GRB 051103 and GRB 070201 as Giant Flares from SGRs in Nearby Galaxies

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Abstract. The Konus-Wind observations of extremely bright short hard GRB 051103 and GRB 070201 are presented. Results of gamma-ray data temporal and spectral analysis together with IPN sources localization are bringing evidences of the bursts being initial pulses of Giant Flares from Soft Gamma-ray Repeaters in the nearby galaxies M81/M82 and M31.

Keywords: gamma-ray bursts, soft gamma-ray repeaters, M31, M81/M82 group
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INTRODUCTION

Observations of giant flares (GFs) from SGR 1900+14 on August 27, 1998, and from SGR 1806-20 on December 27, 2004 renewed discussions of an old suggestion that some of short/hard gamma-ray bursts may represent initial pulses of GFs from considerably more remote SGRs [11, 12]. The energy of the initial pulse of the giant flare from SGR 1806-20 was found of $\sim 2 \times 10^{46}$ erg, making it possible to estimate the maximum distance at which flares of this kind can still be revealed as short bursts to be 30–50 Mpc [14, 6, 20, 25, 16]. Such estimates give reason to believe that giant flares can be detected not only in galaxies of the Local group, but also in nearby galaxies and clusters of galaxies, such as, e.g., clusters in Virgo, Ursa Major, Leo. Several attempts of archival search in BATSE catalog [8, 23] and among IPN localized GRBs [17, 18] were performed based on some of commonly accepted observational GF criteria (i.e. short duration, single pulse event with hard energy spectrum and proximity of GRB localization box to a starforming galaxy). Unfortunately no clear remote GF candidates were found and the upper limit of GF fraction among short/hard GRBs was established on the level from few to as much as forty percent.

On November 3, 2005 and February 1, 2007 Konus-Wind GRB spectrometer detected two exceptionally bright short/hard bursts. Results of gamma-ray data temporal and spectral analysis together with IPN sources localization are bringing evidences of the bursts are being initial pulses of Giant Flares from SGRs in the nearby galaxies M81/M82 and M31.

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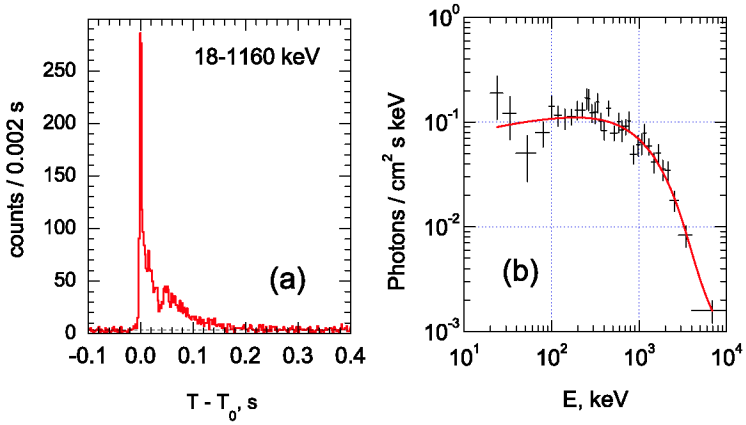

FIGURE 1. Konus-Wind light curve (a) and deconvolved photon spectrum (b) of GRB 051103

OBSERVATIONS

GRB 051103

GRB 051103 was detected by Konus-Wind at 09:25:43UT [4]. It was a single-pulsed event (Fig. 1a) with steep ($\sim$ 4 ms) front edge, quasi-exponential decay ($\tau \sim 55$ ms) and total duration of $\sim$ 170 ms. The burst had been the brightest GRB observed by the Konus-Wind in 11 years, its peak count rate on the 2 ms scale in 18–1160 keV energy range reached $\sim 1.5 \times 10^5 s^{-1}$ level. The variations of the hardness with time indicate that the spectrum shows a clearly pronounced evolution and rapidly becomes softer.

Three multichannel spectra were measured with an accumulation time of 64 ms for each spectrum. Spectrum 1 (Fig. 1b) covers the most intense and hardest part of the burst. Emission is seen up to 10 MeV. The spectrum is well fitted by the Band GRB model with the following parameter values: $\alpha = 0.16^{+0.19}_{-0.15}$, $E_0 = 1050^{+270}_{-200}$, and $\beta = 2.9^{+0.5}_{-1.7}$. It should be noted that, in contrast to the most of short/hard bursts, the spectrum have $\alpha > 0$. The peak energy of the νF_ν spectrum, $E_p = 2300^{+350}_{-150}$ keV. The sum spectrum (2+3) characterizes the final stage of the burst. Emission is observed up to $E \sim 2$ MeV. The spectrum is well described by a power-law model with an exponential cutoff with $\alpha = 0.43^{+0.34}_{-0.40}$, $E_0 = 220^{+70}_{-50}$ keV. The corresponding peak energy is $E_p = 530 \pm 80$ keV. The total fluence of the whole burst is $S = (4.4 \pm 0.5) \times 10^{-5}$ erg cm^{-2} and the 2-ms peak flux, $F_{max} = (2.8 \pm 0.3) \times 10^{-3}$ erg cm^{-2} s^{-1}. The detailed report of Konus-Wind observations one can find in [2].

The GRB 051103 was also observed by the spacecraft HETE-2 (FREGATE), Mars Odyssey (GRS and HEND), Swift (BAT, outside the field of view), and RHESSI (PCA). The center of the resulting IPN 120 sq. arcmin error box [4] has coordinates $\alpha = 9^h52^m32^s$, $\delta = 68^o$ 50' 42" (J2000). The localization area lies close to the M81 galaxy but does not overlap with its optical image. The box center is 21 arcmin away from the center of M81. The values of the fluence and peak flux correspond to an isotropic energy

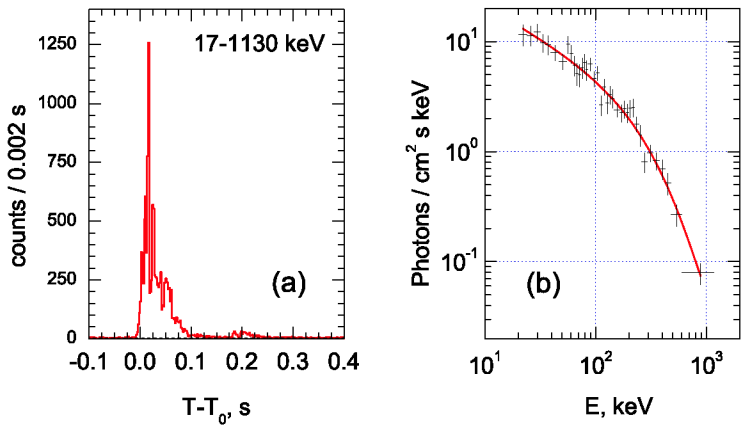

FIGURE 2. Konus-Wind light curve (a) and deconvolved photon spectrum (b) of GRB 070201

output of $Q = 7 \times 10^{46}$ erg, and an isotropic peak luminosity $L = 4 \times 10^{48}$ erg s^{-1} if the source of GRB 051103 is situated in M81/M82 group at $D = 3.6$ Mpc.

GRB 070201

15 months later even more intensive short/hard GRB triggered Konus-Wind on February 1, 2007 at 15:23:10.785 UT [5]. Its light curve in 17–1130 keV energy range (Fig. 2a) displays a narrow pulse with a rather steep leading edge ($\sim$20 ms) followed by more prolonged decay to T-T$_0 \approx 180$ ms. The maximum count rate occurs in a ≤ 2 ms long interval. The burst profile is not smooth: in most cases, the variations in the count rate are evident at the top of the pulse and in its decay phase are statistically significant. A weak secondary flash is observed at T-T$_0 \approx 180$–280 ms.

Four multichannel spectra were measured in the course of the burst, each with an accumulation time of 64 ms. They cover the energy range from 17 keV to 14 MeV, but no statistically significant emission is seen above 2 MeV. The spectra are well described by a power-law model with an exponential cutoff. Spectrum 1 (Fig. 1b) has parameters $\alpha = -0.52^{+0.13}_{-0.15}$, $E_p = 360^{+40}_{-38}$ keV which describe the main pulse emission. Spectrum 3+4 which covers the weak secondary wave is considerably softer ($\alpha = -1.06^{+0.42}_{-0.52}$, $E_p = 123^{+54}_{-25}$ keV). The total burst fluence in the 20 keV–1.2 MeV range is $Q = 2.00^{+0.10}_{-0.26} \times 10^{-5}$ erg cm^{-2}. The 2-ms peak flux measured from T$_0$+0.016 s in the same energy band is $F_{max} = 1.61^{+0.29}_{-0.50} \times 10^{-3}$ erg cm^{-2} s^{-1}. For further details of Konus-Wind observations see [15].

GRB 070201 was detected by Konus-Wind with a time resolution of up to 2 ms, by INTEGRAL (SPI-ACS) with a resolution of 50 ms, by MESSENGER [3] with a resolution of 1 s, and by the Swift BAT with 1 s resolution outside the coded field of view (J. Cummings, pvt. comm., 2007). It was noted [21] that Wind-INTEGRAL annulus [5] passes through M31 spiral arms. The initial triangulation was given in [7] and the center

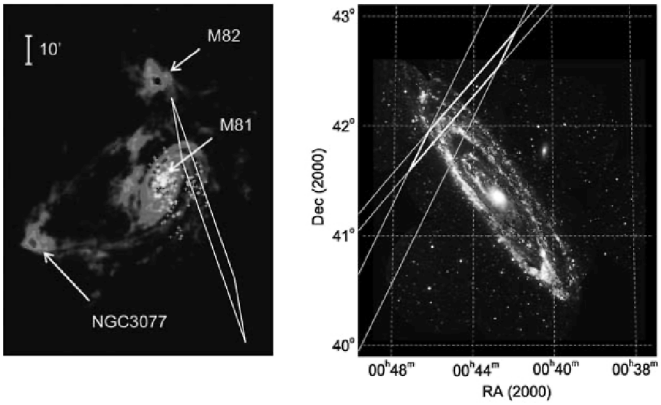

FIGURE 3. IPN localization box for GRB 051103 overlayed with VLA 21-cm map of M81/M82 group (a) and for GRB 070201 overlayed with GALEX M31 UV image(b)

of the refined 446 arcmin^2 3σ error box [15] lies $\sim 1^o$ away from the center of M31 (Fig. 3b). Assuming that the source of GRB 070201 is in M31 at a distance of 0.78 Mpc, the measured values of the fluence and peak flux correspond to an isotropic energy output $Q = 1.5 \times 10^{45}$ erg, and an isotropic peak luminosity $L = 1.2 \times 10^{47}$ erg s^{-1}.

DISCUSSION

The observed properties of GRB 051103 and GRB 070201 light curves and energy spectra make them real candidates to the giant flares in extragalactic SGRs. Proximity of the IPN localization boxes to the large spiral galaxies strongly supports this hypothesis. Lipunov [9] reported that the localization region of GRB 051103 definitely lies outside the spiral arms of the M81 galaxy, but noted that the structure of the galaxy is appreciably distorted by the tidal interaction. Figure 3a shows the 21-cm map[1] of the M81/M82/NGC 3077 group, on which the IPN box of GRB 051103 is overlayed and the positions of the X-ray sources discovered in the M81 galaxy and its vicinity [24] are marked. The figure clearly demonstrates that the IPN box envelops the region that contains a considerable fraction of the intergalactic HI and intergalactic stellar population of M81.

The Andromeda galaxy, M31, as the closest massive galaxy, has long been regarded [13] as one of the most likely candidates for searching for observable GFs from distant extragalactic SGRs. Figure 3b shows the UV image of M31 [26]. The IPN error box overlaps both the $R \approx 10$ kpc ring and of the weaker $R \approx 14$ kpc outer ring - the main starforming regions of the galaxy. 22 sources from an *XMM-Newton* X-ray survey of M31 [22] fall within the error box. SGRs in the quiescent state are typically sources

[1] See Yun, http://www.astro.umass.edu/~myun/m81hi.html

of pulsating soft X-rays with an average (0.5–10) keV luminosity of 10^{35}–10^{36} erg s^{-1} and a spectrum which can be described as a combination of a blackbody and power law. Spectral studies of the unidentified soft X-ray sources in the error box which could be SGRs in M31 would clearly be important.

If GRB 051103 is not related to the flare in SGR, it would be probably expected that an optical transient (OT) should appear in the IPN box. A search for optical and radio transients has been performed [9, 10, 19], but yielded only the upper limit to its brightness. Recently support for the SGR GF hypothesis of GRB 070201 came with results [1] from LIGO Gravitational Wave Observatory that put very strong limitation on the burst origin from the compact objects merger at $D < 3.5$ Mpc.

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