KONUS-WIND OBSERVATION OF THE ULTRA-LUMINOUS GRB 110918A

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Abstract. The exceptionally intense long GRB 110918A was discovered by several GRB observing missions: *INTEGRAL* (SPI-ACS), *Konus-WIND*, *Mars Odyssey* (HEND), and *MESSENGER* (GRNS) on September 18, 2011. This GRB was localized by the Interplanetary Network (IPN) and its bright X-ray counterpart was found in close vicinity of the IPN box in the *Swift*/XRT follow-up observations starting 1.2 days after the trigger. The optical afterglow was discovered by the Isaac Newton Telescope and its spectroscopic redshift $z = 0.982$ was measured with the GMOS spectrograph mounted on the Gemini-N telescope. GRB 110918A is the brightest burst detected by *Konus-WIND* for more than 17 years of its continuous observations. The instrument's light curves in three energy bands covering 22–1450 keV range show an extremely bright, short, hard pulse followed by three weaker, softer, partly overlapping pulses within next 25 seconds. A spectral lag between the light-curves is determined, showing a substantial increase in the course of the burst. The emission is detected up to 12 MeV. Modeling the time-integrated energy spectrum with the Band function yields a moderate value of $E_{peak} = 340$ keV, while the time-resolved spectral analysis reveals strong hardness-intensity correlation and a hard-to-soft evolution of the emission: E_{peak} falls from ~ 4 MeV at the onset of the huge initial pulse to ~ 50 keV at the final stage of the burst. The total 20 keV–10 MeV energy fluence amounts to $S = (7.8 \pm 0.4) \times 10^{-4}$ erg cm⁻² and a 64-ms peak flux $F_{max} = (9.2 \pm 0.4) \times 10^{-4}$ erg cm⁻² s⁻¹, which corresponds to a huge isotropic-equivalent energy release $E_{iso} = (2.1 \pm 0.1) \times 10^{54}$ erg and the record-breaking peak luminosity $L_{iso;max} = (4.7 \pm 0.2) \times 10^{54}$ erg s⁻¹.

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Fig. 1. *Left:* the light curves of GRB 110918A recorded by Konus-*WIND* in three energy bands (three upper panels) and their hardness ratios evolution (two lower panels). *Right:* the temporal behavior of the Band spectral model parameters (E_{peak} , α , β) obtained from the time-resolved fits. The light curve in the 22–1450 keV band is given for the reference in the upper panel.

1 Introduction

The exceptionally intense long GRB 110918A was discovered by several GRB observing missions: *INTEGRAL* (SPI-ACS), Konus-*WIND*, *Mars Odyssey* (HEND), and *MESSENGER* (GRNS) on Sep. 18, 2011. This burst source was localized by the Interplanetary Network (Hurley *et al.* 2011) and its bright X-ray counterpart was found in close vicinity of the IPN box in the Swift/XRT follow-up observations starting 1.2 days after the trigger (Mangano *et al.* 2011). The optical afterglow was discovered by the Isaac Newton Telescope (Tanvir *et al.* 2011) and its spectroscopic redshift $z = 0.982$ was measured with the GMOS spectrograph mounted on the Gemini-N telescope (Levan *et al.* 2011). A preliminary analysis of the Konus-*WIND* observation revealed that GRB 110918A is the most intense gamma-ray burst among ~ 2200 GRBs observed by the instrument since November, 1994 (Golenetskii *et al.* 2011). The high energy flux also suggests enormous isotropic-equivalent rest-frame energy (Frederiks & Pal'shin 2011). These preliminary estimates place GRB 110918A among the brightest GRBs ever observed in the era of cosmological GRBs and this burst deserves, without a doubt, a detailed consideration.

2 Time histories

GRB 110918A triggered the Konus-*WIND* γ -ray spectrometer (Aptekar *et al.* 1995) at $T_0 = 77222.856$ s UT (21:27:02.856) on September 18, 2011. In the triggered mode, count rates are recorded in three energy bands: G1(22–90 keV),

G2(90–375 keV), and G3(375–1450 keV) with an accumulation time varying from 2 to 256 ms. The burst light curve in the three energy bands (Fig. 1, left) is clearly divided into two groups of pulses ($T_0 - T_0 + 12$ s) and ($T_0 + 12$ s – $T_0 + 28$ s), each, in turn, having two pronounced peaks. As shown in the same Figure, the temporal evolution of the G2/G1 and G3/G2 hardness ratios indicates an apparent hardness-intensity correlation of the emission against a general tendency of spectral softening in the course of the event. In the G2+G3 energy band (90–1450 keV), the duration T_{90} is 19.6 ± 0.1 s and $T_{50} = 14.3 \pm 0.1$ s. The peak 64-ms count rate reached is $(1.46 \pm 0.02) \times 10^5$ counts/s in the bin starting at $T_0 + 0.368$ s. We examined the spectral lag using the cross-correlation function between the 16-ms G1, G2, and G3 light curves at different phases of the burst. The statistically significant positive lags of 40–400 ms are derived for both the first ($T_0 - T_0 + 12$ s) and the second ($T_0 + 12 - T_0 + 25$ s) groups of pulses. However, for the second group of pulses the observed lags are 2–4 times longer than for the initial phase of the event.

3 Spectral analysis and energetics in gamma-rays

During the main phase of GRB 110918A, 35 energy spectra were recorded in 128 quasi-log channels of two overlapping energy bands PHA1 (20–1450 keV) and PHA2 (375 keV–14 MeV). Their accumulation time is varied from 0.064 s to 8.192 s, depending on the current intensity of the burst, the emission is seen up to 12 MeV. The spectral analysis was performed with XSPEC, version 12.5. A good quality of the fit with the Band GRB function is achieved for the majority of the spectra, which enabled us to construct the temporal behavior of the model parameters α , β , E_{peak} (Fig. 1, right). The time-resolved spectral analysis confirms strong hardness-intensity correlation and a hard-to-soft evolution of the emission: the low-energy photon index α evolution is strongly correlated with the burst intensity, and E_{peak} falls from ~ 4 MeV at the onset of the huge initial pulse to ~ 50 keV at the final stage of the burst.

The spectrum at the culmination of the initial pulse is described by $\alpha = -0.33 \pm 0.09$ (90% conf.), $\beta = -2.3 \pm 0.1$, and $E_{peak} = 1080 \pm 150$ keV ($\chi^2 = 0.67$, 68 dof). We analyzed the time-averaged spectrum of the whole burst and its separate phases. It should be emphasized that, having $E_{peak} = 340 \pm 60$ keV, $\alpha = -1.65 \pm 0.05$, and $\beta = -2.25 \pm 0.09$ ($\chi^2 = 0.96$, 81 dof) the overall time-integrated spectrum is, indeed, an “average” one and doesn’t reflect the strong spectral evolution. As it is expected from the time-resolved spectral analysis, the average spectra of the first ($T_0 - T_0 + 13.312$ s) and the second ($T_0 + 13.312 - T_0 + 28.416$ s) groups of pulses are strongly different. With only the low-energy photon index being close ($\alpha \sim -1.2$), the values of E_{peak} differ almost by an order of magnitude (630 keV and 80 keV, respectively), and the high-energy photon index β is sufficiently harder for the first group of pulses (-2.3 *vs.* -3.3 for the second group).

Based on the results of our spectral and temporal analyses, we calculated the observed energetics of GRB 110918A in gamma-rays. The 20 keV–10 MeV energy

fluence S measured from T_0 to $T_0 + 28.416$ s amounts to $(7.8 \pm 0.5) \times 10^{-4}$ erg cm $^{-2}$. In the same energy range, the 64-ms peak energy flux $F_{max} = (9.2 \pm 0.4) \times 10^{-4}$ erg cm $^{-2}$ s $^{-1}$ in the interval beginning at $T_0 + 0.384$ s, at the culmination of the huge initial pulse.

Assuming the redshift $z = 0.982$ (Levan *et al.* 2011) and a standard cosmology with $H_0 = 71$ km/s/Mpc, $\Omega_M = 0.27$, and $\Omega_\Lambda = 0.73$, we derive the following rest-frame parameters of the prompt gamma-ray emission: the isotropic-equivalent energy release $E_{iso} = (2.1 \pm 0.1) \times 10^{54}$ erg, the peak luminosity $L_{iso\ max} = (4.7 \pm 0.2) \times 10^{54}$ erg/s (both in the bolometric 1–10 000 keV energy range), and the intrinsic peak energy $E_{p,i} = 680 \pm 140$ keV. These estimations make GRB 110918A the most luminous gamma-ray burst ever observed in the cosmological era.

4 Summary

The detailed analysis of the ultra-luminous GRB 110918A observation by the Konus-*WIND* gamma-ray spectrometer reveals that the burst is the brightest among ~ 2200 GRBs recorded by the instrument since November, 1994. The record-breaking values of the peak count rate, peak energy flux, and the total energy fluence are obtained. Also, assuming the redshift $z = 0.982$, this burst is the most luminous GRB ever observed since the start of the era of cosmological GRB studies in 1997. The temporal behavior of the light curves hardness ratios, the obtained spectral lags, and the results of time-resolved spectral fits show an apparent hardness-intensity correlation of the observed emission and a general spectral softening in the course of the burst.

The detailed coverage of the Konus-*WIND* results on GRB 110918A as well as the refined IPN localization, the X-ray afterglow observations with *Swift*/XRT, and the optical monitoring with *Swift*/UVOT can be found in the forthcoming paper (Frederiks, Hurley *et al.*, in preparation).

This work was supported by a Russian Space Agency contract the Russian Foundation for Basic Research projects 11-02-12082-ofi-m-2011 and 12-02-00032-a, and the Ministry of Education and Science of Russian Federation contract #11.G34.31.0001 with SPbSPU and leading scientist G.G. Pavlov.

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