Properties of Konus-Wind SGR bursts

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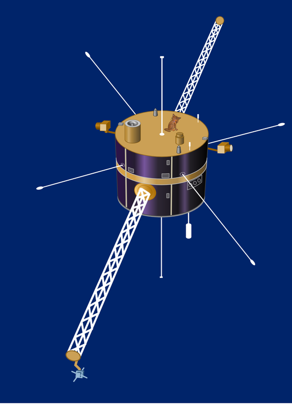


Abstract

We review the preliminary results of systematic temporal and spectral analysis of the KW 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 (CPL), and double blackbody (2BB) functions. We also discuss energetics and durations of the bursts, distributions of spectral parameters and correlations between them.

Introduction

The soft gamma repeaters (SGRs) are a rare, enigmatic class of astrophysical objects. There are 15 sources discovered during more than 30 years of observations. SGRs are believed to be isolated neutron stars with rotation periods of $\sim 5-12$ s and inferred surface magnetic field strength $B \sim 10^{15}$ G. They are characterized by sporadic and unpredictable periods of bursting activity in soft gamma-rays (< 200 keV). These periods of activity usually last between few days and few weeks and are separated by periods of quiescence of several years, where a much weaker ($L \sim 10^{35}-10^{36}$ erg/s; $0.5-10$ keV) persistent X-ray source observed.

The bursting activity is quite diverse:

- Short bursts (most common, duration $t \sim 0.1$ s, peak luminosity $L_{max} < 10^{42}$ erg/s, total energy release $E_{tot} \leq 10^{41}$ erg)
- Intermediate bursts ($t \sim 1-40$ s, $L_{max} \sim 10^{42}-10^{43}$ erg/s, $E_{tot} \sim 10^{41}-10^{43}$ erg)
- Giant flares (3 events so far; initial short ($t < 1$ s) and hard ($L_{max} \sim 10^{45}-10^{47}$ erg/s, $E_{tot} \sim 10^{44}-10^{46}$ erg) spike followed by a much longer (~ 6 min) tail, modulated with the spin period of the neutron star.

From its launch in 1994, Konus-*Wind* (KW) has detected ~ 250 bursts from 6 SGRs.

KW SGRs Properties

Table: KW SGRs detection statistics

Name	Type of bursts: Sb	Ib	GF	Series	Total
SGR 1806-20	~ 88	~ 30	1	14	133
SGR 1900+14	~ 49	~ 6	1	10	66
SGR 1627-41	~ 9	~ 2	0	3	14
SGR 0501+4516	5	0	0	0	5
SGR 1550-5418	~ 22	~ 3	0	3	28
SGR 1935+2154	~ 10	~ 3	0	0	13

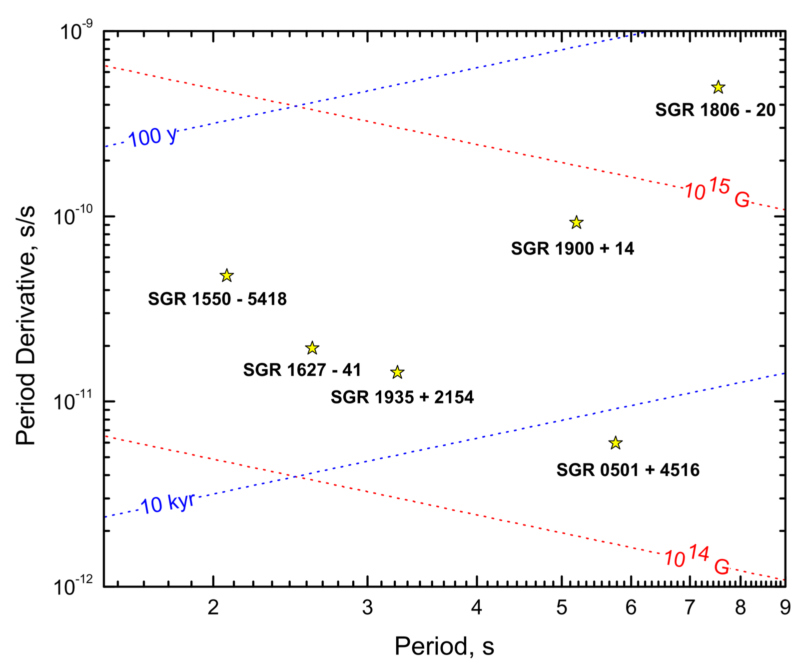


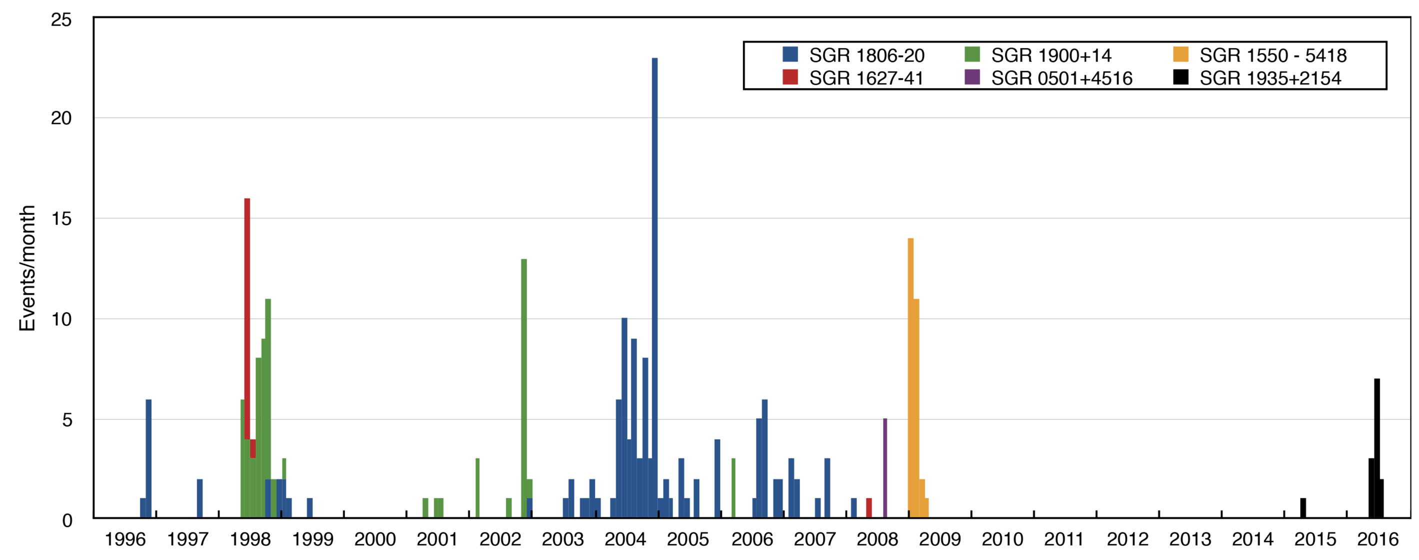
Table: SGRs Associations and Distances

Name	Distance (kpc)	Proposed Associations
SGR 1806-20	9 ± 2	W31, MC 13A, Star cluster
SGR 1900+14	12.5 ± 1.7	Star cluster
SGR 1627-41	11.0 ± 0.3	CTB 33, MC 71, SNR G337.00.1
SGR 0501+4516	~ 2	SNR G160.9+2.6*
SGR 1550-5418	6 ± 2	SNR G327.240.13
SGR 1935+2154	$\cdots$	SNR G57.2+0.8*

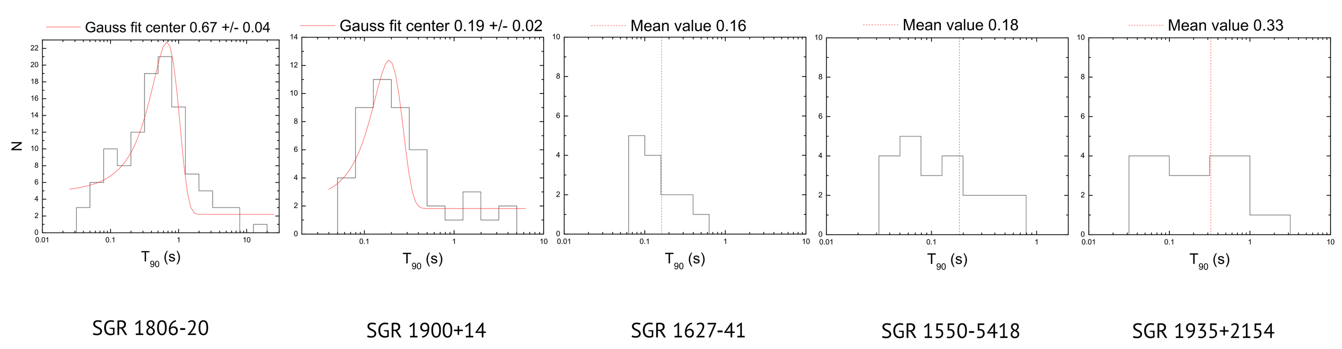
Note. — * This association is unconfirmed.

Temporal and spectral analysis

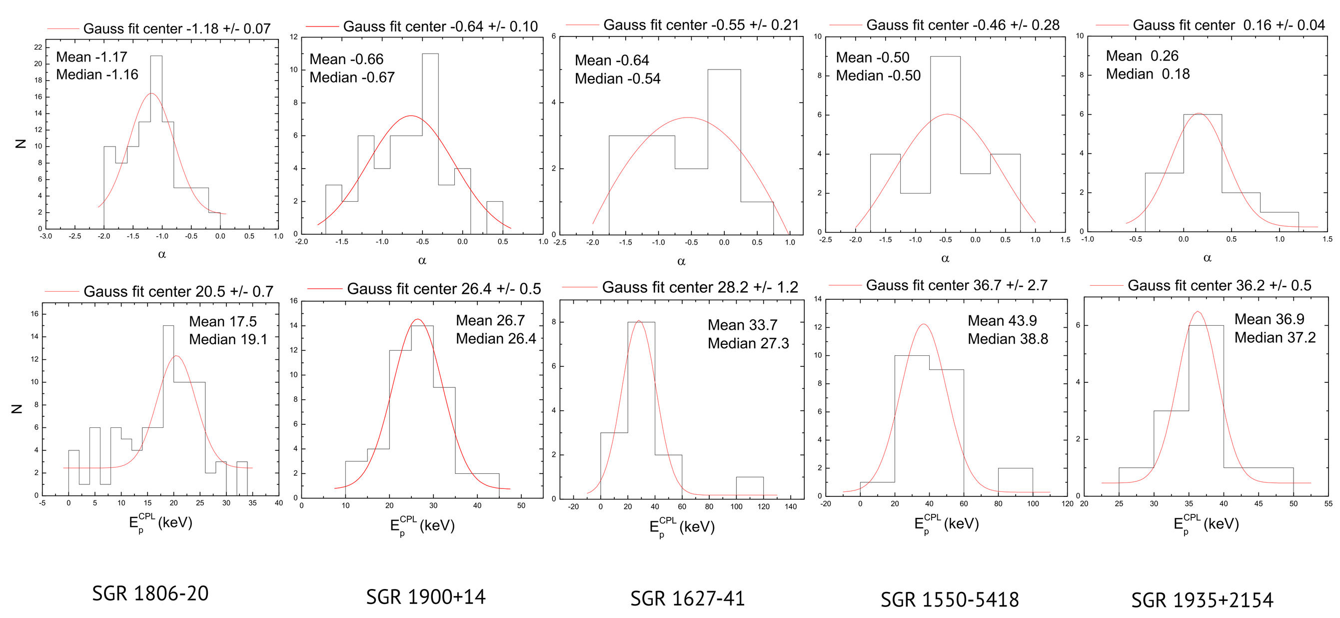
KW SGRs activity history



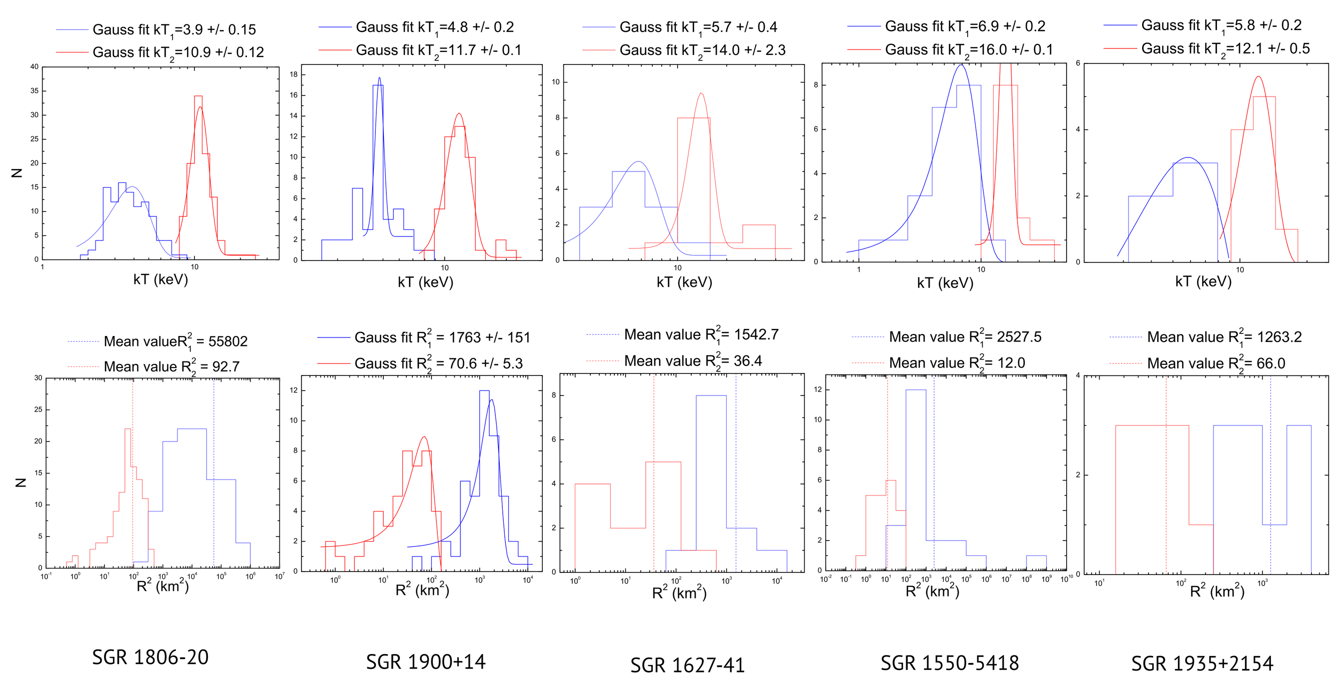
Distributions of T_{90}.



Distributions of CPL model parameters: index α and E_p.

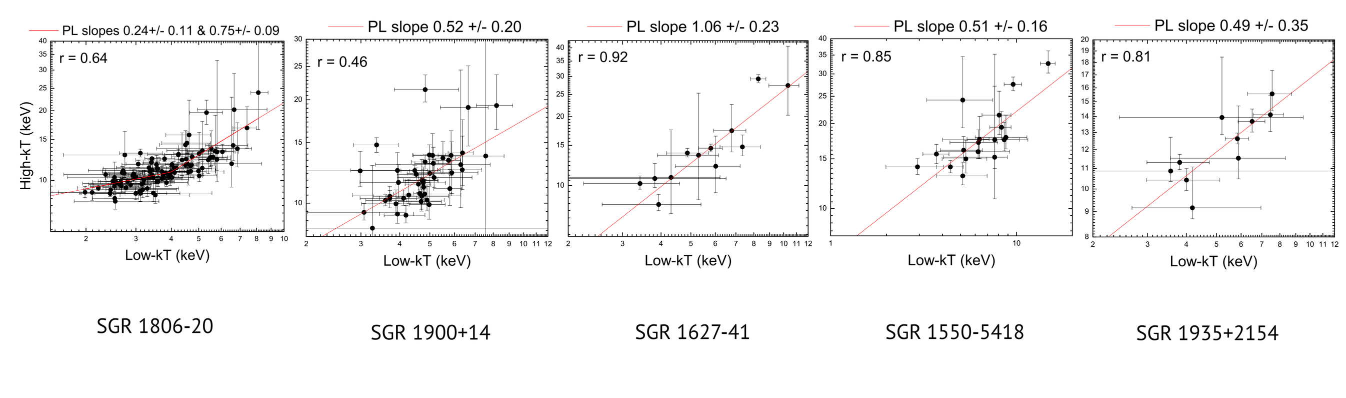


Distributions of 2BB model parameters: blackbody temperatures and radii of the emission areas.

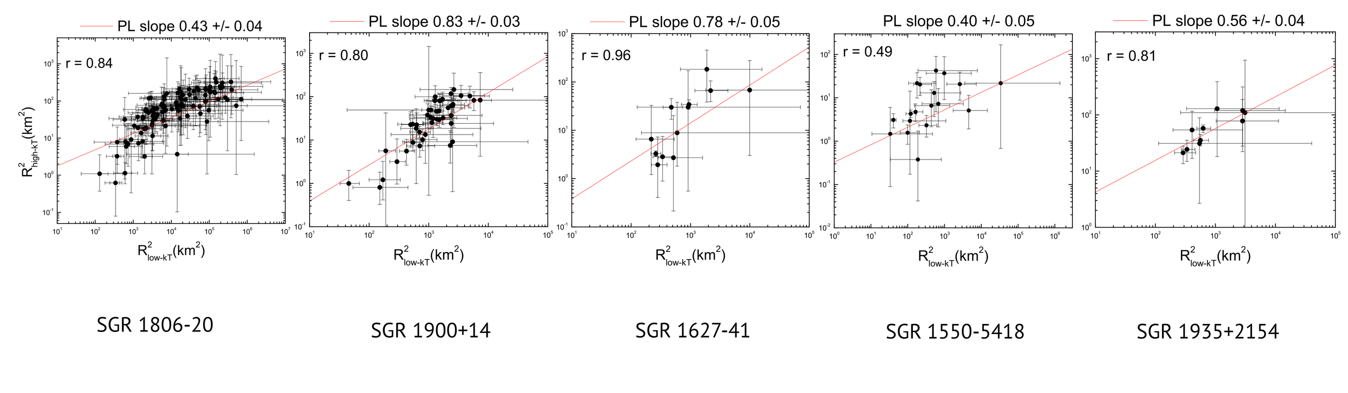


Parameters correlations

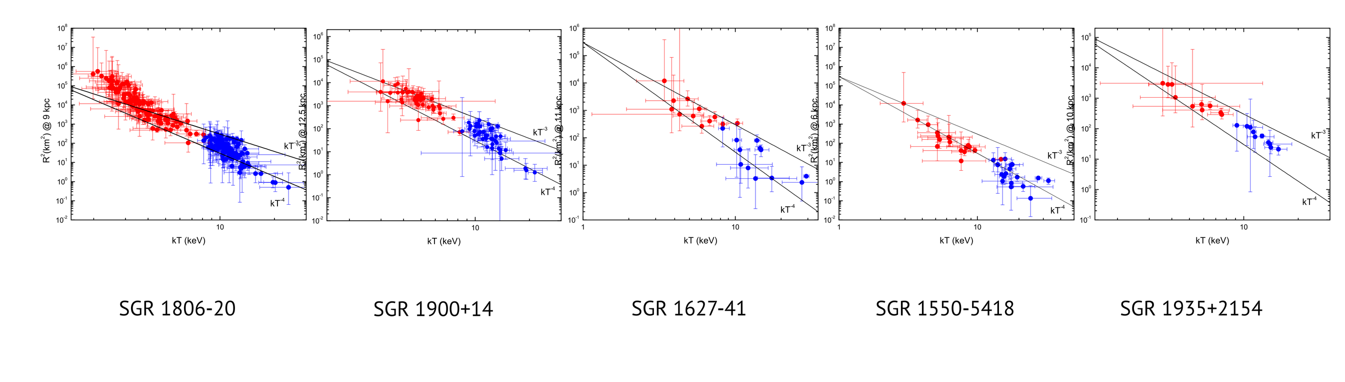
Correlations between temperatures of the low temperature (low-kT) BB vs high temperature (high-kT) BB



Correlations between the radii of the emission areas corresponding to the low-kT and high-kT BBs



Correlations between the radii of the emission areas vs temperature for both BBs simultaneusly



Results and Discussion

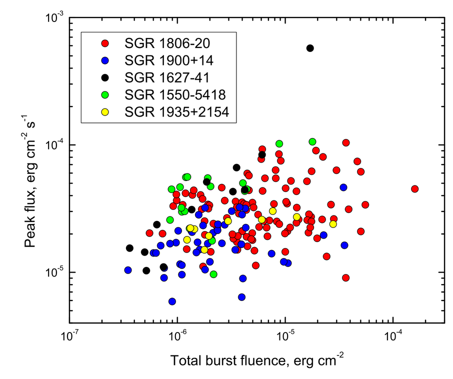
Here, we present the results of systematic temporal and spectral analyses of 201 short and intermediate bursts from 5 SGRs. Giant flares and burst series were excluded from our analysis since they require a special treatment. Also, we do not include SGR 0501+4516 because of a very low burst statistics. The results of KW study of this SGR have been already published in [1].

We show the distributions of T_{90} for 5 studied SGRs. 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 [2] and results obtained in other studies (e.g.[3, 4]), two model functions were used to fit time-integrated spectra: the CPL model, parametrized as E_p:

$$f(E) \propto E^{\alpha} \exp(-(2+\alpha)E/E_p),$$

where α is the power-law (PL) photon index and E_p is the peak energy in the νF_ν spectrum and a sum of two BB functions with the normalization proportional to the surface area (2BB). Our spectral analysis shows that the KW-measured SGR spectra are equally well descibed by both CPL and 2BB models. For each SGR, a mean $\Delta\chi^2$ between those model fits is less than 4. This corresponds to a p-value = 0.04.

The obtained burst energetics is shown 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. The obtained E_p value distributions peak between 20 and 40 keV. The observed variety in α distributions between different SGR sources confirms the results obtained in previous studies [4, 5, 6] 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: $kT_1 \sim 3-7$ keV, $R_1 \sim 13-100$ km and $kT_2 \sim 11-16$ keV, $R_2 \sim 3-10$ km. These values are consistent with those found in others studiers[5, 7, 8]. 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.



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 [9]. 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 integrated analysis in the literature. But in work [4] the slope of PL fit for temperatures is much steeper (1.86 ± 0.09) than obtained here for SGR 1550-5418. We also investigated 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 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.

References

[1] Aptekar et al. Konus-Wind Observations of the New Soft Gamma-Ray Repeater SGR 0501+4516. *ApJL*, 698, 2009.

[2] Kozlova et al. The first observation of an intermediate flare from SGR 1935+2154. *MNRAS*, 460, 2016.

[3] Lin et al. Fermi/Gamma-Ray Burst Monitor Observations of SGR J0501+4516 Bursts. *ApJ*, 739, 2011.

[4] van der Horst et al. SGR J1550-5418 Bursts Detected with the Fermi Gamma-Ray Burst Monitor during its Most Prolific Activity. *ApJ*, 749, 2012.

[5] Feroci et al. Broadband X-Ray Spectra of Short Bursts from SGR 1900+14. *ApJ*, 612, 2004.

[6] Lin et al. Broadband Spectral Investigations of SGR J1550-5418 Bursts. *ApJ*, 756, 2012.

[7] Olive et al. Time-resolved X-Ray Spectral Modeling of an Intermediate Burst from SGR 1900+14 Observed by HETE-2 FREGATE and WXM. *ApJ*, 616, 2004.

[8] Nakagawa et al. A Comprehensive Study of Short Bursts from SGR1806-20 and SGR1900+14 Detected by HETE-2. *PASJ*, 59, 2007.

[9] G. Younes et al. Time resolved spectroscopy of sgr j1550−5418 bursts detected with fermi/gamma-ray burst monitor. *ApJ*, 785, 2014.

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