Mem. S.A.It. Vol. 90, 67

Memorie della

GRB observations with Konus-WIND experiment

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Abstract. We give a short review of gamma-ray burst (GRB) observations with the Konus-*Wind* (KW) experiment, which has been providing a continuous all-sky coverage in the 20 keV-15 MeV band during the period from 1994 to present. The recent results include a systematic study of GRBs with known redshifts and a search for ultra-long GRBs in the KW archival data. We also discuss the KW capabilities for multi-messenger astronomy.

Key words. Gamma rays : bursts – gamma rays : observations

1. Introduction

Cosmic Gamma-ray Bursts (GRBs) are the brightest sources of the high-energy electromagnetic radiation. The physical processes behind the huge luminosity of the GRB sources are of fundamental interest since they provide an opportunity to study physical phenomena in vicinities of stellar-mass black holes. The high luminosities of GRBs make them detectable out to the edge of the visible universe thus enabling to study the nature of the first stars and to probe the matter properties along the whole line of sight to the sources.

In this paper, we give a short review of the GRB studies with Konus-WIND experiment which has been a continuous all-sky coverage in the wide 20 keV-15 MeV band for almost 25 years, from November 1994 to present.

2. The KW experiment overview

2.1. The Instrument

Konus-*WIND* is a gamma-ray spectrometer aimed primarily at GRB and Soft Gamma Repeater (SGR) studies (Aptekar et al. 1995). It consists of two identical NaI(Tl) detectors, each with 2π field of view, mounted on opposite faces of the rotationally stabilized *WIND* spacecraft, both observing the whole sky. Each detector has an effective area of 80–160 cm^2 depending on the photon energy and incident angle. The energy range of gamma-ray measurements covers the interval from 20 keV up to 15 MeV.

The instrument has two operational modes: waiting and triggered. While in the waiting mode, the count rates are recorded in three energy bands covering ~20–1500 keV energy range with 2.944 s time resolution. In the triggered mode, the count rates in the three bands are recorded for ~230 s with

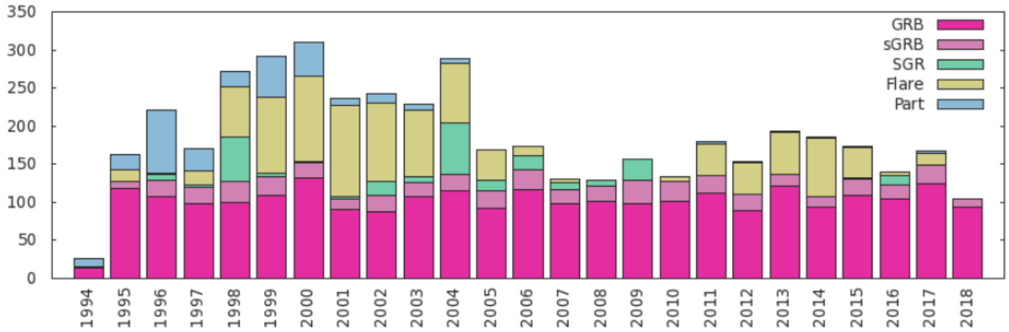

Fig. 1. Statistic of ~4700 KW triggers from November 1994 to the end of 2018.

time resolution varying from 2 ms up to 256 ms. Simultaneously, spectral measurements are carried out in the wide 20 keV–15 MeV band. For a more detailed description of KW see, e.g. Svinkin et al. (2016) and Tsvetkova et al. (2017).

2.2. KW observations in 1994-2019

Fig. 1 presents yearly statistics of KW triggers in 1994–2018. Among >4700 triggers to date[1] ~3100 are GRBs, including ~500 short GRBs; ~260 – bright SGR bursts, including two Giant SGR flares (Mazets et al. 1999; Frederiks et al. 2007a); and $\gtrsim$1000 are Solar flares[2]. Some notable KW GRB detections include the γ-ray coverage of the naked-eye GRB 080319B (Racusin et al. 2008), the detailed study of the ultra-luminous GRB 110918A (Frederiks et al. 2013), and the discovery of two extragalactic SGR candidates (Frederiks et al. 2007b; Mazets et al. 2008).

The fraction of short GRBs in the KW sample is ~15%; a detailed study of temporal and spectral properties of ~300 short KW GRBs is given in Svinkin et al. (2016). A recent analysis of duration and spectral-hardness distributions of ~3000 KW GRBs (Svinkin et al., JPCS submitted) suggests that about 14% of them can be Type I (merger-origin) and others are presumably Type II (collapsar-origin).

[1] `http://www.ioffe.ru/LEA/kw/triggers/index.html`

[2] `http://www.ioffe.ru/LEA/sun.html`

Since 2004 *WIND* has been in an orbit at the L1 libration point at a distance of ~5 lt-s. Far outside the Earth magnetosphere, KW has the advantages over Earth-orbiting GRB monitors of continuous coverage, uninterrupted by Earth occultation, and a steady background. This makes KW the key vertex of the interplanetary network (IPN) of γ-ray detectors, which presently comprises six spacecraft with orbits that range from near-Earth to Martian, and provides GRB coordinates via triangulation; the IPN localizations including KW data are regularly reported in Gamma-Ray Burst Coordinates Network (GCN) circulars[3] and were published in several catalogs (e.g. Pal'shin et al. 2013; Hurley et al. 2017) Recently, the sample of 2301 GRBs, detected by Konus-Wind in the triggered mode between 1994 and 2017 and localized by the IPN, was examined for evidence of gravitational lensing and no candidates for the gravitationally lensed GRBs were found at good confidence (Hurley et al. 2019).

The continuous KW waiting-mode data are well-suited to the search, both blind and targeted, for gamma-ray transients in response to particular events, such as GRB-less supernovae (e.g. Whitesides et al. 2017; Margutti et al. 2019), high-energy neutrino events, or gravitational-wave (GW) candidates (Aasi et al. 2014; Hurley et al. 2016). In the case of non-detection, KW is able of setting upper limits on soft γ-ray emission flux from these events

[3] `https://gcn.gsfc.nasa.gov/gcn/`

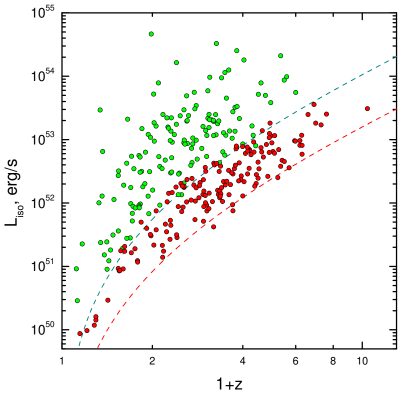

Fig. 2. KW GRBs with known redshifts in the $z-L_{\rm iso}$ plane. Green points show 150 triggered bursts (T17), red points – ∼170 waiting-mode events (preliminary). The dashed lines denote KW detection limits ($\sim10^{-6}$ and $\sim10^{-7}$erg cm^{-2} s^{-1}, respectively).

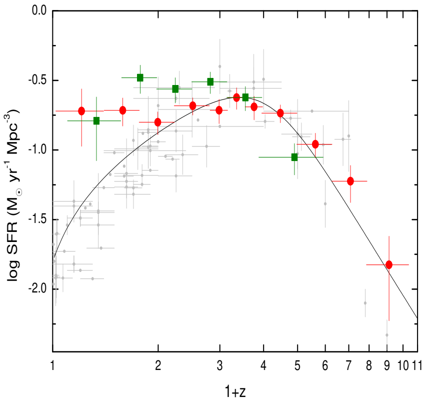

Fig. 3. Comparison of the GRBFR derived from the KW sample (colored points) and the SFR (grey points and line, see T17 for references); green points show the results from 150 triggered bursts (T17) and red points – from the full KW sample (preliminary).

at several 10^{-7}erg cm^{-2} s^{-1} (10 keV–10 MeV), thus allowing to constrain an energetics of possible accompanying GRB.

3. Recent results

3.1. GRBs with known redshifts

The first part of The Konus-*WIND* Catalog of Gamma-Ray Bursts with Known Redshifts (Tsvetkova et al. 2017, T17) presented the sample of 150 triggered GRBs (including 12 short), at $0.1 \leq z \leq 5$, the largest set of GRBs with known redshifts detected by a single instrument over a wide energy range. Along with the burst durations, spectral parameters, and bolometric rest-frame energetics, T17 reports the updated GRB rest-frame hardness-intensity correlations, GRB luminosity and energy-release functions and their evolutions, and the GRB formation rate (GRBFR).

The second part of the catalog, which is in preparation now, extends the T17 sample with ∼20 more triggered bursts and ∼170 weaker *Swift* GRBs, detected by KW in the waiting mode; the redshift range of the extended KW sample of > 320 GRBs is $0.04 \leq z \leq 9.4$. Fig. 2 presents the burst distribution in the $z-L_{\rm iso}$ plane, and Fig. 3 shows the KW-derived GRBFR, which features a notable excess over star-formation rate (SFR) at $z < 1$ and nearly traces the SFR at higher redshifts.

3.2. Search for ultra-long GRBs in the KW archival data

Ultra-long GRBs comprise a special class of events with durations of kisoseconds. About a dozen such events are known and their exact nature is still elusive. The continuous KW waiting-mode data provide an excellent opportunity to observe prompt emission of ultra-long GRBs for the whole duration (Fig. 4) and to constrain their spectra and fluences in the wide energy band (e.g. Pal'shin et al. 2008; Golenetskii et al. 2011; Virgili et al. 2013; Evans et al. 2014; Greiner et al. 2014).

An extensive search for hard X-ray and soft γ-ray transient events in the archive of KW waiting-mode observations (Kozlova et al., JPCS submitted) revealed ∼5300 confirmed GRBs and GRB candidates. A search for "very-long" (T_{90} > 250 s) GRBs in this sample (Svinkin et al., in preparation) has dis-

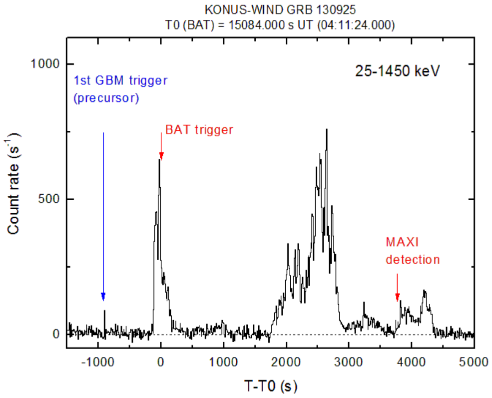

Fig. 4. Light curve of ultra-long GRB 130925A recorded by KW whole duration of the burst (black line).

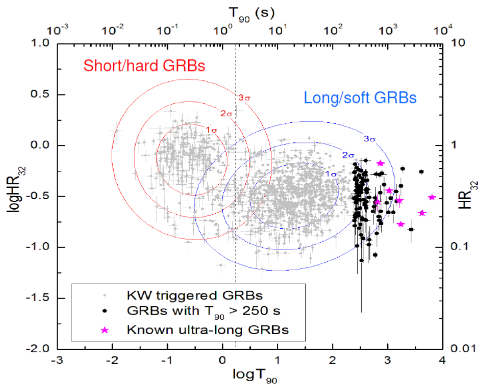

Fig. 5. ness-duration distribution of very- and ultra-long GRBs detected in the KW waiting mode (preliminary). The distribution of 1143 KW bright GRBs (grey points, Svinkin et al. 2016) is shown in the background.

covered 110 such events; 13 of them have full duration > 1000 s, including eight previously unknown ultra-long GRBs. A preliminary analysis of the sample suggests, that T_{50} and T_{90} distributions of very- and ultra-long GRBs smoothly extend that of ‘normal’ long/soft KW GRBs; the similar behavior is implied to the two-dimensional distributions in the hardness-duration planes (Fig. 5).

4. Conclusions

We gave the short review of GRB observations with the Konus-*Wind* experiment, which has been providing a continuous all-sky coverage in the 20 keV-15 MeV band for almost 25 years, from November 1994 to present. The KW GRB sample is the largest to date: it comprises of ~3100 triggered events, including ~500 short; and ~2200 more bursts detected in the waiting mode. The continuous KW waiting-mode data are well-suited to the search for γ-ray transients in response to GRB-less supernovae, high-energy neutrino events, or GW candidates. The recent progress obtained with the KW data includes the systematic study of 150 GRBs with known redshifts, the largest sample detected by a single instrument over a wide energy range; and the extensive search for very- and ultra-long GRBs in the KW archival data, which has revealed eight previously unknown ultra-long bursts and implied a smooth transition from ’normal’ to ultra-long GRB populations.

Acknowledgements. This work is supported by RSF grant 17-12-01378.

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