Konus catalog of SGR activity: 1978 to 2000

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ABSTRACT

Observational data on the bursting activity of all five known Soft Gamma Repeaters are presented. This information was obtained with Konus gamma-ray burst experiments on board Venera 11-14, Wind, and Kosmos-2326 spacecraft in the period from 1978 to 2000. These data on rates, time histories, and energy spectra of repeated soft bursts obtained with similar instruments and collected together in a comparable form should be useful for further studies of SGRs.

1. INTRODUCTION

Recurrent short gamma-ray bursts with soft energy spectra have been known for twenty years. The first two sources of repeating bursts were discovered and localized in March 1979 with the Konus experiment aboard the Venera 11 and Venera 12 missions (Mazets & Golenetskii 1981). The extraordinary intense gamma-ray outburst on 1979 March 5 (Mazets et al. 1979a) was followed by a series of 16 weaker short bursts from source FXP0526-66, during the next few years (Golenetskii et al. 1984). At the same time, in March 1979, three short bursts were detected from another source, B1900+14 (Mazets, Golenetskii, & Guryan 1979). It was suggested that repeated soft bursts represent a distinct class of events different in their origin from the majority of gamma-ray bursts (Mazets & Golenetskii 1981; Mazets et al. 1982). In 1983, the Prognoz 9, ICE and SMM spacecraft observed a numerous series of soft recurrent bursts from the third source, 1806-20 (Atteia et al. 1987; Laros et al. 1987; Kouveliotou et al. 1987), confirming the existence of a new class of objects. These sources of recurrent soft bursts were named Soft Gamma Repeaters, SGRs.

Curiously, a retrospective analysis of Venera 11 and Prognoz-9 data showed that the short burst of January 7, 1979 (Mazets et al. 1981) belonged to SGR 1806-20 (Laros et al. 1986). Thus, the first three SGRs were detected within only three months. However, as has become clear, SGRs are actually a very rare class of astrophysical objects (Norris et al. 1991; Kouveliotou et al. 1994; Hurley et al. 1994). Indeed, the fourth source, SGR 1627-41, was discovered and localized only in 1998 (Hurley et al. 1999a; Woods et al. 1999; Smith et al. 1999; Mazets et al. 1999a). In 1997 two bursts were observed coming from the fifth

SGR to be identified, SGR 1801-23 (Hurley et al. 1997; Cline et al. 2000).

The five known SGRs have displayed different levels of activity. SGR 0526-66 has been silent since 1983. SGR 1900+14 emitted three bursts in 1979 (Mazets, Golenetskii, & Guryan 1979) and three bursts in 1992 (Kouveliotou et al. 1993). After a long period of silence, the burst activity of SGR 1900+14 resumed in May 1998 at a very high and irregular level and lasted until January 1999 (Hurley et al. 1998; Hurley et al. 1999b; Mazets et al. 1999b). On 1998 August 27 SGR 1900+14 emitted a giant outburst with a complex time history which exhibited a striking similarity to the 1979 March 5 event (Cline, Mazets, & Golenetskii 1998; Mazets et al. 1999c; Hurley et al. 1999c). SGR 1806-20 was a prolific source in 1979-1998 both in terms of active periods and in the numbers of emitted bursts (Laros et al. 1987; Atteia et al. 1987; Kouveliotou et al. 1994; Frederiks et al. 1997; Marsden et al. 1997; Göğüs et al. 2000). SGR 1627-41 was active in June-July 1998 (Hurley et al. 1999a; Woods et al. 1999a; Mazets et al. 1999a). Only two bursts from SGR 1801-23 were detected, on June 29, 1997 (Cline et al. 2000).

X-ray studies of SGR 0526-66 (Rothschild et al. 1994), SGR 1806-20 (Cooke 1993), SGR 1900+14 (Hurley et al. 1996), and SGR 1627-41 (Woods et al. 1999a) have revealed quiescent soft X-ray counterparts to all these objects. Measurements of a rapid spin-down of SGR 1806-20 and SGR 1900+14 have been interpreted (Kouveliotou et al 1998; 1999) as establishing SGRs as "magnetars", i.e. as young isolated neutron stars with a superstrong magnetic field up to 10^{14}-10^{15} G (Duncan & Thompson 1992; Thompson & Duncan 1995). At the same time, arguments for significantly lower magnetic fields in SGRs have also been made (Marsden, Rothschild, & Lingenfelter 1999; Harding, Contopoulos, & Kazanas 1999).

This catalog contains data on soft bursts from five soft gamma repeaters observed with the Konus experiments aboard the Venera 11, 12, 13, 14 missions in 1978-1983, with the Konus-Wind experiment on the Wind spacecraft in 1994-2000, and with the Konus-A experiment aboard Kosmos-2326 in 1995-1997. Our data on time histories and energy spectra of bursts presented here should be useful for further SGR studies especially when compared with results from similar instruments. The catalog including initial processed data is also available electronically at: http//www.ioffe.rssi.ru/LEA/SGR/Catalog/

2. INSTRUMENTS AND OBSERVATIONS

2.1. The Konus experiment on the Venera missions

The Konus instrument consisted of six identical gamma-ray detectors. Each sensor had a NaI(Tl) scintillator 80 mm in diameter and 30 mm in height viewed by a PM-tube through a thick lead glass window. The passive lateral shielding of the crystal resulted in a cosine-like angular sensitivity of the detector. The axes of the six detectors were aligned along orthogonal axes of the spacecraft. This arrangement provided an instrument capability for burst localization with an accuracy of between one and a few degrees depending on the intensity of the burst (Golenetskii, Il'inskii, & Mazets 1974). The instrument operated in a triggered mode. The trigger threshold was set to be about 6σ above the current background level in the energy window 50-150 keV. When triggered, the instrument recorded a burst time history with resolutions of 1/64, 1/4, and 1 s as well as 8 energy spectra in the energy region 30 keV–2 MeV measured with an accumulation time of 4 s (Mazets at al. 1979b).

Observations of gamma-ray bursts (GRBs) from Veneras 11 and 12 were made from September 1978 until February 1980. The experiment was continued on Veneras 13 and 14 from November 1981 to April 1983 with improved spectral resolution (32 energy channels instead of 16) and time resolution 1/256 s instead of 1/64 s (Mazets et al. 1983).

2.2. The Konus-Wind experiment

On the U.S. Global Geospace Science Wind spacecraft, two scintillation gamma-ray detectors are monitoring northern and southern ecliptic hemispheres. Each detector contains a NaI(Tl) crystal 130 mm in diameter and 75 mm in height in a housing with an entrance window made of beryllium. A burst time history is recorded in three energy windows G1(10-50 keV), G2(50-200 keV), G3(200-750 keV) with a variable time resolution from 2 ms up to 256 ms. These records include prehistory sections of event time profiles recorded with 2 ms time resolution. Up to 64 energy spectra are measured in the energy range 10 keV–10 MeV. The accumulation time for each spectrum is automatically adapted to the current burst intensity within the range from 64 ms to 8 s. Time history records are of fixed duration 229.632 s. Spectral measurement may take significantly shorter or longer depending on the total accumulation time for the set of 64 energy spectra (Aptekar et al. 1995). Observations of GRBs from Wind have been made since November 1994.

2.3. The Konus-A experiment

The near-Earth orbiting Kosmos-2326 spacecraft was equipped with the Konus-A experiment for the study of GRBs. This experiment consisted of two gamma-ray burst detectors with associated electronic units. The first was a spectroscopic gamma-ray detector identical to the burst detectors flown on the Wind spacecraft. The second was an ensemble of four directionally sensitive gamma-ray detectors which were arranged to create an instrumental capability to localize a burst arriving from the zenith-centered hemisphere. Studying GRBs by means of two identical instruments from two spacecraft increased significantly the reliability of identifying faint details and features in burst time histories and energy spectra. Observations from Kosmos-2326 were carried out from December 1995 to October 1997.

3. CATALOG

3.1. Catalog structure

The catalog presents data from three experiments in chronological order, but separately for each SGR. The information for each SGR is displayed in the same sequence.

First, a Table is given which contains the main characteristics of the events. The first three columns specify burst order numbers, burst names according to date of appearance, and trigger times T_0. Burst duration ΔT measured from rise time to fall time is given in the fourth column. Burst rise and fall times are both determined using the criterion that a burst was present only while the observed counts exceeded the background level by over three σ in three successive time bins in the time history. The next two columns present values of peak fluxes and fluences. The spectral parameter kT is given in the seventh column. To ensure uniformity of data presentation, the kT values were obtained by fitting energy photon spectra to optically-thin thermal bremsstrahlung using:

$$F(E_\gamma) \propto E_\gamma^{-1} \exp\left(-\frac{E_\gamma}{kT}\right). \tag{1}$$

The last column contains remarks related mainly to measurements on the Wind and Kosmos spacecraft. Events detected in the trigger mode are marked with an index 'T'. They provide the most complete temporal and spectral data. In some cases more than one event can be detected during a trigger mode record which lasts about four minutes. These events are marked with index 'S'. The values T_0 shown in the third column in these cases denote the time of appearance of a serial event. The mark 'B' indicates weaker events observed in the background mode which provides a coarse time resolution and no direct spectral data. In this case, the kT value was evaluated from the accumulated "hardness ratio" G2/G1. For the weakest events, only an upper limit for kT could be obtained. Only coarse G2 count rate values are available in the spacecraft houskeeping data for events that occured during the "dead time" of the instrument, when information about previous triggered events is read out. Such events are denoted by the mark 'H'.

Second, a set of figures is presented showing time histories and energy spectra for the observed bursts. Time histories are usually given for the two energy windows G1 and G2 together with the count rate ratio G2/G1. Deconvolved background-subtracted photon spectra were accumulated in the marked time intervals. On the time history graphs, these intervals are shown enclosed between two vertical dotted lines. For some weak events, an important fraction of the burst falls into the prehistory period. A spectrum accumulated after T_0 is often too uncertain to be shown on the graph. In this case, the parameter kT must be evaluated from the hardness ratio G2/G1 integrated for the whole burst. In some cases e.g. for serial events, the spectrum accumulation time is much longer than the burst duration. Such spectra when divided by the total accumulation time, for display in the Figures, exhibit correspondingly depressed intensities. If the burst duration is known the values can easily be corrected.

Finally, there are several special events the study of which is expected to be of great importance for a deeper understanding of the SGR origin. More extensive information concerning these outbursts and event series is presented together with comments and explanations.

The data presented have been corrected for interferences and dead time. After background subtraction, instrumental energy-loss spectra were deconvolved to incident photon spectra.

3.2. SGR 0526-66

This is the first known source of soft repeated bursts. It was discovered and localized with the Konus experiment on board the Venera 11 and Venera 12 missions in 1979 when on March 5 a giant outburst accompanied by a long pulsating (8 s) tail was observed to be followed a few days later by several weak recurrent bursts (Mazets et al. 1979a). A much more precise localization performed by Cline et al. (1982) resulted in a very small error box which projected onto the supernova remnant N 49 located in the Large Magellanic Cloud (LMC) at a distance of 55 kpc. This source continued moderate activity until 1983 (Golenetskii et al. 1984). A weak persistent soft X-ray flux from SGR 0526-66 in its quiescent state has been detected with ROSAT (Rothschild et al. 1994). The data for 17 events are presented in Table 2.1 and displayed in Figures 2.1–2.18.

3.3. SGR 1900+14

The second source of soft recurrent bursts was also discovered and localized in March 1979 (Mazets, Golenetskii & Guryan 1979). Several bursts from this SGR were observed during its reactivation period in 1992 by BATSE (Kouveliotou et al. 1993). SGR 1900+14 is believed to be associated with the supernova remnant G42.8+0.6 (Kouveliotou et al. 1994) situated at distance of 10.4 kpc (Case & Bhattacharya 1998) but see also Vrba et al. (2000). ASCA observations in April 1998 revealed a 5.16 s periodicity in persistent X-ray emission from this source (Hurley et al. 1999d). A further episode of bursting activity began in May 1998 and continued until January 1999. BATSE (Göğüs et al. 1999), BeppoSAX (Feroci et al. 1999), and Konus-Wind (Mazets et al. 1999b) investigated numerous bursts.

On August 27, 1998, a giant outburst in SGR 1900+14 was observed (Cline, Mazets, &

Golenetskii 1998; Hurley et al. 1999c; Feroci et al. 1999). This event strikingly resembled the March 5 outburst from SGR 0526-66. It also consisted of a huge brief initial pulse followed by a slowly decaying and coherently pulsating (5.16 s) tail (Mazets et al. 1999c). The close similarity between these two giant outbursts indicates their common nature.

The appearance rate of repeated bursts was very irregular and clusters of bursts were observed. During the most crowded cluster, events followed one another in time intervals as short as a few burst lengths.

The data related to SGR 1900+14 are presented in Table 3.1 and shown in Fig. 3.1–3.66.

3.4. SGR 1806-20

The third repeater, SGR 1806-20 was discovered and localized during a period of high activity in 1979-1983 in observations from the ICE, Prognoz-9 and SMM spacecraft (Laros et al. 1986; Laros et al. 1987; Atteia et al. 1987; Kouveliotou et al. 1987).

In subsequent years, the source continued a moderate level of activity. Beginning in 1996, the source became very active again with many clusters of events. A persistent soft X-ray source was observed by Murakami et al. (1994). Kouveliotou et al. (1998) discovered 7.47 s pulsations in the X-ray flux. Kulkarni and Frail (1993) located SGR 1806-20 inside the supernova remnant G10.0-0.3 at a distance of $\sim$ 14 kpc. Statistical properties of the repeating bursts were studied by Göğüs et al. (2000).

Results of observations of SGR 1806-20 with Konus experiments are presented in Table 4.1 and Fig. 4.1–4.20.

3.5. SGR 1627-41

This source was discovered in summer 1998 with observations from CGRO (Woods et al. 1999), Ulysses (Hurley et al. 1999a), Wind (Mazets et al. 1999a), and RXTE (Smith et al. 1999). The source was precisely localized by the IPN. Its position coincides with the supernova remnant G337.0-0.1 at a distance of $\sim$ 11 kpc (Hurley et al. 1999a). Some evidence was obtained in support of a possible periodicity of 6.7 s (Dieters et al. 1998; Woods et al. 1999), but the observations from ASCA didn't confirm this result (Hurley et al. 2000).

An enormously intense outburst from this source was observed on 1998 June 18. It was a short single pulse without any evidence for the existence of a pulsating decay (Mazets et al. 1999a). Calculation of the outburst intensity has required major dead time corrections. It is of great interest that on June 18 at least one more such event occurred. However, it was detected only in housekeeping data. This circumstance prevented us from making reliable dead time corrections. Hence, only a lower limit of intensity for this burst could be obtained.

Our data from the Konus-Wind experiment are presented in Table 5.1 and Fig. 5.1–5.17.

3.6. SGR 1801-23

Only two short bursts from this source were detected on June 29, 1997 by CGRO, Ulysses, Wind and Kosmos-2326 (Cline et al. 2000). However, it should be remembered that the first active period of SGR 1900+14 observed in March 1979 consisted of only three events.

The data obtained are presented in Table 6.1 and Fig. 6.1.

4. Conclusion

The catalog contains various characteristics of repeated bursts emitted from five SGRs such as burst durations, fluences, peak fluxes, hardness of energy spectra (kT), and spectral variability. These data, also provided as on-line tables at http://www.ioffe.rssi.ru/LEA/SGR/Catalog/, enable users to perform further statistical studies of possible relations between these properties.

Some results of such studies were published earlier by Mazets et al. (1999b) for the SGR 1900+14 using Konus-Wind data and by Woods et al. (1999), Göğüs et al. (1999b;

2000) for the SGR 1806-20, SGR 1900+14, and SGR 1627-41 on the base BATSE, RXTE and ICE data.

As an example of use of the catalog data, the relations between fluences and burst durations are shown in Fig. 1–4 for four SGRs. The correlation between these characteristics is evident for SGR 0526-66, SGR 1900+14, and SGR 1627-41. As another example, the cumulative fluence distributions are presented in Fig. 5–8.

The catalog reveals general similarities between properties of the known SGRs. At the same time there are also evident distinctions. Note, for example, the different patterns of spectral variability for SGR 1900+14 and SGR 1627-41 and its absence for SGR 1806-20.

Studying such similarities, distinctions, and individual features should lead to a deeper understanding of the fleeting but extremely powerful processes operating in SGRs.

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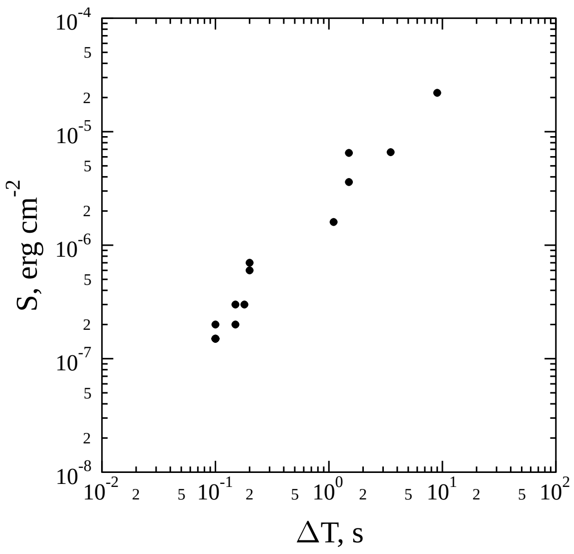

Fig. 1.— Fluence vs duration distribution of 16 triggered bursts (giant outburst on 5 March 1979 has been excluded) from SGR 0526-66 demonstrates a strong correlation ($\rho = 0.98$).

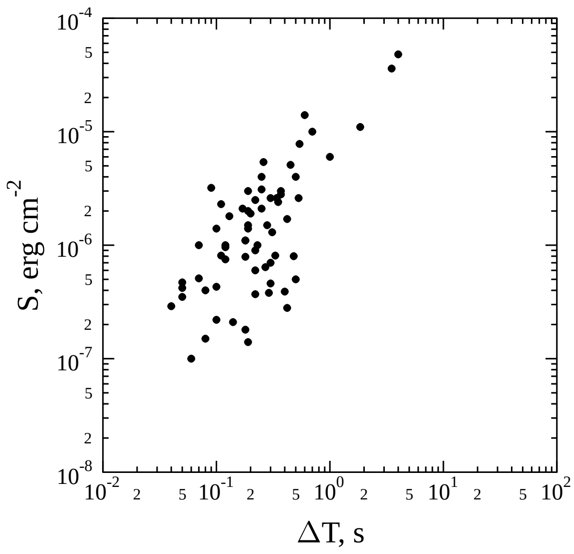

Fig. 2.— Fluence vs duration distribution of 67 triggered bursts (giant outburst on 27 August 1998 has been excluded) from SGR 1900+14 demonstrates a strong correlation ($\rho = 0.70$).

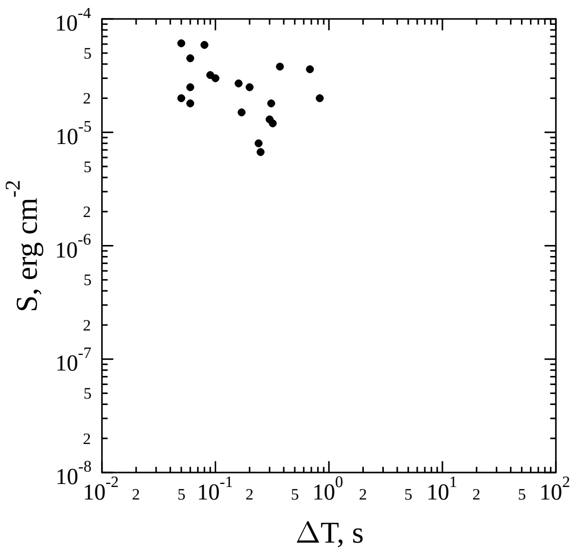

Fig. 3.— Fluence vs duration distribution of 19 triggered bursts from SGR 1806-20 demonstrates no correlation ($\rho = -0.37$).

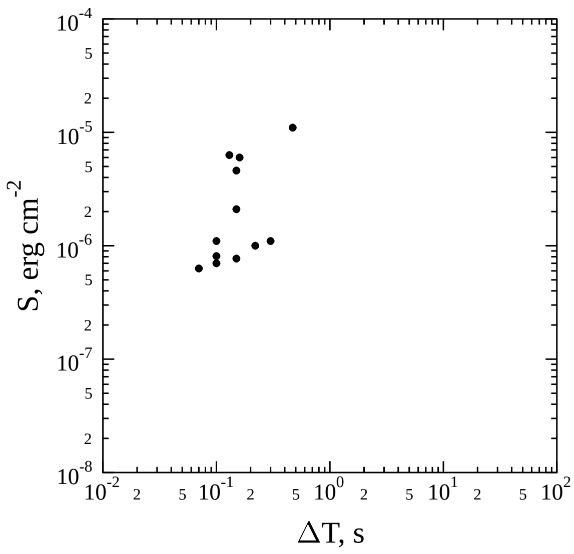

Fig. 4.— Fluence vs duration distribution of 12 triggered bursts (huge outburst on 18 June 1998 has been excluded) from SGR 1627-41 demonstrates a strong correlation ($\rho = 0.70$).

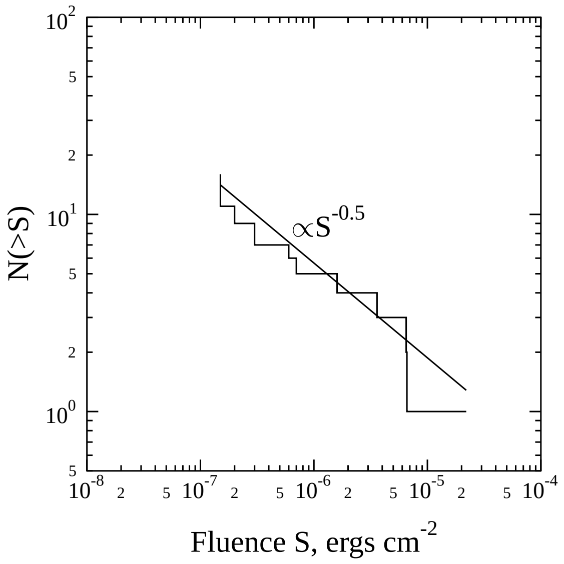

Fig. 5.— Cumulative fluence distribution of 16 bursts from SGR 0526-66 (giant outburst on 5 March 1979 has been excluded).

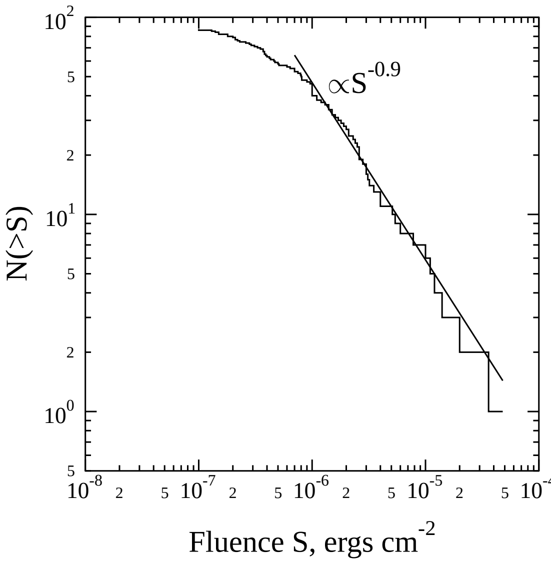

Fig. 6.— Cumulative fluence distribution of 87 bursts (including background events) from SGR 1900+14 (giant outburst on 27 August 1998 has been excluded).

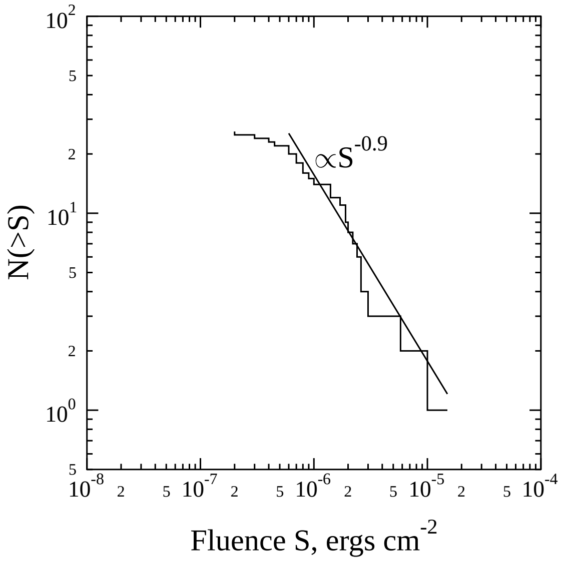

Fig. 7.— Cumulative fluence distribution of 26 bursts from SGR 1806-20.

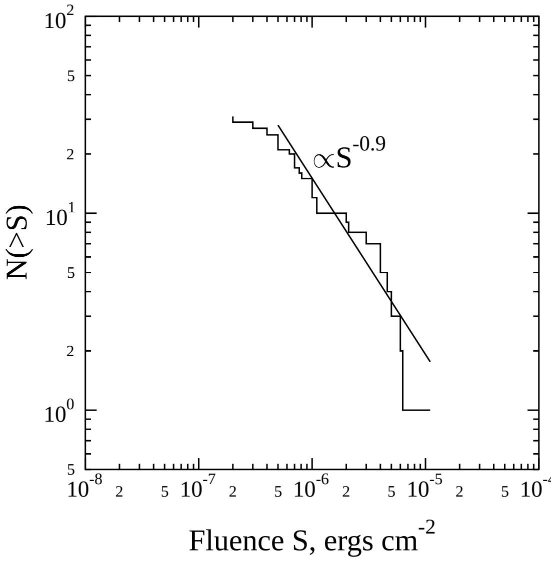

Fig. 8.— Cumulative fluence distribution of 31 bursts (including background events) from SGR 1627-41 (huge outburst on 18 June 1998 has been excluded).

REFERENCES

Aptekar, R. L., et al. 1995, Space Science Rev., 71, 265

Atteia, J.-L., et al. 1987, ApJ, 320, L105

Case, G. L., & Bhattacharya, D. 1998, ApJ, 504, 761

Cline, T. L., et al. 1982, ApJ, 255, L45

Cline, T. L., Mazets, E. P., & Golenetskii S. V. 1998, IAU Circ., 7002

Cline, T. L., et al. 2000, ApJ, 531, 407

Dieters, S., et al. 1998, IAU Circ., 6962

Duncan, R. C., & Thompson, C. 1992, ApJ, 392, L9

Ferocy, M., et al. 1999, ApJ, 515, L9

Frederiks, D. D., et al. 1997, in AIP Conf. Proc. 428, 4th Huntsville Sumposium, Gamma-Ray Bursts, ed. Ch Meegan, R. Preece, & T. Koshut (New York: AIP), 921

Göğüs, E., et al. 1999, ApJ, 526, L93

Göğüs, E., et al. 2000, ApJ, 532, L124

Golenetskii, S. V., Il'inskii, V. N., & Mazets, E. P. 1974, Kosmicheskie Issledovania (Space Research, USSR), 12, 779

Golenetskii, S. V., et al. 1984, Nature, 307, 41

Harding, A. K., Contopoulos, I., & Kazans, D. 1999, ApJ, 525, L125

Hurley, K., et al. 1994, ApJ, 423, 709

Hurley, K., et al. 1996, ApJ, 463, L13

Hurley, K., et al. 1997, IAU Circ., 6743

Hurley, K., et al. 1998, IAU Circ., 6929

Hurley, K., et al. 1999a, ApJ, 519, L143

Hurley, K., et al. 1999b, ApJ, 510, L107

Hurley, K., et al. 1999c, Nature, 397, 41

Hurley, K., et al. 1999d, ApJ, 510, L111

Hurley, K., et al. 2000, ApJ, 528, L21

Kouveliotou, C., et al. 1987, ApJ, 322, L21

Kouveliotou, C., et al. 1993, Nature, 362, 728

Kouveliotou, C., et al. 1994, Nature, 368, 125

Kouveliotou, C., et al. 1998, Nature, 393, 235

Kouveliotou, C., et al. 1999, ApJ, 510, L115

Kulkarni, S., & Frail, D. A. 1993, Nature, 365, 33

Laros, J. G., et al. 1986, Nature, 322, 152

Laros, J. G., et al. 1987, ApJ, 320, L111

Marsden, D., et al. 1997, in AIP Conf. Proc. 428, 4th Huntsville Symposium, Gamma-Ray Bursts, ed C. Meegan, R. Preece, & T. Koshut (New York: AIP), 926

Marsden, D., Rothschild, R. E., & Lingenfelter, R. E. 1999, ApJ, 520, L107

Mazets, E. P., Golenetskii, S. V., & Guryan, Yu. A. 1979, Soviet. Astron. Lett., 5, 343

Mazets, E. P., & Golenetskii S. V. 1981, Ap&SS, 75, 47

Mazets, E. P., et al. 1979a, Nature, 282, 587

Mazets, E. P., et al. 1979b, Soviet. Astron. Lett., 5, 163

Mazets, E. P., et al. 1981, Ap&SS, 80, 3

Mazets, E. P., et al. 1982, Ap&SS, 84, 173

Mazets, E. P., et al. 1983, in AIP Conf. Proc. 101, Positron-Electron Pairs in Astrophysics, ed. M. L. Burns, A. K. Harding, & R. Ramaty, (New York: AIP), 36

Mazets, E. P., et al. 1999a, ApJ, 519, L151

Mazets, E. P., et al. 1999b, Astronomy Letters, 10, 727

Mazets, E. P., et al. 1999c, Astronomy Letters, 10, 735

Murakami, T., et al. 1994, Nature, 368, 127

Norris, J. P., et al. 1991, ApJ, 366, 240

Rothschild, R. E., Kulkarni, S. R., & Lingenfelter, R. E. 1994, Nature, 368, 432

Smith, D., et al. 1999, ApJ, 519, L147

Thompson, C., & Duncan, R.C. 1995, MNRAS, 275, 255

Vrba, F. J., et al. 2000, ApJ, 533, L17

Woods, P. M., et al. 1999a ApJ, 519, L139

Woods, P. M., et al. 1999b ApJ, 527, L47

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Table 2.1. SGR 0526-66[a]

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
1	790305	15:51:39.145					T
	Initial pulse		0.25	1.0×10^{-3}	4.5×10^{-4}	500→30	
	Pulsating tail		> 64		1.0×10^{-3}	$\sim$ 30	
2	790306	06:17:25.201	1.5	4.4×10^{-6}	6.5×10^{-6}	31±5	T
3	790404	00:43:31.317	0.2	2.6×10^{-6}	7.0×10^{-7}	30±10	T
4	790424	18:27:18.241	0.2	2.1×10^{-6}	6.0×10^{-7}	30±15	T
5	811201	09:18:02.424	3.5	2.1×10^{-6}	6.6×10^{-6}	30±2	T
6	820102	17:11:11.109	1.5	2.6×10^{-6}	3.6×10^{-6}	26±3	T
7	820215	10:36:31.071	0.1	1.2×10^{-6}	1.5×10^{-7}	40±15	T
8	820227	00:16:41.178	9.0	7.2×10^{-6}	2.2×10^{-5}	28±3	T
9	820423a	03:43:16.907	0.1	2.3×10^{-6}	2.0×10^{-7}	36±10	T
10	820423b	16:29:21.315	0.15	2.6×10^{-6}	3.0×10^{-7}	45±15	T
11	820510	13:27:55.921	0.1	1.8×10^{-6}	1.5×10^{-7}	···	T
12	820530	12:46:13.968	0.1	1.8×10^{-6}	1.5×10^{-7}	35±15	T
13	820708	10:18:18.979	0.1	2.1×10^{-6}	1.5×10^{-7}	30±15	T
14	820921	18:37:54.138	0.1	1.8×10^{-6}	1.5×10^{-7}	27±15	T
15	821231	04:17:21.363	0.18	2.5×10^{-6}	3.0×10^{-7}	27±10	T
16	830321	22:32:11.400	0.15	2.1×10^{-6}	2.0×10^{-7}	24±10	T
17	830405	07:58:07.667	1.1	2.6×10^{-6}	1.6×10^{-6}	31±6	T

[a]The table begins with the March 5 event which is naturally divided into two phases: the giant short initial pulse followed by a long pulsating (8 s) tail (see Fig. 1). Data for these two phases are given separately. Following lines present the data for repeated weaker bursts.

Table 3.1. SGR 1900+14[a]

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
1	790324	16:06:49.826	0.12	1.3×10^{-5}	1.0×10^{-6}	35±2	T
2	790325	01:58:19.017	0.19	7.6×10^{-6}	1.5×10^{-6}	36±2	T
3	790327	10:30:34.886	0.05	3.0×10^{-6}	3.5×10^{-7}	30±15	T
4	980526	22:24:09.458	0.33	1.6×10^{-5}	8.1×10^{-7}	27±2	T
5	980527	04:14:31.202	0.12	1.6×10^{-5}	7.5×10^{-7}	27±3	T
6	980530a	09:03:35.886	0.30	1.7×10^{-5}	7.0×10^{-7}	32±2	TS
7		09:03:37.262	0.30	6.0×10^{-6}	4.6×10^{-7}	20±2	S
8		09:03:38.366	0.42	1.9×10^{-6}	2.8×10^{-7}	22±4	S
9		09:03:39.678	0.42	1.3×10^{-5}	1.7×10^{-6}	20±1	S
10		09:03:40.670	0.27	1.4×10^{-5}	6.4×10^{-7}	28±2	S
11		09:03:41.886	0.18	1.4×10^{-6}	1.8×10^{-7}	30±5	S
12		09:03:42.414	0.14	2.4×10^{-6}	2.1×10^{-7}	18±3	S
13		09:03:43.822	0.30	1.5×10^{-5}	2.6×10^{-6}	19±1	S
14		09:03:44.350	0.22	5.0×10^{-6}	3.7×10^{-7}	18±3	S
15		09:03:44.654	0.37	1.6×10^{-5}	3.0×10^{-6}	20±1	S
16		09:03:45.470	0.22	1.1×10^{-5}	9×10^{-7}	29±1	S
17		09:03:45.950	0.19	2.0×10^{-5}	2.0×10^{-6}	26±1	S
18		09:03:46.782	0.60	4.9×10^{-5}	1.4×10^{-5}	26±1	S
19		09:03:48.046	0.54	3.6×10^{-5}	7.8×10^{-6}	21±1	S
20		09:03:51.550	0.08	9.6×10^{-6}	4×10^{-7}	27±2	S
21		09:03:51.774	0.50	2.4×10^{-5}	4.0×10^{-6}	27±1	S
22		09:03:52.382	0.08	4.1×10^{-6}	1.5×10^{-7}	27±4	S
23		09:03:53.598	0.10	6.8×10^{-6}	2.2×10^{-7}	18±3	S

Table 3.1—Continued

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
24		09:03:54.878	0.29	3.1×10^{-6}	3.8×10^{-7}	33±3	S
25		09:04:00.270	0.22	8.2×10^{-6}	6.0×10^{-7}	25±2	S
26		09:04:10.446	0.50	$\geq 2.6\times10^{-6}$	5.0×10^{-7}	31±3	S
27		09:04:33.038	0.70	$\geq 3.8\times10^{-5}$	1.0×10^{-5}	27±1	S
28		09:05:14.318	0.19	$\geq 1.4\times10^{-6}$	1.4×10^{-7}	25±6	S
29		09:05:54.382	≤ 0.75	$\geq 4.2\times10^{-7}$	2.1×10^{-7}	30±7	S
30		09:06:31.502	≤ 0.5	$\geq 3\times10^{-6}$	1.2×10^{-6}	27±1	S
31		09:06:44.558	≤ 0.75	$\geq 1.4\times10^{-6}$	3.8×10^{-7}	16±4	S
32		09:08:51.3	≤ 4	$\geq 1\times10^{-6}$	3.5×10^{-6}	25±1	S
33	980530b	11:28:52.737	0.28	1.4×10^{-5}	1.5×10^{-6}	18±1	T
34	980530c	12:47:18.778	0.37	2.3×10^{-5}	2.8×10^{-6}	27±1	T
35	980530d	23:27:37.482	0.18	9.3×10^{-6}	7.9×10^{-7}	36±3	T
36	980601	13:33:55	≤ 3	$\cdots$	3.3×10^{-7}	≤ 35	B
37	980604	03:13:43	≤ 3	$\cdots$	2.3×10^{-7}	≤ 100	B
38	980607a	08:32:32.512	0.26	3.4×10^{-5}	5.4×10^{-6}	25±1	T
39	980607b	21:14:15.040	0.10	2.1×10^{-5}	4.3×10^{-7}	29±2	T
40	980616a	01:50:26.582	0.25	2.7×10^{-5}	3.1×10^{-6}	19±1	T
41	980616b	17:22:59.574	0.11	4.0×10^{-5}	2.3×10^{-6}	22±1	T
42	980719a	08:26:24.995	0.04	1.1×10^{-5}	2.9×10^{-7}	32±3	T
43	980719b	16:40:11.217	0.05	1.1×10^{-5}	4.2×10^{-7}	31±2	T
44	980721	03:19:00.412	0.07	1.2×10^{-5}	5.1×10^{-7}	24±2	T
45	980821	21:30:24.989	0.19	2.4×10^{-5}	3.0×10^{-6}	28±1	T
46	980827	10:22:17.578			$> 9.7\times10^{-3}$		T

Table 3.1—Continued

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
	Initial pulse		0.35	$> 3.1 \times 10^{-2}$	$> 5.5 \times 10^{-3}$	300→20	
	Pulsating tail		> 230		4.2×10^{-3}	~ 20	
47	980828	23:14:10.680	0.10	3.1×10^{-5}	1.4×10^{-6}	20±1	T
48	980829a	10:16:34.068	3.50	2.4×10^{-5}	3.6×10^{-5}	20±1	T
49	980829b	18:18:45.166	1.85	1.4×10^{-5}	1.1×10^{-5}	17±1	T
50	980831a	15:47:38.156	0.12	1.5×10^{-5}	9.6×10^{-7}	18±1	T
51	980831b	19:13:47.249	0.19	1.3×10^{-5}	1.4×10^{-6}	18±1	TS
52		19:17:25.361	≤ 0.5	$\geq 3 \times 10^{-6}$	1.0×10^{-6}	17±2	S
53	980831c	22:22:06.721	1.00	1.1×10^{-5}	6.0×10^{-6}	17±1	T
54	980901a	04:54:16.387	0.53	1.7×10^{-5}	2.6×10^{-6}	17±1	T
55	980901b	16:13:02	···	···	2.6×10^{-7}	≤ 25	B
56	980901c	17:00:32.594	0.18	9.5×10^{-6}	1.1×10^{-6}	18±1	TS
57		17:03:49.202	≤ 0.5	$\geq 4 \times 10^{-6}$	1×10^{-6}	17±1	S
58		17:06:25.1	~ 32	$\geq 10^{-5}$	2×10^{-5}	22 ± 1	S
59	980902a	17:20:19.649	0.35	1.1×10^{-5}	2.4×10^{-6}	20±1	T
60	980902b	19:47:31.640	0.25	1.7×10^{-5}	2.1×10^{-6}	20±1	T
61	980908	06:43:41	≤ 3	···	1.8×10^{-7}	≤ 35	B
62	980911	18:22:38.838	0.34	1.5×10^{-5}	2.6×10^{-6}	20±1	T
63	980912	21:17:19.646	0.05	2.1×10^{-5}	4.7×10^{-7}	23±2	T
64	980915a	18:17:42.117	0.25	3.2×10^{-5}	4.0×10^{-6}	18±1	T
65	980915b	21:40:27	≤ 3	···	3.7×10^{-7}	≤ 30	B
66	980917	09:45:41.987	0.22	2.6×10^{-5}	2.5×10^{-6}	20±1	T
67	980925	12:03:47	≤ 3	···	1.3×10^{-7}	≤ 40	B

Table 3.1—Continued

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
68	980927	02:07:55.646	0.23	8.3×10^{-6}	1.0×10^{-6}	35±2	T
69	981013a	00:31:50.530	0.20	1.8×10^{-5}	1.9×10^{-6}	18±1	TS
70		00:31:57.830	0.06	1.8×10^{-6}	1.0×10^{-7}	35±6	S
71		00:34:26.946	≤ 0.5	$\geq 2.3\times10^{-6}$	7.0×10^{-7}	19±2	S
72		00:35:39.906	≤ 0.3	$\geq 1\times10^{-6}$	2×10^{-7}	20±4	S
73	981013b	13:57:47.699	0.31	1.4×10^{-5}	1.3×10^{-6}	20±1	T
74	981022	15:40:46.627	0.40	2.1×10^{-6}	3.9×10^{-7}	110±30	T
75	981024	01:22:01.645	0.18	2.4×10^{-5}	1.1×10^{-6}	20±1	TS
76		01:25:32.077	≤ 0.25	$\geq 5\times10^{-7}$	1.5×10^{-7}	24±8	S
77		01:25:43.597	≤ 0.5	$\geq 7\times10^{-7}$	3.1×10^{-7}	24±4	S
78		01:27:21.4	≤ 16	···	1.0×10^{-6}	32±6	S
79		01:29:07.9	≤ 24	···	1.2×10^{-5}	25±1	S
80		01:29:48.9	≤ 16	···	1.6×10^{-6}	26±2	S
81	981028a	20:20:53.276	0.11	1.8×10^{-5}	8.1×10^{-7}	23±2	T
82	981028b	23:03:39.997	4.0	1.6×10^{-5}	4.8×10^{-5}	22±1	T
83	981029	21:36:19.861	0.13	2.4×10^{-5}	1.8×10^{-6}	22±1	T
84	981031a	18:32:08.605	0.45	1.7×10^{-5}	5.1×10^{-6}	17±1	T
85	981031b	22:14:07.013	0.09	5.3×10^{-5}	3.2×10^{-6}	24±1	T
86	981109	21:19:09.763	0.07	2.4×10^{-5}	1.0×10^{-6}	20±1	T
87	981130	03:28:53.044	0.17	2.1×10^{-5}	2.1×10^{-6}	20±1	T
88	990110	08:39:01.078	0.48	3.0×10^{-6}	8.0×10^{-7}	75±6	T

[a]It can be seen from this Table that SGR 1900+14 emitted bursts of three types: single bursts, series of bursts, and a giant outburst (August 27 event). These types of events are displayed below in separate sets of Figures.

Table 4.1. SGR 1806-20

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
1	790107	05:31:42.015	0.25	6.7×10^{-6}	1.4×10^{-6}	25±2	T
2	961026	01:33:51.940	0.06	1.8×10^{-5}	8.0×10^{-7}	24±2	T
3	961105	17:02:18	≤ 1.5	⋯	7×10^{-7}	21±5	B
4	961118a	04:52:35	≤ 1.5	⋯	4×10^{-7}	≤ 30	B
5	961118b	05:25:10.181	0.37	3.8×10^{-5}	5.8×10^{-6}	20±1	TS
6		05:25:56.133	~0.10	$\geq 4.0\times10^{-6}$	4.5×10^{-7}	26±4	S
7	961118c	11:26:12	≤ 1.5	⋯	3×10^{-7}	≤ 30	B
8	961118d	16:04:57.507	0.31	1.8×10^{-5}	1.0×10^{-6}	20±2	T
9	961119a	03:04:08.608	0.24	8×10^{-6}	6×10^{-7}	24±3	T
10	961119b	05:30:25.967	0.83	2.0×10^{-5}	1.0×10^{-5}	18±1	T
11	961119c	06:22:07.737	0.30	1.3×10^{-5}	2.2×10^{-6}	20±1	T
12	961119d	07:24:04.153	0.32	1.2×10^{-5}	2.6×10^{-6}	17±2	T
13	961121	07:05:39	≤ 1.5	⋯	2×10^{-7}	≤ 40	B
14	961122	02:17:38.595	0.16	2.7×10^{-5}	2.6×10^{-6}	21±2	T
15	970124	07:47:21	≤ 3	⋯	6×10^{-7}	≤ 30	B
16	970902	10:55:46.779	0.09	3.2×10^{-5}	2.0×10^{-6}	22±1	T
17	970912	06:09:24.080	0.68	3.6×10^{-5}	1.5×10^{-5}	20±1	T
18	981017	15:13:43.353	0.20	2.5×10^{-5}	3.0×10^{-6}	22±2	T
19	981022	05:21:53.701	0.06	2.5×10^{-5}	9.0×10^{-7}	23±2	T
20	981217a	13:21:18.615	0.10	3.0×10^{-5}	1.7×10^{-6}	19±2	T
21	981217b	19:13:58.678	0.08	5.9×10^{-5}	2.4×10^{-6}	20±2	T
22	990104	01:50:25.592	0.05	2×10^{-5}	7×10^{-7}	22±3	T
23	990125	08:33:56.811	0.05	6.1×10^{-5}	1.9×10^{-6}	20±2	T

Table 4.1—Continued

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
24	990205	08:44:11	≤ 3	$\cdots$	8×10^{-7}	≤ 30	B
25	990206	02:10:32.228	0.06	4.5×10^{-5}	1.4×10^{-6}	20$\pm$2	T
26	990601	10:00:08.743	0.17	1.5×10^{-5}	1.9×10^{-6}	19$\pm$2	T

Table 5.1. SGR 1627-41[a]

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
1	980617a	18:53:29	≤ 3	$\cdots$	5×10^{-7}	19$\pm$5	B
2	980617b	18:58:14	≤ 3	$\cdots$	4×10^{-7}	≤ 20	B
3	980617c	19:04:02	≤ 3	$\cdots$	1×10^{-6}	19$\pm$2	B
4	980617d	19:58:31.969	0.15	5.1×10^{-5}	4.6×10^{-6}	29$\pm$2	TS
5		20:06:27.4	≤ 4	$\cdots$	3×10^{-6}	18$\pm$2	S
6	980617e	21:04:40.001	0.15	4.6×10^{-5}	2.1×10^{-6}	20$\pm$1	TS
7		21:07:24.353	~ 1	$\geq 6\times10^{-6}$	2×10^{-6}	21$\pm$1	S
8	980617f	21:17:06	≤ 4	$\cdots$	4×10^{-6}	$\cdots$	H
9	980617g	21:37:21	≤ 4	$\cdots$	5×10^{-6}	$\cdots$	H
10	980617h	21:57:10	≤ 4	$\cdots$	4×10^{-6}	$\cdots$	H
11	980617i	22:54:08.930	0.30	1.6×10^{-5}	1.1×10^{-6}	21$\pm$2	T
12	980618a	00:06:11	≤ 3	$\cdots$	3×10^{-7}	≤ 30	B
13	980618b	00:15:35	≤ 3	$\cdots$	5×10^{-7}	≤ 20	B
14	980618c	00:51:04	≤ 3	$\cdots$	2×10^{-7}	≤ 70	B
15	980618d	01:42:33.495	0.50	0.028	7.6×10^{-4}	20-120	T
16	980618e	03:07:49	$\cdots$	$\cdots$	5×10^{-7}	≤ 30	B
17	980618f	03:25:16.450	0.22	1.5×10^{-5}	1.0×10^{-6}	22$\pm$2	TS
18		03:28:30.010	≤ 0.3	$\geq 4\times10^{-6}$	1×10^{-6}	30$\pm$2	S
19	980618g	04:04:24	≤ 4	$\cdots$	$\geq 5\times10^{-5}$	$\cdots$	H
20	980618h	04:30:29.019	0.47	1.5×10^{-4}	1.1×10^{-5}	38$\pm$1	T
21	980618i	04:34:20	≤ 3	$\cdots$	4×10^{-7}	$\cdots$	B
22	980618j	05:42:09	≤ 3	$\cdots$	5×10^{-7}	38$\pm$8	B
23	980618k	06:16:33.125	0.07	1.8×10^{-5}	6.3×10^{-7}	26$\pm$2	T

Table 5.1—Continued

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
24	980618l	07:34:08	≤ 3	···	3×10^{-7}	≤ 25	B
25	980618m	12:19:23	≤ 3	···	2×10^{-7}	≤ 40	B
26	980618n	16:38:04.665	0.15	8.7×10^{-6}	7.7×10^{-7}	23 ± 2	T
27	980618o	17:51:16	≤ 3	···	7×10^{-7}	27 ± 4	B
28	980622a	13:29:56.270	0.16	6.3×10^{-5}	6.0×10^{-6}	31 ± 1	T
29	980622b	14:11:25	≤ 4	···	7×10^{-7}	···	H
30	980622c	18:56:39.058	0.10	4.0×10^{-5}	1.1×10^{-6}	29 ± 2	T
31	980625	10:56:19.575	0.13	1.1×10^{-4}	6.3×10^{-6}	33 ± 1	T
32	980629	07:25:06.756	0.10	1.8×10^{-5}	7.0×10^{-7}	27 ± 2	T
33	980712	21:50:40.106	0.10	3.2×10^{-5}	8.1×10^{-7}	26 ± 2	T

[a]It is clear that the appearance rate of soft bursts from this source was very high. About 30 events occured during three days in June 1998. This explains why about 25 per cent of events were detected in housekeeping data. A huge outburst was observed on 1998 June 18 (980618d). At least one more such outburst was detected in housekeeping records, permitting only a lower limit on the fluence to be determined.

Table 6.1. SGR 1801-23

N	Burst name	T_0 h:m:s UT	ΔT (s)	P_{max} (erg cm^{-2} s^{-1})	S (erg cm^{-2})	kT (keV)	Comments
1	970629a	04:00:24	≤ 1.5	$\cdots$	1×10^{-6}	18$\pm$3	B
2	970629b	06:31:33.221	0.25	5.4×10^{-5}	9.6×10^{-6}	16$\pm$1	T