The short/hard GRB020531 and the X-Ray Flash
XRF010213: are they in the same spectral parameters?

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Abstract. A short (T_50 350 ms, 80-300 keV) and hard (photon index
of \sim 1) GRB020531 was detected by the HETE – 2 French Gamma
Telescope (FREGATE) and the Wide-field X-ray Monitor (WXM) in-
struments. Spectral softening is seen in this burst and this property is
similar to that of long GRBs.

XRF010213 is the brightest X-ray flash (XRF) event detected by
HETE – 2. There are two peaks in the WXM 2-18 keV light curve and
the peak flux of the first and the second peaks are \sim 0.7 Crab and \sim 2.4
Crab respectively. The peak flux in the FREGATE 6-10 keV is \sim 2 Crab.
E_p of this burst is \sim 3 keV.

According to this detailed spectral study, these two extremely dif-
ferent GRBs show the similar spectral parameters as that of the long
bursts. This conclusion suggests that both Short/Hard and XRF are
closely related to the long bursts.

1. Short/Hard GRB020531

The HETE-2 FREGATE and WXM detected a short (~ 300 ms in the 30-400
keV energy band and hard GRB at 00:26:18.7 UT on 31 May 2002 (Ricket et al.
2002). Since the Ulysses and the Mars Odyssey also observed this event (Hurley
et al. 2002), we had a well restricted position of this source. The center position
of the source by the IPN was (R.A, Dec.) = (15^h15^m8.25^s, –19°24’16.2") with
a 3 \sigma error area of \sim 22 square arcminutes. Although the optical transient, X-
ray afterglow, and host galaxy of GRB020531 are reported on the GCN Notice,
there is no confirmed afterglow observation.

In Figure 1, the light curves of the FREGATE are shown in five energy
bands. The short peak is seen in 300-500 keV band. On the other hand, the
double peaks are seen in the WXM light curve (Figure 1 right).
1.1. WXM spectral analysis

The results of the WXM spectral analysis for four time intervals are summarized in Figure 1 (right). We selected two regions from the first and the second peaks. The spectral model is a power-law and the time interval of each regions is $\sim 0.5$ s.

The spectral softening is seen from the beginning to the end of the burst. This spectral property is similar to that of the long GRBs (Lamb et al. 2002).

1.2. WXM and FREGATE joint spectral analysis

The WXM and FREGATE joint spectral fitting is conducted using the first peak region. The Band function agrees well for the spectral model with the following parameters: low energy power-law index $\alpha = -0.94\pm0.23$, high energy power-law index $\beta = -1.67\pm0.29$, break energy $E_0 = 216.5^{+467.5}_{-115.5}$ keV. The fluences of 2-25 keV and 30-400 keV in this spectral parameters are $9.2\times10^{-8}$ erg cm$^{-2}$ and $9.9\times10^{-7}$ erg cm$^{-2}$ respectively.

2. X-ray Flash XRF010213

The bright X-ray flash is detected by HETE-2 on 13 February 2001 at 12:35:35 UT (Ricker et al. 2001). Since the HETE-2 was in the PV phase at that period, the localization was done by the ground analysis. The celestial coordinate of this source is (R.A., Dec.) = $(10^h31^m36^s, 5^\circ30'30")$ with a 95% error radius of $30'$. Although the optical and the radio transient were searched for this region, no afterglow was found for XRF010213.

As we can see in Figure 3, two peaks are seen in the WXM light curves. The first peak is visible for all four WXM energy bands. On the other hand, the second peak is only seen in below 10 keV.
2.1. WXM spectral analysis

We conducted the time resolved spectral analysis for the WXM data. The spectral parameters in the power-law model with exponential cutoff are summarized in Table 1. Since it is difficult to constrain the photon index, we fix this value to 1. The cutoff energy seems to be shifted to the low energy region in the late phase.

Table 1. The WXM spectral parameters of XRF010213 in the power-law model with exponential cutoff. The errors are shown in 90% confidence regions.

<table>
<thead>
<tr>
<th></th>
<th>1st region</th>
<th>2nd region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration [sec.]</td>
<td>14.7</td>
<td>39.3</td>
</tr>
<tr>
<td>Photon index $\alpha$</td>
<td>1.0 (fixed)</td>
<td>1.0 (fixed)</td>
</tr>
<tr>
<td>$E_{\text{cutoff}}$ [keV]</td>
<td>$12.6^{+19.4}_{-5.6}$</td>
<td>$2.8^{+0.3}_{-0.3}$</td>
</tr>
<tr>
<td>normalization @ 1keV [ph cm$^{-2}$ s$^{-1}$ keV$^{-1}$]</td>
<td>$0.62^{+0.30}_{-0.21}$</td>
<td>$6.84^{+1.15}_{-0.96}$</td>
</tr>
<tr>
<td>$\chi^2$/d.o.f.</td>
<td>0.87/13</td>
<td>1.60/13</td>
</tr>
<tr>
<td>2-25 keV fluence [10$^{-7}$ erg cm$^{-2}$]</td>
<td>1.32</td>
<td>5.98</td>
</tr>
</tbody>
</table>

2.2. WXM and FREGATE joint spectral analysis

The time integrated spectral analysis is performed using both WXM and FREGATE data. We use the Band function with fixing the low energy power-law index to -1 for fitting the spectra. The Band function shows a acceptable fitting in the spectral parameters as follows: the low energy power-law index $\alpha = -1.0$ (fixed), the high energy power-law index $\beta = -3.0^{+0.3}_{-0.5}$ and the break energy $E_0 = 3.4 \pm 0.4$ keV. The fluence of 2-25 keV and 30-400 keV in this spectral model are $7.3 \times 10^{-7}$ erg cm$^{-2}$ and $5.8 \times 10^{-8}$ erg cm$^{-2}$ respectively.
3. Summary

GRB020531 is the short/hard GRB well localized by HETE/WXM and IPN. The double peaks are observed in the X-ray range. The spectral softening is seen in the emission of the second peak and this characteristics is very similar to the long GRBs. The peak energy could be higher than the FREGATE highest energy channel (∼ 400 keV).

XRF010213 is the bright X-ray flashes in the fluence of 7.3 ×10⁻⁷ erg cm⁻² at 2-25 keV. The time resolved spectral analysis of WXM shows that the break energy seems to be shifted to the low energy region at the second time interval. The peak energy is around 3 keV according to the time integrated joint spectral analysis of WXM and FREGATE.

These two differently categorized GRBs, short/hard burst and XRF, show similar spectral parameters as that of the long bursts. This observed property suggests that short/hard bursts and XRF are closely related to the long bursts and possibly all in a same origin.

References

Ricker G. et al. 2002, GCN Circ. 1399
Hurley K. et al. 2002, GCN Circ. 1402
Ricker G. et al. 2001, GCN Circ. 934