ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

SEPTEMBER **1999**, PAGE 487

Astron. Astrophys. Suppl. Ser. **138**, 487–488 (1999)

GRB redshift determination in the X–ray band

S. Campana[1], G. Ghisellini[1], D. Lazzati[1,2], F. Haardt[3], and S. Covino[1]

[1] Osservatorio Astronomico di Brera, Via Bianchi 46, I–23807 Merate (Lc), Italy
[2] Dipartimento di Fisica, Università degli Studi di Milano, Via Celoria 16, I–20133 Milano, Italy
[3] Dipartimento di Fisica dell'Università di Como, via Lucini 3, I–22100 Como, Italy

Received December 29, 1998; accepted June 23, 1999

Abstract. If $\gamma-$ray bursts originate in dense stellar forming regions, the interstellar material can imprint detectable absorption features on the observed X–ray spectrum. Such features can be detected by existing and planned X–ray satellites, as long as the X–ray afterglow is observed after a few minutes from the burst. Detection of these X–ray features will make possible the determination of the redshift of $\gamma-$ray bursts even when their optical afterglows are severely dimmed by extinction. For further detail see Ghisellini et al. (1999).

Key words: gamma-rays: bursts — X–rays: general — line: formation

1. The $N_{\rm H}$–redshift plane

If γ-ray bursts (GRBs) originate in a dense environment their X–ray afterglow spectra are modified by absorption features and the imprinted edges can be used to determine their redshifts. Given the time decay law observed in the GRB X–ray afterglows, the necessary S/N ratio to reveal an absorption feature can be achieved only if the X–ray observation starts immediately after the burst itself, or if the collecting effective area of the detector is much larger than 100 cm^2.

We have simulated the observed spectrum by using the response matrices of some future planned missions, such as JET-X ($A \sim 200$ cm^2 at 1.5 keV and $A \sim 40$ cm^2 at 8.1 keV for the two telescopes; Citterio et al. 1996), AXAF with Back Illuminated (BI) CCDs ($A \sim 700$ cm^2 at 1.5 keV and $A \sim 40$ cm^2 at 8.1 keV; Kellogg et al. 1997) and XMM with the EPIC detectors ($A \sim 3600$ cm^2 at 1.5 keV and $A \sim 1500$ cm^2 at 8.1 keV for three telescopes; Gondoin et al. 1996) and assuming: *i*) $F(100\,{\rm s}) = 10^{-8}$ erg cm^{-2} s^{-1} between 2 and 10 keV at the beginning of the observation; *ii*) a power law time decay of the flux $\propto t^{-1}$; *iii*) an intrinsic (unabsorbed) power law spectrum of photon index $\Gamma = 1$ constant in time. All the simulations reported here refer to observations of 10 ks.

We simulated two different cases: a GRB afterglow at $z = 0.25$ and intrinsic $N_{\rm H} = 3\ 10^{21}$ cm^{-2} and $z = 4$ and $N_{\rm H} = 10^{24}$ cm^{-2}, which are relevant for the oxygen and iron edge, respectively. A galactic column density of $3\ 10^{20}$ cm^{-2} has also been included (for an overview of the $N_{\rm H}$ values with BeppoSAX see Owens et al. 1998). In the case of the oxygen edge (at 0.52 keV) the satellite energy band is extremely important in order to recover the correct GRB redshift. We keep fixed the edge energies, even if in the case of a warm absorber fit should be worse.

In the case of JET-X, the minimum energy of 0.3 keV limits the maximum detectable redshift to ~ 0.7. The influence of the galactic absorption plays also a crucial role, such that only for low values ($\lesssim 5\ 10^{20}$ cm^{-2}) we are able to disentangle the intrinsic and the galactic absorption.

In Fig. 1 (left side) we report the contour plots in the $N_{\rm H} - z$ plane of the simulated models as observed with different X–ray satellites. The three contours refer to 1, 2 and $3\,\sigma$ confidence levels. In Fig. 1a is shown the case of the JET-X telescope. It can be noted that the input redshift and column density are not recovered satisfactorily. In particular, the presence of different absorption features (O, Ne, Mg, Si) results in the elongated contour in the $N_{\rm H} - z$ plane. In the case of AXAF (Fig. 1b), the recovery of the GRB redshift is eased by the higher throughput at low energies guaranteed by the BI CCDs. The large effective area of XMM poses no problem for the identification of the redshift (Fig. 1c).

In the case of the Fe edge there are less problems due to the fact that beyond iron there are not prominent K edges. This is testified by Fig. 1 (right side), in which for all the considered instrument the redshift and the column density are recovered with a high degree of confidence. Note however that at these large redshift, the iron abundance may be lower than the solar value.

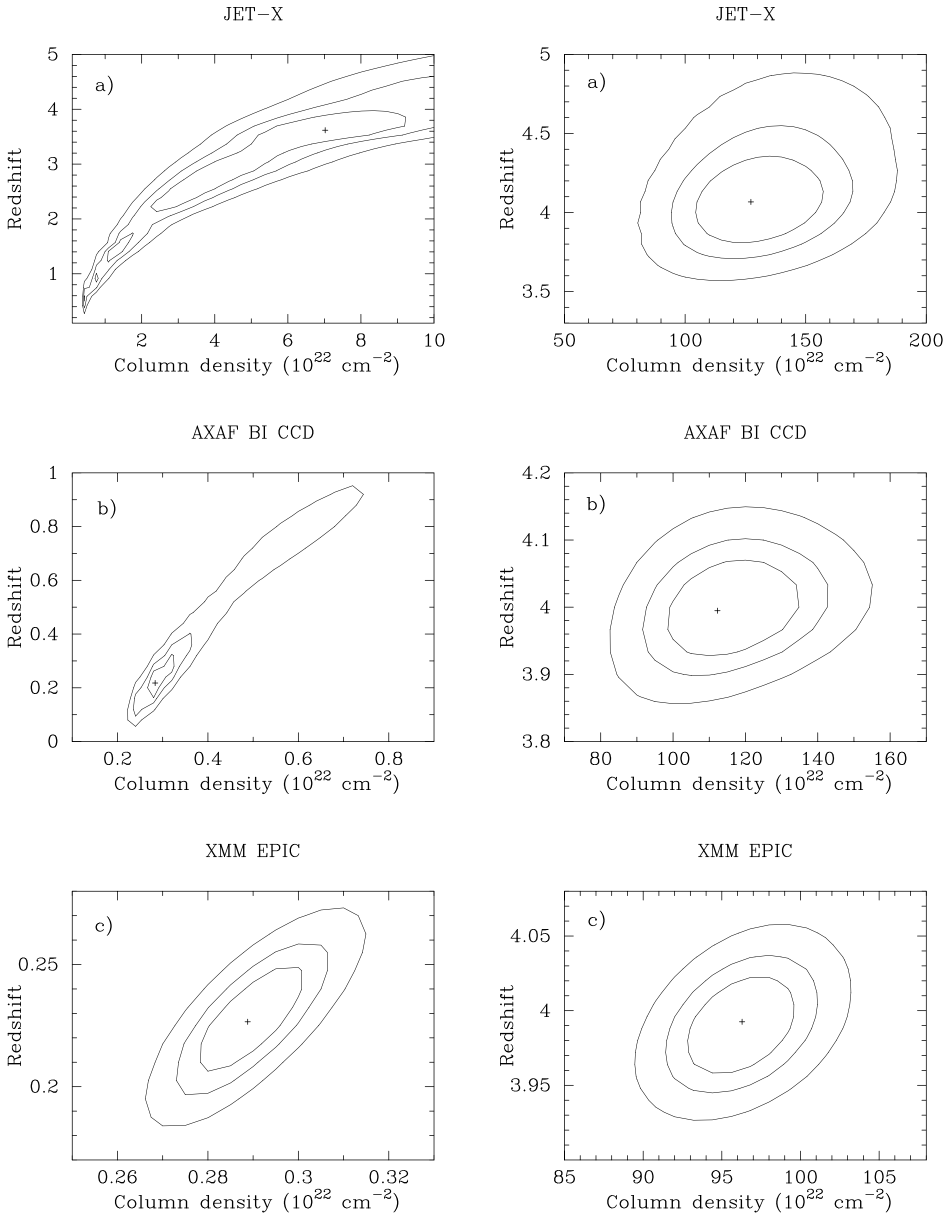

Fig. 1. Column density – redshift contour plots for different X–ray instruments. LEFT SIDE: The input model has $z = 0.25$ and $N_{\rm H} = 3\ 10^{21}$ cm^{-2}. The upper panel **a)** shows the case of JET-X. The middle panel **b)** presents the case of AXAF with BI CCDs and the lower panel **c)** the case of XMM. RIGHT SIDE: The input model has $z = 4$ and $N_{\rm H} = 10^{24}$ cm^{-2}

2. Discussion

Oxygen and iron edges are the most prominent absorption features in the spectra of X–ray sources. This individuates two almost distinct accessible part of the redshift–column density plane for GRB: one characterized by a moderate $N_{\rm H} \sim 10^{21} - 10^{22}$ cm^{-2} and $z \sim 0.1 - 0.5$ and the other one by a column larger than 10^{23} cm^{-2}. Note that for a standard dust to gas ratio, a column of $N_{\rm H} = 10^{22}$ cm^{-2} corresponds to an optical extinction $A_V \sim 6$ mag, precluding the possibility to detect the optical afterglow. If, furthermore, it were not possible to perform spectroscopic optical observation of the host galaxy (either because a precise position is lacking, or because it is too faint), then the X–rays could be the only mean to determine the redshift, especially for strong bursts located at $z > 2 - 3$, for which the iron edge lies in the most sensitive energy range of X–ray detectors.

References

Citterio O., et al., 1996, SPIE 2805, 56
Ghisellini G., et al., 1999, ApJ 517, 168
Gondoin P., et al., 1996, SPIE 2808, 390
Kellogg E.M., et al., 1997, SPIE 3113, 515
Owens A., et al., 1998, A&A 339, L37