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Search for gamma-ray counterparts to FRBs in Konus-*Wind* data

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Abstract. We report preliminary results of the search in the Konus-*Wind* experiment data for hard X-ray/soft γ-ray emission in coincidence with publicly reported fast radio bursts (FRBs). We find no significant associations for any of the 581 FRBs in our sample and report upper limits to the high-energy fluence/peak flux for three spectral shapes, which generally describe short GRB, long GRB and magnetar giant flare spectra. In addition to study each individual FRB, we perform a stacking analysis of the bursts from each repeating source in our sample and a separate stacking analysis of the bursts from the non-repeating FRBs. We find no statistically significant excess of the cumulative emission over background level for either case.

Keywords: fast radio bursts, magnetars, gamma-rays

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Поиск гамма-излучения, сопровождающего быстрые радиовсплески по данным эксперимента Конус-Винд

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Аннотация. В данной работе представлены методика и предварительные результаты архивного поиска гамма-транзиентов вблизи опубликованных быстрых радиовсплесков (FRB) по многолетним данным эксперимента Конус-Винд, осуществляющего непрерывный мониторинг излучения всего неба в диапазоне энергий гамма квантов 20–1500 кэВ. Значимых отождествлений для 581 FRB обнаружено не было и, для каждого события приведены верхние пределы на флюенс/пиковый поток для трех спектральных моделей, описывающих короткие и длинные гамма-всплески и внегалактические магнетарные вспышки. Помимо результатов анализа индивидуальных кривых блеска, проведен анализ усредненных кривых для одиночных событий и отдельно по каждому повторному источнику.

Ключевые слова: быстрые радиовсплески, магнетары, гамма-излучение

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Introduction

Fast radio burst (FRBs) are bright (~Jy), short-duration (~ms) radio transients of still unknown origin. Since their discovery in 2007, and confirmation as an extragalactic population in 2013, over 600 FRBs, as of 2022 April 27, have been publicly reported (Transient Name Server TNS; http://www.wis-tns.org/). Repeating bursts have been observed from twenty-two FRB sources. Nineteen FRB sources have been localized to arcsecond accuracy and directly associated with a host galaxy, revealing a wide range of galaxy types and local environments surrounding the FRBs [1].

Until now, no clear physical picture of either the central engine that produce an FRB or the mechanism by which the emission is generated has emerged. A wide range of models have been proposed, none of which is able to explain alone the variety of observed events. The most promising models consider magnetars as potential FRB sources. In support of them, an FRB-like event of 2020 April 28 was, for the first time, associated with a known hard X-ray source: the Galactic magnetar SGR 1935+2154 [2,3]. The bright radio burst was accompanied by the simultaneous emission of hard X-rays [4–7], with properties similar to those of short, repeating bursts from Galactic magnetars, except for the peculiarly hard energy spectrum [5].

Like for gamma ray bursts (GRBs) and other classes of astrophysical objects initially detected in a single band, it becomes evident that any progress in our understanding of these enigmatic events could be made only through a coordinated observation campaigns and theoretical efforts in an as wide as possible energy band. The presence or absence of simultaneous or delayed emission corresponding to FRBs in different wavebands can constrain the emission mechanisms and is crucial to identify the FRB progenitor(s).

To date, there have been a number of multiwavelength counterpart searches for FRBs without any significant detection [8–15], however most of them were focused on certain objects or based on small FRB samples available at the time of these publications. In this work, we, taking the advantages of the huge increase in the number of detected FRBs and over 25 years of continuous full-sky observations performed by the Konus-Wind gamma-ray spectrometer (KW), carry out a systematic search for high-energy emission from repeating and non-repeating FRB bursts.

Here, we present preliminary results of the search in KW data for hard X-ray/soft γ-ray counterparts to over 700 publicly reported FRBs events. The paper is organized as follows. In Section 2 we present an FRB sample used in the search. In Section 3, we briefly describe our technique of the counterpart search and upper limit calculations for individual and stacked events and estimate the KW upper limits. In Section 4 we summarize the results and conclude.

FRB sample

For our analysis we selected all publicly reported FRBs from the TNS (799 events, accessed on 2022 April 27). Six events had to be discarded due to zero coordinates or times and 25 events due to data gaps in KW. In addition, we decided to preliminarily exclude 14 repeating sources, which have less than six bursts per source and have no accurate localization. So we ended up with the sample of 718 FRB events, including 573 non-repeating FRBs and 145 bursts from eight repeating sources: FRB 20121102A, FRB 20180814A, FRB 20180916B, FRB 20181030A, FRB 20190303A, FRB 20190711A, FRB 20200120E, FRB 20201124A. Fig. 1 shows dispersion measure distributions for the selected FRBs.

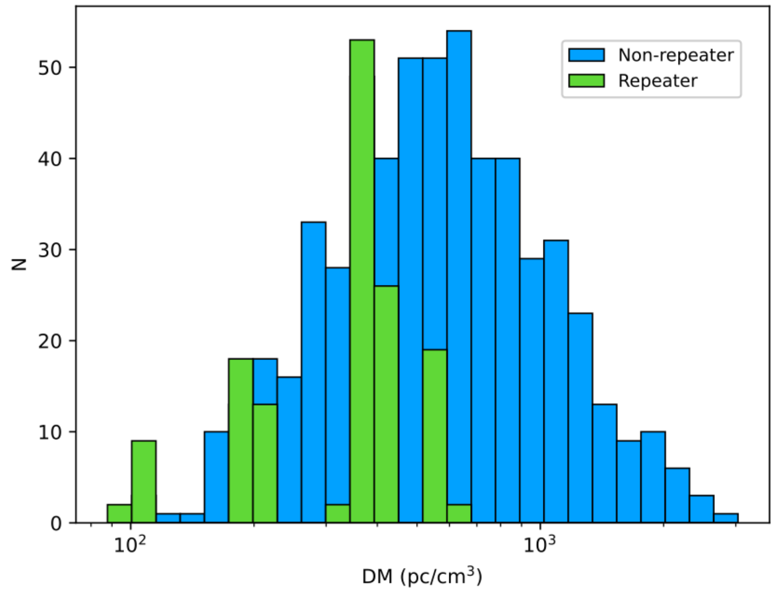

Fig. 1. Dispersion measure (DM) distributions for the selected sample of 581 FRBs: 573 "one-off" events and 145 bursts from 8 repeating sources. For 19 FRB sources associated with host galaxies, luminosity distances spans the range from 3.6 Mpc to 4 Gpc

Konus-Wind analysis

Konus-*Wind* [16], running successfully since 1994, is a scintillation gamma-ray spectrometer, which consists of two identical NaI (Tl) detectors. It was developed at the Ioffe Institute and mounted on board Wind spacecraft (NASA), which is currently in a Lissajous orbit at the L1 libration point of the Sun-Earth system. The experiment has a unique set of properties, which make it a powerful tool to study hard X-ray/soft gamma-ray transients: stable background, continuous coverage of the full sky, high temporal resolution, and the wide (20 keV–15 MeV) energy range of spectral measurements. The instrument has two operational modes: waiting (continuous) and triggered. The continuous waiting-mode data allow searches for sources that are too weak to trigger KW. In this mode, count rates are recorded in three energy windows G1 (20–80 keV), G2 (80–320 keV), and G3 (320–1300 keV) with 2.944 s time resolution.

To search for FRB counterparts, we first estimate the burst arrival times T_0 at the KW position for each FRB. We consider two time corrections: a frequency-dependent delay due to dispersion of the radio frequency with respect to soft γ-rays (infinite frequency) and a propagation delay between KW and the radio telescope site. The calculated time corrections range from ms to hundreds of seconds, with a mean (median) value of 9.2 (4.9) s. We then search for a significant (> 5σ) high-energy emission increase over the surrounding background level during the 400 s time interval centered on the T0. Since there were no KW triggers in the intervals of interest, the search is performed in the waiting-mode data using six energy channel combinations (G1, G2, G3, G1+G2, G2+G3, and G1+G2+G3) and temporal scales from 2.944 s to 100 s [17]. The background is estimated using two intervals, before (T_0 – 1000 s, T_0 – 250 s) and after (T_0 + 250 s, T_0 + 1000 s) the search interval.

For upper limit calculations we apply the standard KW technique [18] using three spectral templates, which generally describe short-GRB, long-GRB, and magnetar giant flares (MGF) spectra: the Band function and two exponentially cut off power laws (CPLs), with the parameters listed in Table 1.

For a possible short event lasting less than 2.944 s and having a typical short GRB or MGF spectrum we provide limit on the 20–1500 keV fluence. For a typical long GRB spectrum we derive a limiting peak flux (20–1500 keV, 2.944 s scale).

In addition to study each individual FRB source, we perform a stacking analysis of background-subtracted KW data on bursts from each repeating source in our sample and a separate stacking analysis of the bursts from the non-repeating FRBs. In either case, we find no statistically significant excess in the cumulative light curve.

Table 1

Three source spectrum models used in our upper limit calculations

Description	Model	Parameters		
		α	β	E_p (keV)
Typical long GRB [19]	Band	–1.0	–2.5	300
Typical short GRB [19]	CPL	–0.5	...	500
MGF [20]	CPL	–0.6	...	1190

Results and conclusions

For all individual FRBs in our sample, we detect no significant hard X-ray/soft γ-ray emission in 200 s long intervals preceding and following the FRB arrival time. We report upper limits on hard X-ray/soft γ-ray emission in Fig. 2.

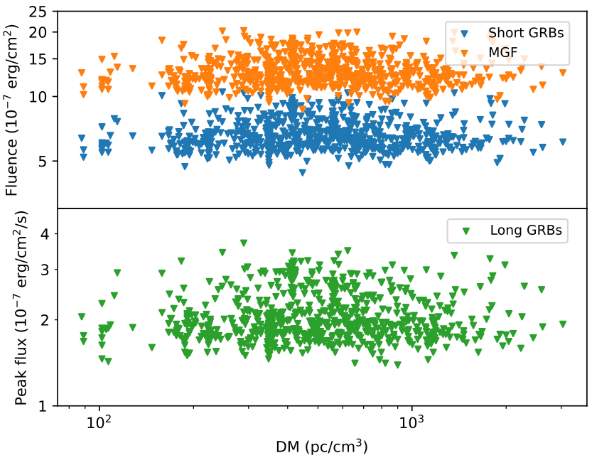

Fig. 2. KW upper limits on FRB high-energy emission (20-1500 keV) of 581 FRBs from our sample. Top panel: upper limits on short-GRB and MGF fluences. Bottom panel: upper limits on a long-GRB peak flux.

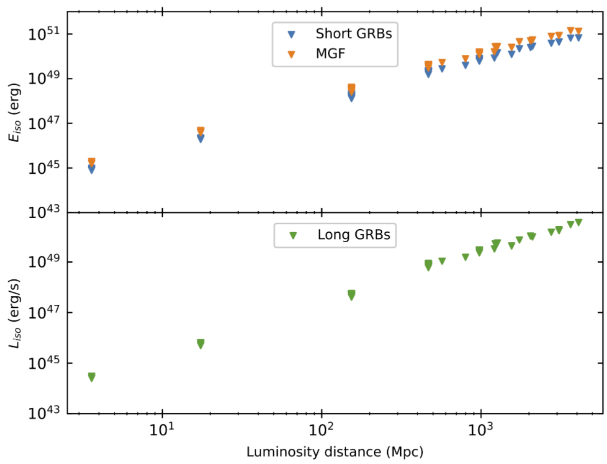

Fig. 3. Upper limits on the total isotropic equivalent energy release and peak luminosity for FRBs with known distances (redshifts)

The obtained individual upper limits are (5–10)·10^{-7} erg cm^{-2} for the short GRB template, (9–20)·10^{-7} erg cm^{-2} for the MGF template, and (1–4)·10^{-7} erg cm^{-2} s^{-1} for long bursts. The stacked data analysis allows us to set about a factor of 20 more stringent than the individual upper limits. For FRBs with measured host distances we estimate upper limits on the total isotropic equivalent energy release E_{iso} and the peak luminosity L_{iso} (see Fig. 3).

The two by far closest FRB repeaters, FRB 20181030A (at 20 Mpc) and FRB 20200120E (at 3.6 Mpc) are promising sources for constraining FRB emission models. The derived upper limits are $E_{iso} < 2.2\cdot10^{46}$ erg and $E_{iso} < 9\cdot10^{44}$ erg for short GRBs from FRB 20181030A and FRB 20200120E, respectively. The harder MGF spectral template results in about a factor of two less stringent upper limits, $E_{iso} < 4.3\cdot10^{46}$ erg and $E_{iso} < 2\cdot10^{45}$ erg, respectively. These limits do not rule out coincident magnetar giant flares, whose E_{iso} range from 10^{44} erg to 10^{46} erg, as well as less energetic recurrent short and intermediate SGR bursts, with the typical emitted energies below 10^{42} erg.

The presented results are preliminary. They can be significantly improved as more distances to FRB sources will be obtained and, hopefully, closer distances will be applicable.

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