Properties of Konus-Wind SGR bursts

A V Kozlova on behalf of the Konus-Wind team
Ioffe Institute, 26 Polytekhnicheskaya, St. Petersburg, 194021, Russia
E-mail: ann_kozlova@mail.ioffe.ru

Abstract. We present preliminary results of systematic temporal and spectral analysis of the Konus-Wind observational data on short and intermediate SGR bursts. We conclude that the burst energy spectra are equally well described, in the 20−200 keV range, by both power-law with an exponential cutoff, and double black-body functions. We also discuss energetics and durations of the bursts, distributions of the spectral parameters and correlations between them.

1. Introduction
Soft gamma repeaters (SGRs) are a rare, enigmatic class of astrophysical objects. There are 25 sources discovered during more than 30 years of observations [1]. The SGRs are believed to be isolated neutron stars with rotation periods of ∼ 5−12 s and inferred surface magnetic field strength $B \sim 10^{14} − 10^{15}$ G. They are characterized by sporadic and unpredictable periods of bursting activity in soft gamma-rays (≤ 200 keV). These periods of activity may last from few days to few years and are separated by long periods of quiescence, where a much weaker persistent X-ray source observed. The bursting activity is quite diverse and consists of three types of events: the most intense, giant flares, characterized by short, hard initial pulse having a huge energy release of $\sim 10^{44}−10^{46}$ erg followed by a long-duration decaying tail; the most frequent short duration bursts with peak luminosity $L_{max} < 10^{42}$ erg/s; and intermediate bursts with energies and luminosities between the short bursts and giant flares.

From its launch in 1994, Konus-Wind (KW) has detected ∼ 250 bursts from 6 SGRs. In next section we present the results of systematic temporal and spectral analyses of 201 short and intermediate bursts from 5 SGRs. Giant flares and burst series were excluded from our analysis since they require a special treatment. Also, we do not include SGR 0501+4516 because of a very low burst statistics. The results of KW study of this SGR have been already published in [2].

2. Results and Discussion
Our analyses include 106 bursts from SGR 1806-20, 47 bursts from SGR 1900+14, 14 bursts from SGR 1627-41, 22 bursts from SGR 1550-5418, and 12 bursts from SGR 1935+2154. For each studied SGR we investigate the distribution of $T_{90}$ parameter, defined as the time during which 90 % of the total burst counts have been accumulated. SGR 1806-20, with the greatest number of intermediate bursts, have a longer average burst duration of ∼ 0.7 s compared to ∼ 0.2 s for the rest. All durations fall well within the same order of magnitude, indicating a similar origin for the bursts across the SGR population.
Motivated by our previous work [3] and results obtained in other studies (e.g.,[4, 5]), two model functions were used to fit time-integrated spectra: the power-law with an exponential cutoff (CPL) model, parametrized as $E_p$: $f(E) \propto E^\alpha \exp\left(-\frac{2+\alpha}{E_p}E\right)$, where $\alpha$ is the power-law (PL) photon index and $E_p$ is the peak energy in the $\nu F_\nu$ spectrum and a sum of two black-body (BB) functions with the normalization proportional to the surface area (2BB). Our spectral analysis shows that the KW-measured SGR spectra are equally well described, in the 20–200 keV range, by both CPL and 2BB models. For each SGR, a mean $\Delta \chi^2$ between those model fits is less than 4. A detailed study of the bright burst from SGR 1935+2154 [3] showed that such a difference in $\chi^2$ does not allow to favour any of the models even in the case of a high count statistics.

The obtained burst energetics is shown in figure 1 with the peak flux vs the total fluence distribution for each SGRs. These parameters are calculated using the best-fit model flux in the 20 to 200 keV range. In the spectral fits with the CPL model, we find $E_p$ value distributions peak between 20 and 40 keV similar for all studied SGRs. The observed variety in $\alpha$ distributions between different SGR sources ($\alpha \sim -1.2$ for SGR 1806-20, $\alpha \sim -0.5$ for SGR 1900+14 and SGR 1550-5418, $\alpha \sim -0.2$ for SGR 1627-41, $\alpha \sim 0.2$ for SGR 1935+2154) confirms the results obtained in previous studies [5, 6, 7] and could arise from differences in value of magnetic field, geometry, or plasma temperature. The temperatures and emission areas we find for the 2BB model are similar among SGRs: low-kT $\sim 3 - 7$ keV, $R_{\text{low-kT}} \sim 13 - 100$ km and high-kT $\sim 11 - 16$ keV, $R_{\text{high-kT}} \sim 3 - 10$ km. These values are consistent with those found in others studies [6, 8, 9]. The 2BB temperatures are distributed in rather narrow ranges for all of the bursts, despite orders of magnitude difference in energy release. This suggests that these parameters depend weakly on either the burst magnitude or morphology.
SGR 1806-20  
SGR 1900+14  
SGR 1627-41  
SGR 1550-5418  
SGR 1935+2154

Figure 3. Correlations between the emitting areas corresponding to the low-kT and high-kT BBs.

In figures 2, 3 we show that 2BB temperatures are well correlated, and the same is true for their emission areas. For SGR1806-20 we find that the temperatures of the low-kT BB vs high-kT BB are best fit with a broken power law (BPL) with the break located at ~ 4 and 11 keV. This result is consistent with the time-resolved spectroscopy of GBM bursts from SGR 1550-5418 [10]. Other SGRs distributions do not require BPL and show only a positive correlation between the low- and high-kTs. The areas of the emitting regions of the low- and high-kT BBs are positively correlated for all SGRs. It is consistent with the reports on time-integrated analysis in the literature (e.g. [9]). The slope of PL fit for low-kT vs high-kT distribution obtained for SGR 1550-5418 (see figure 3) is much shallower than the 1.86 ± 0.09, previously reported in [5]. However, we note that this difference could arise from the 8 – 200 keV GBM energy range, which is softer than energy range covered in our work. We also investigated (see figure 4) the relation between the emission area and temperature for both BB components simultaneously. All SGRs showed a similar trend: the area of low-kT BB decreases with kT at a

Figure 4. Correlations between the radii of the emission areas vs temperature for both BBs simultaneously.
slower pace than the area of the high-kT BB. A further study of such similarities, distinctions, and individual features should lead to a deeper understanding of the emission mechanism taking place during SGR bursts.

Acknowledgments
This work is supported by RFBR grant 15-02-00532.

References
[1] Olausen S A and Kaspi V M 2014 ApJS 212 6
[2] Aptekar R L, Cline T L, Frederiks D D, Golenetskii S V, Mazets E P and Pal’shin V D 2009 ApJL 698 L82–L85
[3] Kozlova A V et al. 2016 MNRAS 460 2008–2014
[4] Lin L, Kouveliotou C and van der Horst A J 2011 ApJ 739 87
[5] van der Horst A J et al. 2012 ApJ 749 112
[6] Feroci M, Caliandro G A, Massaro E, Mereghetti S and Woods P M 2004 ApJ 612 408–413
[7] Lin L et al. 2012 ApJ 756 54
[8] Olive J F, Hurley K, Sakamoto T, Atteia J L, Crew G, Ricker G, Pizzichini G, Barraud C and Kawai N 2004 ApJ 616 1148–58
[9] Nakagawa Y et al. 2007 PASJ 59 653–78
[10] Younes G et al. 2014 ApJ 785 52