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Fast spectral variability of GRBs with known redshifts(*)

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Summary. — The fast spectral variability of gamma-ray bursts (GRBs) with known redshifts is investigated using the Konus-Wind experiment data in time scale up to 2 ms. Tracks of these GRBs in the luminosity-peak energy plane (L_{iso}, E_P) in the rest-frame are obtained. The distribution of maximum values of an instantaneous luminosity in the GRB's rest frame L_{iso} is derived for such GRBs depending on the peak energy E_P.

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1. – Introduction

The fast spectral variability of 30 GRBs with known redshifts is analyzed on the base of the Konus-Wind experiment data. The advantage of such approach is that all measurements are performed by the same instrument. For all these events reliable values of the redshifts are available [1].

The Konus-Wind instrument records burst time history in three energy windows G1, G2, and G3 with a variable time resolution from 2 up to 256 ms. The nominal values of energy intervals at the beginning of the experiment were G1 (10–50 keV), G2 (50–150 keV), and G3 (150–750 keV). The boundaries increase in course of time due to the degradation of photocathodes and by the end of 2004 the energy windows were the following: G1 (20–70 keV), G2 (70–300 keV), and G3 (300–1300 keV). Multichannel energy spectra are measured in the energy range 20 keV–10 MeV with accumulation times of 64 ms–8 s adapted to current intensities of burst [2].

2. – Data analysis

It is possible to consider time history in three energy windows as three-channel energy spectrum recorded with fine temporal resolution. The spectra are described by the power

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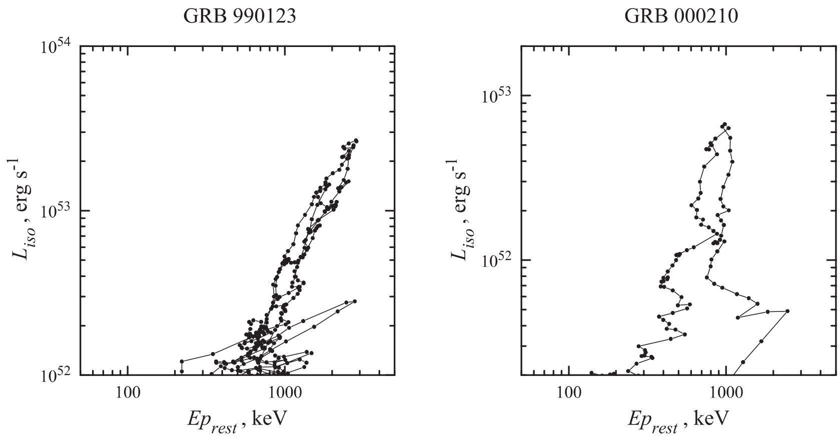

Fig. 1. – Examples of correlation tracks in the rest frame.

law with the exponential cut-off model:

$$N(E) = A \left(\frac{E}{100\text{keV}} \right)^{\alpha} \exp \left(-\frac{E}{E_0} \right) \qquad \left[\frac{\text{photons}}{\text{cm}^2 \text{ s keV}} \right].$$

We determine the values of three parameters A, E_0, α so that three-channel detector response fits to the obsereved three-channel spectrum. The uncertainties in parameters

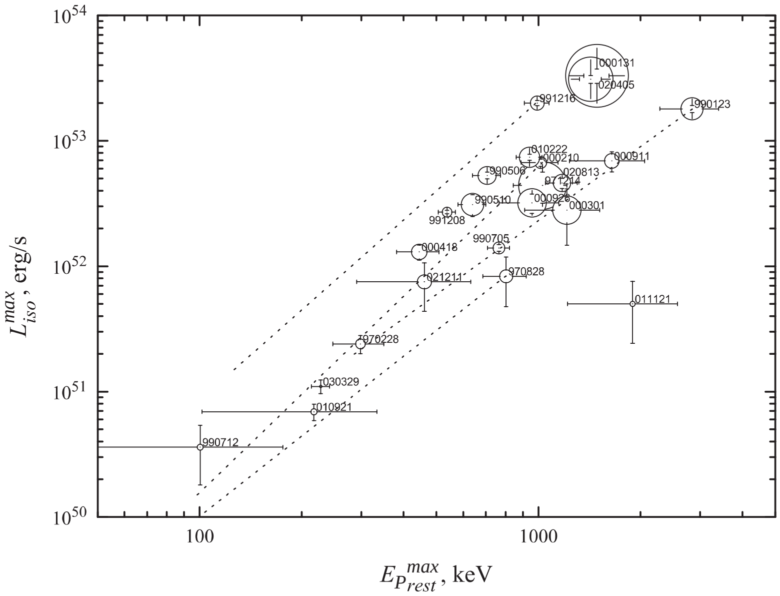

Fig. 2. – Maximum isotropic luminosity L_{iso}^{max} *vs.* maximum peak energy in the rest frame $E_{P_{rest}}^{max}$. Circle size is proportional to the value of redshift. Several slopes of the individual correlation tracks are shown with dotted lines.

are estimated by propagation of counting statistics errors. The uncertainty of peak energy E_P is less than E_0 and α due to the strong anticorrelation between α and E_0. In most cases it is possible to verify the results using multichannel energy spectra.

TABLE I. – *Energetic properties of 30 GRBs with known redshifts detected by Konus-Wind.*

Date	Z	Fluence $10^{-6}\frac{\text{erg}}{\text{cm}^2}$	Peak flux $10^{-7}\frac{\text{erg}}{\text{cm}^2\text{s}}$	$E_{P\,integr}$ keV	$E_{P\,rest}^{\,max}$ keV	E_{iso}^{rad} 10^{52} erg	L_{iso}^{max} $10^{51}\frac{\text{erg}}{\text{s}}$
970228	0.7	11 ± 4	15.7 ± 5.7	132 ± 21	298 ± 51	1.62 ± 0.59	3.9 ± 1.4
970508	0.83	2.6 ± 3	–	92 ± 26	–	0.55 ± 0.65	–
970828	0.96	58 ± 10	22 ± 6.4	–	803 ± 117	16.2 ± 2.8	12 ± 3
971214	3.42	8.8 ± 2.4	5.2 ± 1.4	173 ± 18	1028 ± 186	24.2 ± 6.8	63 ± 18
980703	0.97	28 ± 12	–	244 ± 36	–	7.8 ± 3.3	–
990123	1.6	320 ± 21	88 ± 5.7	636 ± 25	2842 ± 560	238 ± 15	169 ± 11
990506	1.31	194 ± 12	76 ± 4.7	350 ± 12	706 ± 67	98 ± 6	89 ± 6
990510	1.62	27 ± 5	37 ± 7.2	145 ± 13	639 ± 60	20.3 ± 3.9	74 ± 14
990705	0.84	102 ± 6	51 ± 3.1	318 ± 7	765 ± 57	21.7 ± 1.3	20 ± 1
990712	0.43	16.9 ± 1.1	4.4 ± 2.2	–	72 ± 64	0.93 ± 0.06	0.34 ± 0.18
991208	0.71	163 ± 5	185 ± 5.8	183 ± 3	537 ± 31	24.6 ± 0.8	47 ± 1
991216	1.02	248 ± 12	468 ± 22	378 ± 10	992 ± 83	78.2 ± 3.7	296 ± 14
000131	4.51	44 ± 6	16 ± 2.0	235 ± 20	1488 ± 127	188 ± 24	374 ± 48
000210	0.85	76 ± 5	242 ± 15	407 ± 14	1015 ± 127	16.4 ± 1.0	97 ± 6
000301	2.03	8.3 ± 0.6	12 ± 5.7	–	1213 ± 303	9.5 ± 0.7	42 ± 20
000418	1.12	26 ± 4	28 ± 4.0	134 ± 10	445 ± 64	10.0 ± 1.4	22 ± 3
000911	1.06	192 ± 34	100 ± 18	1023 ± 86	1647 ± 412	65 ± 12	69 ± 12
000926	2.04	26 ± 4	15 ± 2.6	101 ± 6	957 ± 191	29.7 ± 5.1	53 ± 9
010222	1.48	139 ± 8	87 ± 4.9	309 ± 12	941 ± 82	89 ± 5	138 ± 8
010921	0.45	20 ± 3	9.2 ± 1.4	82 ± 9	290 ± 116	1.18 ± 0.18	0.80 ± 0.12
011121	0.36	227 ± 25	109 ± 12	882 ± 93	1896 ± 678	8.56 ± 0.93	5.6 ± 0.6
020124	0.69	11 ± 6	–	124 ± 18	–	1.61 ± 0.82	–
020405	3.2	83 ± 6	35 ± 2.5	209 ± 6	1427 ± 105	206 ± 15	360 ± 26
020813	1.25	141 ± 13	60 ± 5.6	315 ± 15	1174 ± 126	66 ± 6	63 ± 6
021004	0.25	1.2 ± 14	–	84 ± 44	–	0.02 ± 0.25	–
021211	1	3.6 ± 11	14 ± 6.2	80 ± 9	461 ± 170	1.1 ± 3.2	8.5 ± 3.8
030226	1.99	13 ± 6	–	117 ± 14	–	13.8 ± 6.25	–
030328	1.52	35 ± 8	–	132 ± 7	–	23.7 ± 5.14	–
030329	0.17	197 ± 7	200 ± 7.6	104 ± 2	228 ± 14	1.53 ± 0.06	1.81 ± 0.07
031203	0.11	3.7 ± 3	–	144 ± 46	–	0.011 ± 0.01	–

Note: $E_{P\,integr}$ is the peak energy of the time-integrated energy spectrum and E_{iso}^{rad} is total radiated isotropic energy during the whole burst.

The peak energy $E_P = E_0(\alpha+2)$ and the energy flux

$$F = \int_{E_P/2}^{2E_P} EN(E)\mathrm{d}E$$

are determined for each spectrum. The choice of energy band depending on E_P makes the flux less sensitive to the value of E_P than in the case of fixed finite boundaries.

In most cases the values of peak energy and flux form a distinct track in the (F, E_P) plane. For the bursts with known redshifts correlation tracks can be recalculated to the rest frame of the burst source. We consider a relation between peak energy in the rest frame $E_{P rest} = E_P(1+Z)$ and the isotropic luminosity $L_{iso} = F \cdot 4\pi D_L^2(Z)$ where $D_L(Z)$ is a luminosity distance:

$$D_L(Z) = \frac{c}{H_0}(1+Z)\int_0^Z \frac{\mathrm{d}z}{\sqrt{\Omega_M(1+z)^3+\Omega_\Lambda}}.$$

We assume a standard cosmology model with $H_0 = 65\ \mathrm{km\,s^{-1}Mpc^{-1}}$, $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ [3].

Most of the tracks has a sharp maximum point (fig. 1). The maximum values of L_{iso} and $E_{P rest}$ are determined on the timescale of 64 ms. The distribution of these maximum values is shown in fig. 2. The spectral and energetic properties of the considered bursts are summarized in table I.

3. – Discussion

It is reasonable to assume that the correlation tracks reflect the properties of the mechanism of energy transfer and conversion into gamma-rays. Specifically, the harder spectra corresponds to the greater luminosity. In average, the correlation tracks can be approximated by a power law

$$L_{iso} \propto E_{P rest}^{\gamma}$$

In most cases indices γ lie within the interval of 1.8–3 (see, for example, fig. 1) having an average value of 2.5.

The plot L_{iso} *vs.* $E_{P rest}$ for a set of bursts agrees generally with a slope of individual correlation tracks confirming the common radiative mechanism realized in the bursts. Deficiency of the low luminosity bursts with high redshift in the plot is undoubtedly due to the selection effects. At the same time it is clear that L_{iso} depends on the energy stored in the source and therefore can not be considered as a standard candle.

REFERENCES

[1] http://www.mpe.mpg.de/∼jcg/grbgen.html.
[2] Aptekar R. L. *et al.*, *Space Science Rev.*, **71** (1995) 265.
[3] Davis T. M. and Lineweaver C. H., *Publications of the Astronomical Society of Australia (PASA)*, **21** (2004) 97.