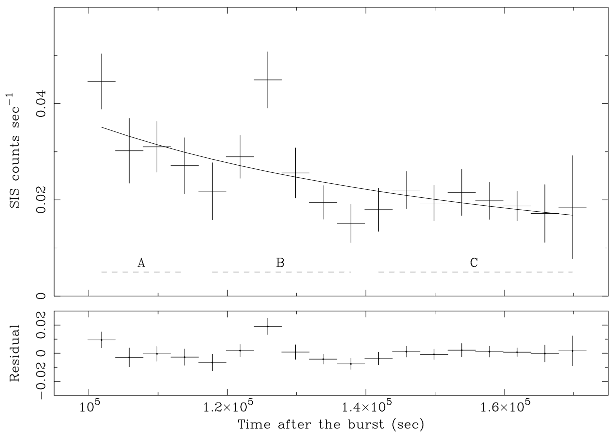

Fig. 1. SIS light curve with time bins of 4000 s. It displays the time variation of the source brightness. A simple power-law decay model cannot fit the data; the solid line shows the "best-fit" model. Dashed lines labeled "A", "B" and "C" indicate the intervals for which spectral studies are done

for the period "C". This is $4.1^{+2.1}_{-1.6}\ 10^{21}$ cm^{-2} which is larger than the galactic value towards the source direction, $3.4\ 10^{20}$ cm^{-2}, estimated by COLDEN at The Einstein On-Line Service, Smithsonian Astrophysical Observatory. For other periods, however, derived column densities are consistent with the galactic values.

Another remarkable result is an excess feature around 5 keV in the spectrum of "B" which can be represented by a gaussian line (see Fig. 2). Introducing a line improves the fitting by $\Delta\chi^2 = 11.15$ with three additional line parameters, and results in χ^2 of 58.85 for 58 *dof*. An F-test gives the confidence of 98.3%. The best fit line centroid is $E_{\rm line} = 5.04^{+0.23}_{-0.31}$ keV, the line width $\sigma = 0.31^{+0.38}_{-0.31}$ keV, and the line flux $F_{\rm Fe} = (1.5 \pm 0.8)\ 10^{-13}$ ergs cm^{-2} s^{-1}. While, for the spectra of "A" and "C", the model including a line results in its normalization consistent with zero. The upper-bounds (90% confidence) of line flux are $9.5\ 10^{-14}$ ergs cm^{-2} s^{-1} and $5.6\ 10^{-14}$ ergs cm^{-2} s^{-1} for "A" and "C"respectively. This may imply that the line intensity changed during the observation.

3. Summary

ASCA saw a fading X-ray afterglow from GRB 970828. However its flux not monotonically decayed but displayed a "flare activity" around $t = 1.25\ 10^5$ s. The BeppoSAX observed an X-ray flux variability also in the GRB afterglow of GRB 970508 (Piro et al. 1997). It is a rather broad ($\delta t > 10^5$ s at $t \approx 10^5$ s) "bursting activity", while the activity seen with ASCA is narrower in time; $\delta t/t \sim 0.05$. Fenimore et al. (1998) suggests that this small $\delta t/t$ implies a small *surface filling factor* similar to the GRB activities themselves and there would be fine structures in the relativistic shell much smaller than Γ^{-1} where Γ is the bulk Lorentz factor.

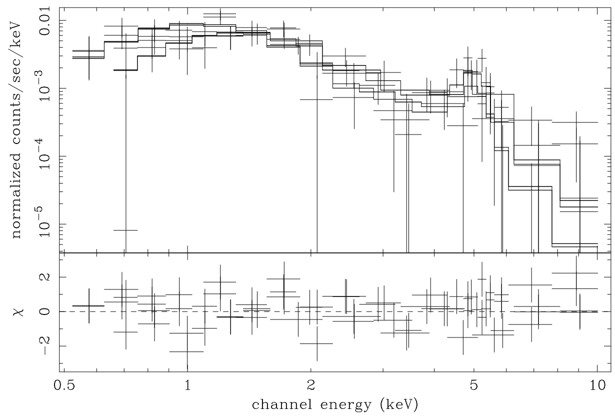

Fig. 2. The X-ray spectrum for the period (B) shown in Fig. 1 fitted with the model of "absorbed power-law" $(\exp(-N_{\rm H}\sigma(E)) * E^{-\alpha})$

ASCA discovered in the afterglow spectra the evidence of a large absorption column density and an emission line possibly caused by the Fe K_α line emissions red shifted by $z = 0.33$. This would be the first GRB with its red shift determined only by the X-ray observation if this interpretation is true. A detection of a red-shifted Fe emission line is also reported by the BeppoSAX team for the GRB 970508 afterglow (Piro et al. 1999a; Piro et al. 1999b). The Fe line seen in the GRB 970828 was variable in time with the time scale of $\sim$ 10 000 s and appeared $\sim 10^5$ s after the burst. This suggests a rather small line forming region of $\sim 10^{14} - 10^{15}$ cm and implies a dense matter ($n > 10^{12}$ for the matter with the solar abundance) in the vicinity of the source if the line is formed by the photoionization-recombination process or the "reflection" mechanism (Yoshida et al. 1999).

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