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HETE-2 localization and observation of the gamma-ray burst GRB 020813(*)

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Summary. — A bright, long gamma-ray burst (GRB) was detected and localized by the instruments on board the High Energy Transient Explorer 2 satellite (*HETE*-2) at 02:44:19.17 UTC (9859.17 s UT) on 2002 August 13. The location was to the GRB Coordinates Network (GCN) about 4 minutes after the burst allowing, early observations of a counterpart in the optical. In the prompt emission, the burst had a duration of approximately 125 s, and more than four peaks. We analyzed the time-resolved energy spectrum of the prompt emission of GRB020813 using the Wide Field X-ray Monitor (WXM) and the French Gamma Telescope (FREGATE) in 2–400 keV in detail. We find that the former part of the burst shows extremely hard X-ray spectrum.

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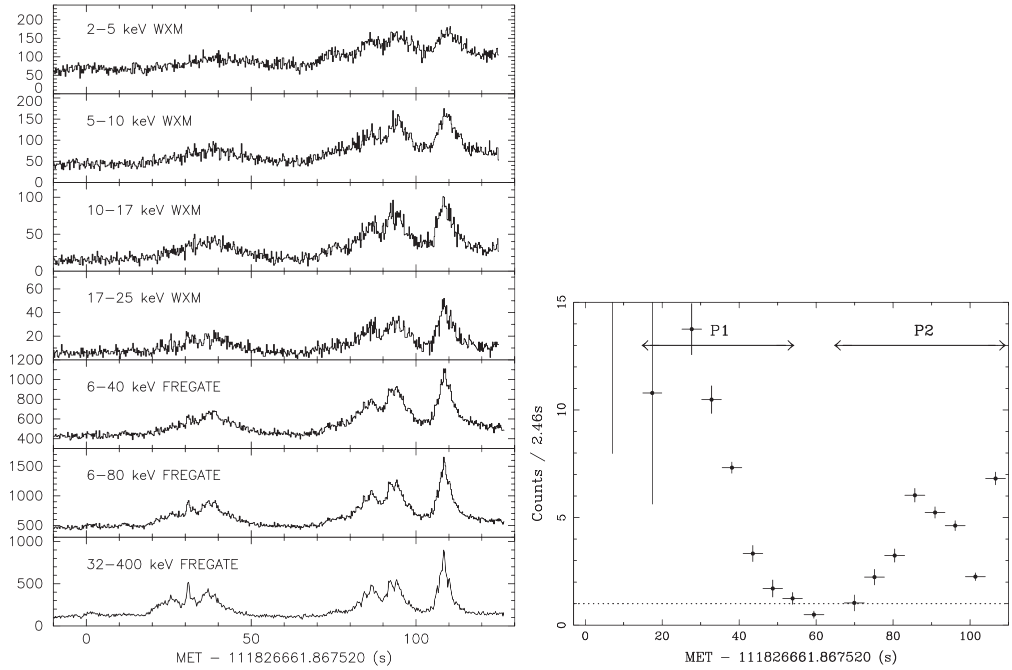

Fig. 1. – Left: The energy resolved light curves of GRB 020813. Right: Hardness ratio of the fluxes $S_\gamma(30\text{–}400\,\mathrm{keV})/S_\mathrm{x}(2\text{–}30\,\mathrm{keV})$. Dotted line shows ratio is 1.0.

1. – Observation

GRB 020813 triggered the FREGATE instrument on board HETE-2 [1] on August 13, 2002 at 02:44:19.17 UTC (9859.17 s UT). The trigger occurred in the 30–400 keV band, on the 1.3 s time scale. The WXM flight software localized the burst correctly and its position were R.A. = $19^h46^m31^s$, Dec. = $-19°36'27''$ (J2000.0) with the 90% error radius of 28° which includes statistical and systematic errors. The flight location was reported in a GRB Coordinate Network (GCN) Position Notice at 10:50:48 UT, 4 minutes 14 s after the burst.

2. – Light curve

Figure 1 (left) shows the complex light curve of GRB 020813 in four WXM energy bands (2–5, 5–10, 10–17 and 17–25 keV) and three FREGATE energy bands (6–40, 6–80 and 32–400 keV). There are more than three peaks in the WXM energy bands and more than four spiky peaks in the FREGATE energy bands. The photon counts of the peak is higher at later phases. Comparison of the burst light curve in the WXM and the FREGATE energy bands shows that the forth peak is much harder than others. The duration in the WXM and the FREGATE energy bands is longer than 80 seconds. Moreover, the variability pattern seems to be more complex at higher energies. We can see a number of "shots" in the 32–400 keV light curve, whose time scale is as fast as 5 s.

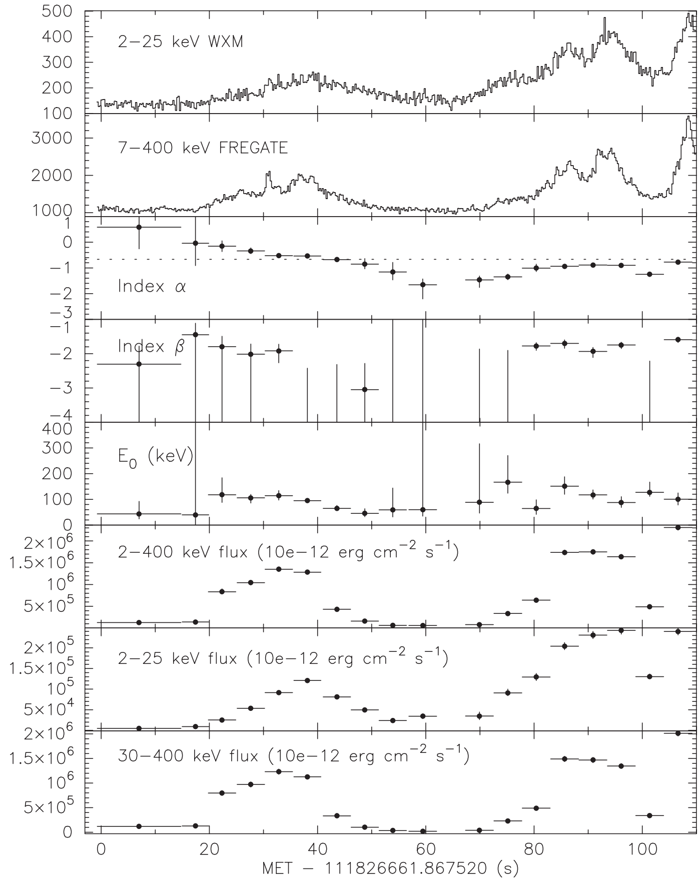

Fig. 2. – Summary of spectral analysis with the Band function shown with the light curve in two energy bands.

3. – Spectrum

Considering the fast time variability, we analyzed the spectrum every 5 s interval, which is also limited by the time resolution of the FREGATE spectral data.

Figure 1 (right) shows the hardness ratio of the fluxes S_γ(30–400 keV) to the S_γ(2–30 keV). One can see that GRB 020813 possibly consists of two distinct bursts which may have different physical origins. A border of the first and the second bursts is approximately given by $t \sim 60$ s. Note that this corresponds to an epoch when the first gradual burst decayed to the initial (background) level, and succeeding flares started to appear in the light curve (fig. 1, left).

We therefore denote the former part as "P1" and the latter part of the flare as "P2", just for convenience. Time intervals for the P1 and P2 corresponds to 17–52 s and 67–109 s from the burst trigger time, respectively. Note that the peak of P1 shows larger values of S_γ(30–400 keV)/S_γ(2–30 keV) than that of P2, meaning that energy spectra in the peak of P1 is harder than that of the P2 peak.

Figure 2 summarizes the time evolution of spectral parameters of the Band function [2] together with the WXM and the FREGATE light curves measured in 2–25 keV and 7–400 keV, respectively (the first and the second panels). Time variations of low and high-energy photon indices, α and β, are plotted in the third and fourth panels. The spectral cutoff energy E_0 are given in the fifth panel, and fluxes measured in 2–400, 2–25 and 30–400 keV energy bands are plotted in the remaining panels.

4. – Discussion

As is shown in fig. 2, the low-energy power law indices α in the P1 the region, range from -1.16 to -0.0, some of which exceed the "death line" ($\alpha = -0.67$). If the GRB emission is produced in an optically thin plasma via the synchrotron process, resultant X-ray spectrum cannot have a photon spectral index of $\alpha > -0.67$ (*e.g.*, [6]). However, it has already been reported that a number of GRBs detected with BATSE exceeded this critical "death line" [4]. Many authors have suggested different ideas to explain such hard–X-ray spectra (*e.g.*, [3]), but the discussion of low energy spectra was difficult due to relatively low sensitivity of BATSE especially below 30 keV. Since the detectors onboard *HETE*-2 have good sensitivity over the wide energy range (2 to 400 keV), GRB 020813 would be the first case of confirming such an extremely hard GRB spectrum with high reliability.

Averaged P2 spectrum is well described by the Band function of the form with $\alpha \sim -1.00$ and $\beta \sim -1.76$. In contrast to P1, α falls in the range allowed by standard Synchrotron Shock Model (SSM). As was compiled by Sakamoto (2004) [5], the BATSE and the *HETE*-2 data revealed that the "typical" GRB spectrum is well represented by a broken power law (Band function) with $\alpha \sim -1$ and $\beta \sim -2.5$. It implies that the observed break energy corresponds to the peak energy ($\nu \sim \nu_{\rm m}$) in νF_ν space, where the most of the GRB power is emitted. For the case of P2 in GRB 020813, however, the spectrum is still *rising* up to > 400 keV. In the standard picture of SSM, such a break could be explained only when $\nu_{\rm m}$ is well above the total *HETE* band pass.

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