The Activity of the Soft Gamma Repeater SGR 1900+14 in 1998 from Konus-Wind Observations:

1. Short Recurrent Bursts.

E.P.Mazets\textsuperscript{1}, T.L.Cline\textsuperscript{2}, R.L.Aptekar\textsuperscript{1}, P.Butterworth\textsuperscript{2}, D.D.Frederiks\textsuperscript{1}, S.V.Golenetskii\textsuperscript{1}, V.N.Il'inskii\textsuperscript{1}, V.D.Pal'shin\textsuperscript{1}

ABSTRACT

Results are presented of the observations of the soft gamma repeater SGR 1900+14 made on the Wind spacecraft during the source reactivation period from May 1998 to January 1999. Individual characteristics of recurrent bursts, such as their time histories, energy spectra, and maximum and integrated energy fluxes, are considered. Some statistical distributions and relationships are also presented. The close similarity of these events to the recurrent bursts observed from other SGRs argues for a common emission mechanism.

\textsuperscript{1}Ioffe Physical-Technical Institute, St.Petersburg, 194021, Russia. Mazets@pop.ioffe.rssi.ru

\textsuperscript{2}Goddard Space Flight Center, Greenbelt, MD 20771, USA.
1. INTRODUCTION

Recurrent short gamma-ray bursts with soft spectra have been known for over 20 years. The first two sources of such bursts were discovered and localized in March 1979 by the Konus experiment on Venera 11 and 12 (Mazets et al., 1981). The extraordinary superintense gamma-ray outburst on March 5, 1979 (Mazets et al., 1979a) was followed by a series of 16 weaker short bursts from the FXP 0526-66 source, which were observed during the next few years (Golenetskii et al., 1984). Also in March 1979, three short soft bursts arriving from the source B1900+14 were detected (Mazets et al., 1979b). In 1983, Prognoz-9 and ICE observed a series of soft recurrent bursts from a third source, 1806-20 (Atteia et al., 1987, Laros et al., 1987). The sources of recurrent soft bursts were given the name soft gamma repeaters, SGRs. Interestingly, a retrospective analysis of Venera 11 and Prognoz-7 data shows that the short gamma-ray burst of 07.01.1979 (Mazets et al., 1981) also belonged to SGR 1806-20 (Atteia et al., 1987). Thus bursts from the first three soft gamma repeaters were detected within a three month period. This is remarkable, because the fourth soft gamma repeater, the SGR 1627-41, was detected and localized only 19 years later, in 1998 (Hurley et al., 1999a, Woods et al., 1999). A fifth SGR has also been observed (Hurley et al., 1997), but it still awaits a good localization.

Important new results came from studies aimed at association of the recurrent bursters with astrophysical objects visible in other wavelengths. The giant narrow initial pulse of the 1979 March 5 event was detected on a dozen different spacecraft. Triangulation yielded a very small source-localization box, about 0.1 square-arcmin, which projected on the outer edge of the N49 supernova remnant in the Large Magellanic Cloud (Cline et al., 1982). Later, ROSAT found a persistent X-ray source in this region (Rothschild et al., 1994).

The association of the SGR 0526-66 with N49 was sometimes questioned because of energy considerations (Mazets and Golentskii, 1981). For a distance of 55 kpc to the N49, the energy release in the March 5 event is $5 \times 10^{44}$ erg, and in the recurrent bursts, up to $8 \times 10^{42}$ erg, giving luminosities which exceed the Eddington limit for a neutron star by a factor of $10^4 - 10^6$ (Mazets and Golentskii, 1981). However arguments for large distances to the SGRs and, accordingly, for large energy releases continued to accumulate. Kulkarni and Frail (1993) established an association of the SGR 1806-20 with the supernova remnant G10.0-0.3, about 14 kpc distant (Corbel et al., 1997). Murakami et al. (1994) used ASCA to localize one of the events from SGR 1806-20 and discovered a soft X-ray source coinciding with its position. Subsequently, the observations of Kouveliotou et al. (1998) from RXTE revealed regular pulsations in the emission of this source with a period $P = 7.47$ s. A parallel analysis of ASCA archived data for 1992 confirmed this period and permitted determination of its derivative $\dot{P} = 2.6 \times 10^{-3}$ s yr$^{-1}$. 
SGR 1900+14 is located close to the G48.2+0.6 supernova remnant and is believed to be associated with it (Kouveliotou et al., 1994). Coinciding with this repeater in position is a soft X-ray source reliably localized from ROSAT (Hurley et al., 1996). ASCA observations of this source made in April 1998 revealed a 5.16-s periodicity of the emission (Hurley et al., 1999b). When the SGR 1900+14 resumed its activity in June and August 1998 (Hurley et al., 1999c), RXTE observations confirmed this period and established the spin-down rate of the neutron star $\dot{P} = 3.5 \times 10^{-3} \text{s yr}^{-1}$ (Kouveliotou et al., 1999).

RXTE observations also yielded some evidence for a possible 6.7-s periodicity of the new SGR 1627-41 (Dieters et al., 1998). Thus the known soft gamma repeaters exhibit an association with young ($< 10^4$ years) supernova remnants, a periodicity of 5-8 s, and a secular spin-down by a few ms per year. Thompson and Duncan (1995, 1996) suggested that the soft gamma repeaters are young neutron stars with superstrong, up to $10^{15}$ G, magnetic fields and high spin-down rates because of high losses due to magnetic dipole radiation – the so-called magnetars. The fractures produced by magnetic stress in a neutron star’s crust give rise to the release and transformation of magnetic energy into the energy carried away by particles and hard photons.

In this paper, we present the results of observations of recurrent bursts from SGR 1900+14 made in 1998 with a gamma-ray burst spectrometer onboard the Wind spacecraft (Aptekar et al., 1995).

2. OBSERVATIONS

Until 1998, recurrent bursts from the SGR 1900+14 were observed during two intervals: three events in 1979 (Mazets et al., 1979b) and another three in 1992 (Kouveliotou et al., 1993). SGR 1900+14 resumed burst emission in May 1998 (Hurley et al., 1998; Hurley et al., 1999d), which continued up to January 1999.

This time the frequency of recurrent bursts was found to be high and very irregular. Figure 1 shows the distribution within this time interval of the recurrent bursts with measured fluences $S$. Three subintervals with a distinctly higher source activity stand out. On August 27, 1998, SGR 1900+14 emitted a superintense outburst with a complex and spectacular time structure (Cline et al., 1998; Hurley et al., 1999d). This event is not shown in Fig. 1 because it will be considered in a separate paper (Mazets et al., 1999a). On May 30, 1998, an intense train of recurrent bursts occurred. Several tens of bursts varying in duration from 0.05 to 0.7 s arrived during as short a time as three minutes. The intervals between the bursts decreased at times to such an extent as to become comparable to the
duration of the bursts themselves, and the radiation intensity between them did not drop down to the background level. Figure 2 displays the most crowded part of the train. In Fig. 1 it is represented by the feature with total flux $S = 5.8 \times 10^{-5}$ erg cm$^{-2}$. The high burst occurrence frequency may cause losses in the information obtained. Readout of the information on a trigger event takes up about one hour. If other events arrive within this interval, only a very limited amount of the relevant information will be recorded in the housekeeping channel. Such cases did occur, and quite possibly they comprised two or three weaker trains of recurrent bursts, in particular, on September 1, 1998, 61232–61585 s UT, with a total flux $S \sim 2 \times 10^{-5}$ erg cm$^{-2}$, and on October 24, 1998, 4921–5348 s UT, with $S \sim 10^{-5}$ erg cm$^{-2}$.

All recurrent bursts are short events with a fairly complex time structure and soft energy spectra, which, when fitted with a $dN/dE \propto E^{-1} \exp(-E/kT)$ relation, are characterized by $kT \simeq 20 – 30$ keV. Figure 3 presents time histories of several events recorded before August 27. Their energy spectra are very similar. Figure 4 shows the spectrum of a burst on June 7. After the August 27 event, the second interval of increased activity began (see Fig. 1), but most of the bursts did not change their characteristics. Shown in Fig. 5 are time structures of a few events, and Fig. 6 displays a typical energy spectrum. The only pronounced difference in the period after August 27 was the onset of several long, up to 4 s, bursts with a correspondingly high total energy flux, up to $5 \times 10^{-5}$ erg cm$^{-2}$. Figure 7 presents time histories of two such bursts, with a typical energy spectrum shown in Fig. 8. Such long recurrent bursts were observed to be produced by other SGRs as well (Golenetskii et al., 1984).

As can be seen from these data, recurrent bursts exhibit a complex time structure, which cannot be described by a model of a single pulse with standard characteristic rise and decay times. The burst intensity rises in 15-20 ms. By contrast, long bursts take a substantially longer time to rise, up to $\sim 150$ ms (Fig. 7). In many cases the main rise is preceded by an interval with a weaker growth in intensity or even by a single weak pulse (Figs. 3 and 7). The intensity decay extends practically through the whole event. At the end of a burst one frequently observes a strong steepening of the falloff (Figs. 3 and 7). Large-scale details in the time structure may indicate that the bursts consist of several structurally simpler but closely related events (Figs. 3, 5, and 7).

The value of $kT$ for the photon spectra of different bursts lies in the 18-30 keV region. There is practically no spectral evolution within any one event, which is readily seen from Fig. 7. The maximum fluxes in a burst vary from $2 \times 10^{-6}$ to $5 \times 10^{-5}$ erg cm$^{-2}$ s$^{-1}$. However for 80% of events they lie within a narrow region of $(1 – 3) \times 10^{-5}$ erg cm$^{-2}$ s$^{-1}$. Fluences vary within broader ranges, from $10^{-7}$ to $5 \times 10^{-5}$ erg cm$^{-2}$. This implies that the
energy release is partially determined by the duration of the emission process in the source. Figure 9 presents a fluence vs duration distribution of bursts ($\lg S$ vs $\lg \Delta T_{0.25}$). The measure of burst duration $\Delta T_{0.25}$ is the time interval within which the radiation intensity is in excess of the 25% level of the maximum flux $F_{\text{max}}$. The graph demonstrates a strong correlation between these quantities ($\rho = 0.8$).

As follows from the data presented here, for a 10 kpc distance of the SGR 1900+14 source (Case and Bhattacharya, 1998; Vasisht et al., 1994), and assuming the emission to be isotropic, the maximum source luminosity in recurrent bursts lies within the range of $(1 - 4) \times 10^{41}$ erg s$^{-1}$, and the energy liberated in a recurrent burst is $2 \times 10^{39}$ to $8 \times 10^{41}$ erg.

3. CONCLUSION

The observations of this period of high activity of SGR 1900+14 have substantially broadened our ideas concerning such sources. The giant outburst on August 27 has come as a real surprise. Among other remarkable events is the intense train of bursts on May 30, 1998, when the frequency of recurrent bursts increased within a few minutes by at least a factor of $10^4$ compared to that usually observed during the reactivation periods of known SGRs. On the other hand, the characteristics of the bursts themselves, their time histories, spectra, and intensity do not suggest radical differences from those of recurrent events observed in other soft gamma repeaters (Kouveliotou et al., 1987; Frederiks et al., 1997; Mazets et al., 1999b), which argues for the fundamental similarity between the emission processes occurring in different sources. It appears significant that the giant outburst with an energy release thousands of times larger than that typical of a single recurrent event did not noticeably affect the behavior and individual characteristics of recurrent bursts.

Partial support of the RSA and RFBR (Grant 99-02-17031) is gratefully acknowledged.
REFERENCES

Aptekar, R.L., et al. 1995, Space Science Rev., 71, 265
Atteia, J.-L., et al. 1987, ApJ, 320, L105
Cline, T.L., et al. 1982, ApJ, 255, L45
Cline, T.L., Mazets, E.P., & Golenetskii, S.V. 1998, IAU Circ. 7002
Corbel, S., et al. 1997, ApJ, 478, 624
Dieters, S., et al. 1998, IAU Circ. 6962.
Frederiks, D.D., et al. 1997, in AIP Conf. Proc., v. 428, 4th Huntsville Symposium, Gamma-Ray Bursts, ed. Ch. Meegan, R. Preece, T. Koshut (New York, AIP), p. 921
Golenetskii, S.V., Ilyinskii, V.N., & Mazets, E.P. 1984, Nature, 307, 41
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, in press
Hurley, K., et al. 1999b, ApJ, 510, L111
Hurley, K., et al. 1999c, ApJ, 510, L107
Hurley, K., et al. 1999d, Nature, 397, 41
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. 1987, ApJ, 320, L111
Mazets, E.P., et al. 1979a, Nature, 282, 587
Mazets, E.P., Golenetskii, S.V., & Guryan, Yu.A. Soviet. Astron. Lett., 1979c, 5(No6), 343
Mazets, E.P., et al. 1981, Ap&SS, 80, 3
Mazets, E.P., & Golenetskii, S.V. 1981, Ap&SS, 75, 47
Mazets, E.P., et al. 1999a, Astronomy Letters, in press
Mazets, E.P., et al. 1999b, ApJ, in press
Murakami, T., et al. 1994, Nature, 368, 127
Rothschild, R., Kulkarni, S., & Lingenfelter R. 1994, Nature, 368, 432
Thompson, C. & Duncan, R.C. 1995, MNRAS, 275, 255
Thompson, C. & Duncan, R.C. 1996, ApJ, 473, 322
Vasisht, G., et al. 1994, ApJ, 431, L35
Woods, P.M., et al. 1999, ApJ, in press

This preprint was prepared with the AAS \LaTeX{} macros v4.0.
FIGURE CAPTIONS

Fig. 1.— Distribution of the recurrent-burst occurrence and fluences during the source reactivation period in 1998.

Fig. 2.— The interval with the highest occurrence frequency in the recurrent-burst train on May 30, 1998. G1 and G2 display 15–50 keV and 50–250 keV background-subtracted count rates, respectively.

Fig. 3.— Time structure of several bursts recorded before the August 27 giant burst.

Fig. 4.— A typical energy spectrum of one of the bursts displayed in Fig. 3 (980607a).

Fig. 5.— Time structures of bursts observed after the August 27 event.

Fig. 6.— A typical energy spectrum of one of the bursts (Fig. 5, 981031a).

Fig. 7.— Time histories of two long recurrent bursts recorded in the 15–50 and 50–250-keV energy windows. The behavior of the count-rate ratio of these windows, which characterizes the spectral rigidity, does not practically reveal any spectral evolution in the SGR 1900+14 bursts.

Fig. 8.— The spectrum of the 981028b burst.

Fig. 9.— The strong correlation between the fluence and duration of a burst implies that the energy release in a source is proportional to the duration of emission for a small luminosity scatter.
Fig. 1. Distribution of the recurrent-burst occurrence and fluences during the source reactivation period in 1998.
Fig. 2. The interval with the highest occurrence frequency in the recurrent-burst train on May 30, 1998. G1 and G2 display 15-50 keV and 50-250 keV background-subtracted count rates, respectively.
Fig. 3. Time structure of several bursts recorded before the August 27 giant burst.
Fig. 4. A typical energy spectrum of one of the bursts displayed in Fig. 3 (980607a).
Fig. 5. Time structures of bursts observed after the August 27 event.
**Fig. 6.** A typical energy spectrum of one of the bursts (Fig. 5, 981031a).
Fig. 7. Time histories of two long recurrent bursts recorded in the 15-50 and 50-250 keV energy windows. The behavior of the count-rate ratio of these windows, which characterizes the spectral rigidity, indicates little spectral evolution in the SGR 1900+14 bursts.
Fig. 8. The spectrum of the 981028b burst.
**Fig. 9.** The strong correlation between the fluence and duration of a burst ($\rho = 0.8$) implies that the energy release in a source is proportional to the duration of emission with a small luminosity scatter.