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Dust extinction properties of a sample of bright X-rays afterglows(*)

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Summary. — We have studied a sample of four bright X-rays afterglows of Gamma-ray Bursts (GRBs) for which the optical spectral energy distributions (SEDs), not corrected for extra-galactic dust extinction, have spectral index consistent with the X-rays spectral index, but with fluxes significantly below the X-rays extrapolation assuming a simple power law spectral model. A simple power law model is suggested by the spectral and temporal indices of these afterglows as already noted in previous works, although a spectral break between the X-rays and the optical band cannot be excluded but in one case. Previous works invoked a non standard extinction law to recover the observed spectral "mismatch"; alternatively, the same electron population may have produced the observed NIR-optical emission via synchrotron radiation and the X-rays via Inverse Compton scattering. We have investigated on the non-standard extinction hypothesis, since high redshift environments can be in principle very different from standard (local) interstellar media and GRB circumburst environment may well be modified by the burst itself. Although the uncertainty on the underlying spectral model prevented us to reach firm conclusions, we found that an extinction curve weakly dependent on the wavelenght makes the optical SED consistent with the X-rays flux extrapolation assuming a simple power law model and provides at the same time rest frame visual extinction values nicely in agreement with the equivalent hydrogen column densities measured from X-rays analysis. An extinction law weakly dependent on the wavelenght can be provided by dust grains destruction due to the intense X-rays and UV fluxes from the burst itself or by small dust grains coagulation into larger ones. The large sample of optical–to–X-rays spectrally monitored afterglows provided by Swift will address our findings.

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1. – Introduction

Long-duration GRBs are thought to be associated with the gravitational collapse of massive stars (*e.g.,* [10]). Consequently, due to the short life-time of massive stars, the afterglow emission is expected to radiate into the dense and dusty environment of the star forming region where the massive star was formed. However, spectral analysis of a sample of X-rays afterglows with optically detected counterpart shows that, on average, to large equivalent hydrogen column densities N_H correspond small visual extinctions A_V in the rest frame of the GRB, if a Galactic or a Small Magellanic Cloud (SMC) extinction curve is assumed [9]. In addition, optical Spectral Energy Distributions (SEDs) show, on average, small optical reddenings [20], contrary to what is expected from a dusty environment as a star formation region is. In this work we have investigated on the possibility that the GRB host galaxy interstellar matter (ISM) and/or the GRB circumburst environment have a non-standard extinction law, due to causes external to the source (*e.g.,* high density environments; *e.g.,* [6]) or to the source itself (*e.g.,* dust grains destruction due to the intense X-rays [8] and UV fluxes [23] from the GRB). To achieve our goal, we have performed a NIR–to–X-rays spectral analysis of a selected afterglow sample in order to investigate on the extinction effects on both the optical spectral slope and flux normalization.

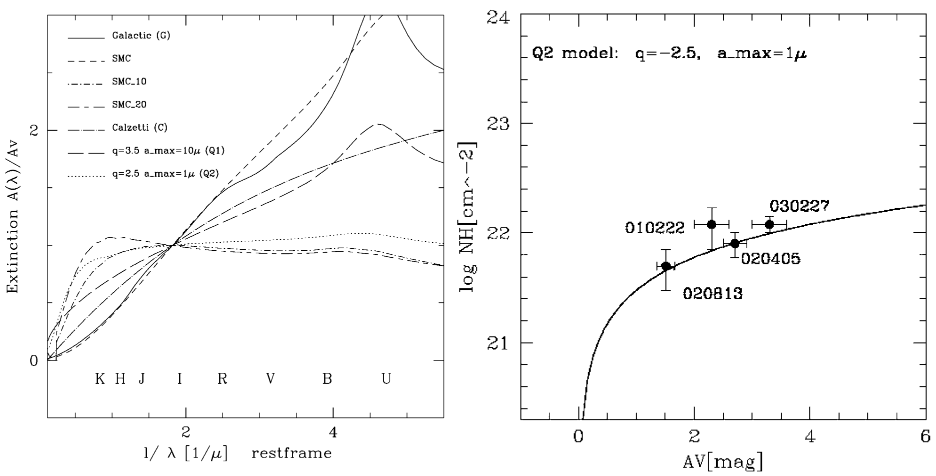

Fig. 1. – *Left Panel:* extinction curves tested in this work (see [21] for details on each curve) except the dust destruction derived extinction curves (SMC10 and SMC20 from Perna, private communications) that we have plotted here to show how similar they can be to the curves derived from dust grain coagulation (Q1 and Q2; [12]). We indicated in the plot the rest frame wavelengths actually observed by a standard photometric system assuming that the host galaxy is at $z = 1$. *Right Panel:* rest frame best fit N_H obtained from X-rays (0.1–10.0 keV) spectral analysis against A_V obtained from NIR–to–X-rays spectral analysis, assuming the Q2 extinction model [12] and a simple power law continuum spectral model. The solid line is the expected N_H/A_V relationship for the Q2 extinction model [12].

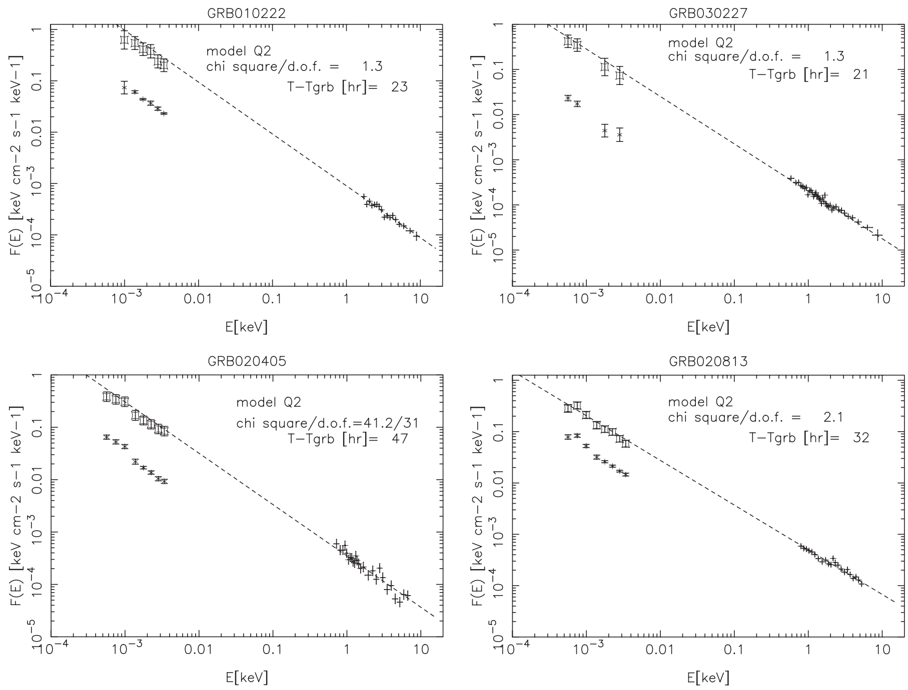

Fig. 2. – The NIR–to–X-rays unabsorbed (open squares and cross points) afterglow spectra. In this plot the optical SEDs corrected for the Galactic extinction (stars) have been further corrected for the host galaxy extinction assuming the extinction curve derived for a dust grain size distribution skewed towards large grains (Q2; fig. 1 [12, 21]). For GRB 030227, we fixed the unknown redshift value at $z = 1.6$ [22].

2. – The Analysis

We have analyzed the afterglows of GRB 030227 (*e.g.*, [4, 22, 15]), GRB 020813 (*e.g.*, [5, 3]), GRB 020405 (*e.g.,* [14, 1, 16]) and GRB 010222 (*e.g.,* [11, 13, 2]). We fitted the NIR–to–X-rays spectra with a power law or with a broken power law model according to the fireball model predictions (*e.g.,* [19]), since for none of these bursts it has been possible to firmly exclude the presence of a spectral break between the NIR band and the X-rays, except for GRB 020405. We took into account the host galaxy extinction effects on the NIR-optical SEDs by testing several possible extinction curves (fig. 1; [21]).

3. – Results and future perspectives

We have analyzed a sample of four bright X-rays afterglows of GRBs for which the optical SEDs, not corrected for extra-galactic dust extinction, have spectral index consistent with the X-rays spectral index, but with fluxes significantly below the X-rays extrapolation assuming a simple power law spectral model. A simple power law model is suggested by the spectral and temporal indices of these afterglows as already noted in previous works (*e.g.,* [4, 5, 14, 1, 11]), although a spectral break between the X-rays and the optical band cannot be excluded (*e.g.,* [13]) except for GRB 020405 (*e.g.,* [1]). We found that an extinction curve weakly dependent on the wavelenght makes the optical SED consistent with the X-rays flux extrapolation (fig. 2). An extinction law weakly dependent on the wavelenght can be provided by dust grains destruction due to the intense X-rays and UV fluxes from the burst itself (*e.g.,* [23,8]), a mechanism expected to be particularly efficient on small grains [17,18]. Another mechanism can be small dust grains coagulation into larger ones (*e.g.,* [6]), a scenario already invoked for other extragalactic dense environments as for a sample of Active Galactic Nuclei [12,7]. Assuming a simple power law and the extinction curve computed from numerical simulations of dust coagulation mechanisms (Q2 model, [12,21]), the measured A_V values are nicely in agreement with the expected A_V/N_H relationship (fig. 1), providing a self-consistent scenario. Similar results can in principle be obtained from the extinction curve computed from numerical simulations of dust destruction mechanisms [17] due to their very similar wavelength dependence (fig. 1). We stress that these results are model dependent and a spectral break between the X-rays and the optical energies cannot be excluded for these afterglows, except for GRB 020405 (*e.g.,* [1]). Indeed, assuming a broken power law a more standard extinction curve can reconcile the NIR–to–X-rays spectrum. The large sample of multi-band monitored afterglows expected in the Swift era will enable us to better constrain the underlying spectral model and to monitor a possible evolution in time of the extinction properties, invariably due to dust destruction mechanisms.

REFERENCES

[1] Berger E., Soderberg A. M., Frail D. A. and Kulkarni S. R., *ApJ*, **587** (2003) 5.
[2] Björnsson G., Hjorth J., Pedersen K. and Fynbo J. U., *ApJ*, **579** (2002) 62.
[3] Butler N. *et al.*, *ApJ*, **597** (2003) 1010.
[4] Castro-Tirado A. J. *et al.*, *A&AL*, **411** (2003) L315.
[5] Covino S. *et al.*, *A&AL*, **404** (2003) L5.
[6] Draine B. T., in *Protostars and Planets II*, edited by Black D. C. and Matthews M. S. (A86-12626 03-90) (The University of Arizona Press) 1985, pp. 621-640.
[7] Elvis F., Fiore F., Giommi P. and Padovani P., *ApJ*, **492** (1998) 91.
[8] Fruchter A., Krolik J. H. and Rhoads J. E., *ApJ*, **563** (2001) 597.
[9] Galama T. J. and Wijers A. M. J., *ApJL*, **549** (2001) L209.
[10] Hjorth J. *et al.*, *Nature*, **423** (2003) 847.
[11] in't Zand J. J. M. *et al.*, *ApJ*, **559** (2001) 710.
[12] Maiolino R., Marconi A. and Oliva E., *A&A*, **365** (2001) 28.
[13] Masetti N. *et al.*, *A&A*, **374** (2001) 382.
[14] Masetti N. *et al.*, *A&A*, **404** (2003) 465.
[15] Mereghetti S. *et al.*, *ApJ*, **590** (2003) 73.
[16] Mirabal N. *et al.*, *ApJ*, **587** (2003) 128.
[17] Perna R., Lazzati D. and Fiore F., *ApJ*, **585** (2002) 775.
[18] Perna R. and Lazzati D., *ApJ*, **580** (2002) 261.
[19] Sari R., Narayan P. and Piran T., *ApJ*, **497** (1998) L17.
[20] Šimon V., Hudec R., Pizzichini G. and Masetti N., *A&A*, **377** (2001) 450.
[21] Stratta G. *et al.*, *ApJ*, **608** (2004) 846.
[22] Watson D. *et al.*, *ApJ*, **595** (2003) L29.
[23] Waxman E. and Draine B. T., *ApJ*, **537** (2000) 796.