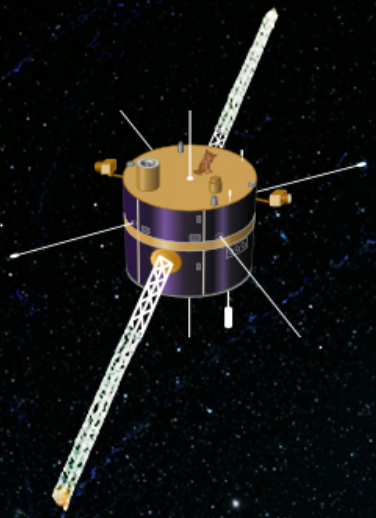
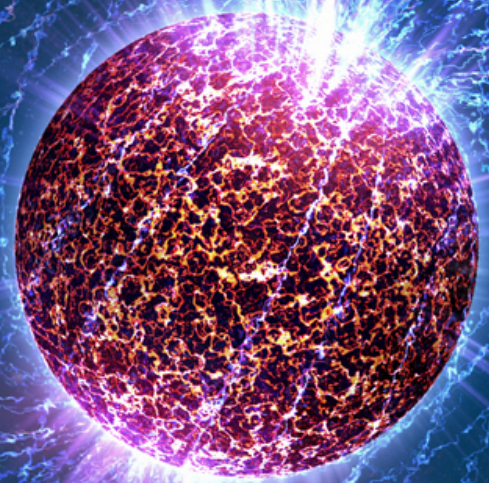


Ioffe Workshop on GRBs and other Transient Sources: 25 years of Konus-Wind

September 9–13, 2019, St.Petersburg, Russia



SGR observations with Konus-Wind

Anna Kozlova, Ioffe Institute

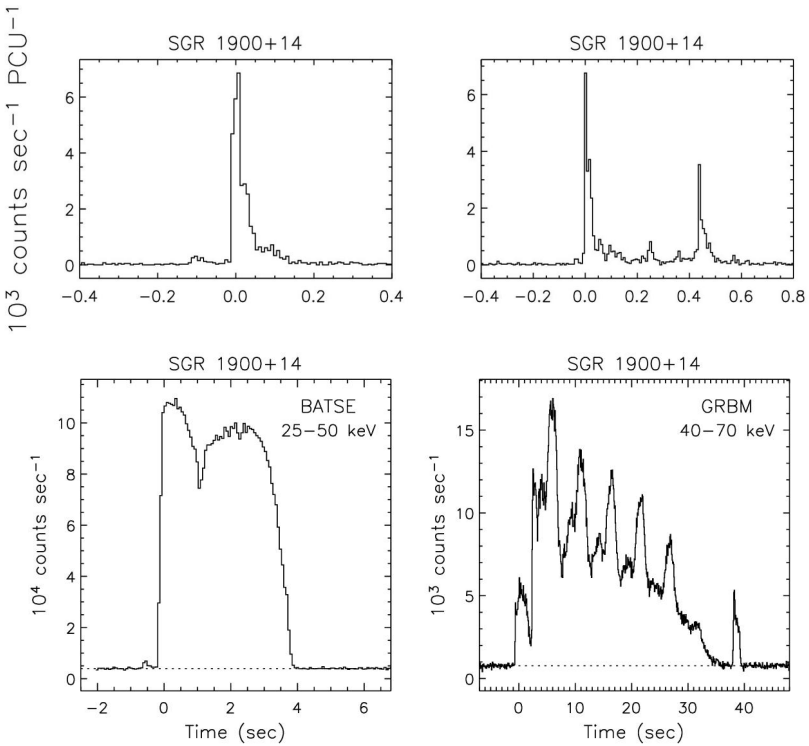
✉ ann_kozlova@mail.ioffe.ru

- Spin periods in a very narrow range $P \sim 2 - 12$ s,
- Huge spin-down rates $\dot{P}/P \sim 10^{-10}$ s/s,
- Persistent soft X-ray sources with $L \sim 10^{34} - 10^{36}$ erg/s,
- Sporadic bursting activity in hard X-rays/soft gamma-rays

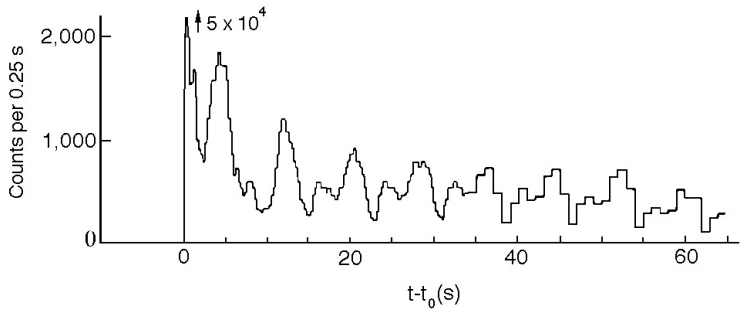
The SGRs are believed to be isolated neutron stars with the high magnetic field ($B \sim 10^{14} - 10^{15}$ G) - magnetars.

See arXiv:astro-ph/0406133 ; arXiv:0804.0250

SGRs: Types of activity



(Woods & Thompson, 2004)



(Мазец и др., 1979)

Short Bursts

- most frequent
- lasts ~ 0.1 s
- $E_{tot} \sim 10^{38} - 10^{40}$ erg

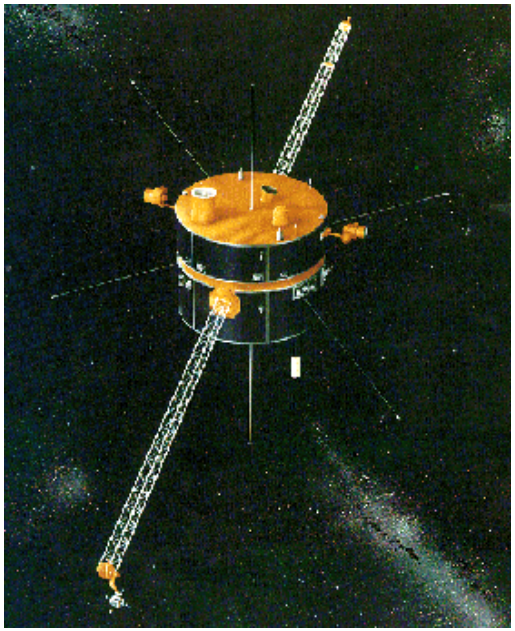
Intermediate Flares

- lasts $\sim 1 - 40$ s
- $E_{tot} < 10^{42}$ erg

Giant Flares

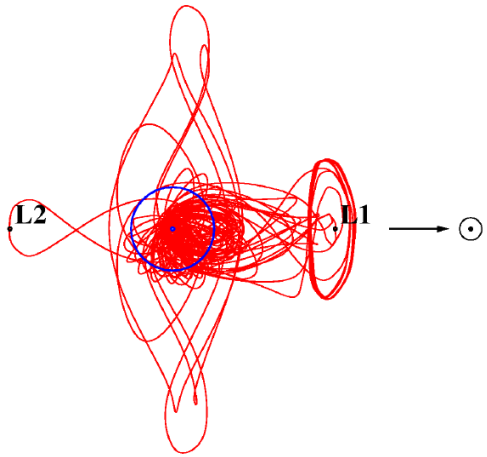
- so far, only 3 GF have been observed
- decaying tail modulated with the NS rotation period
- $E_{tot} \sim 10^{44} - 10^{46}$ erg

Konus-Wind experiment

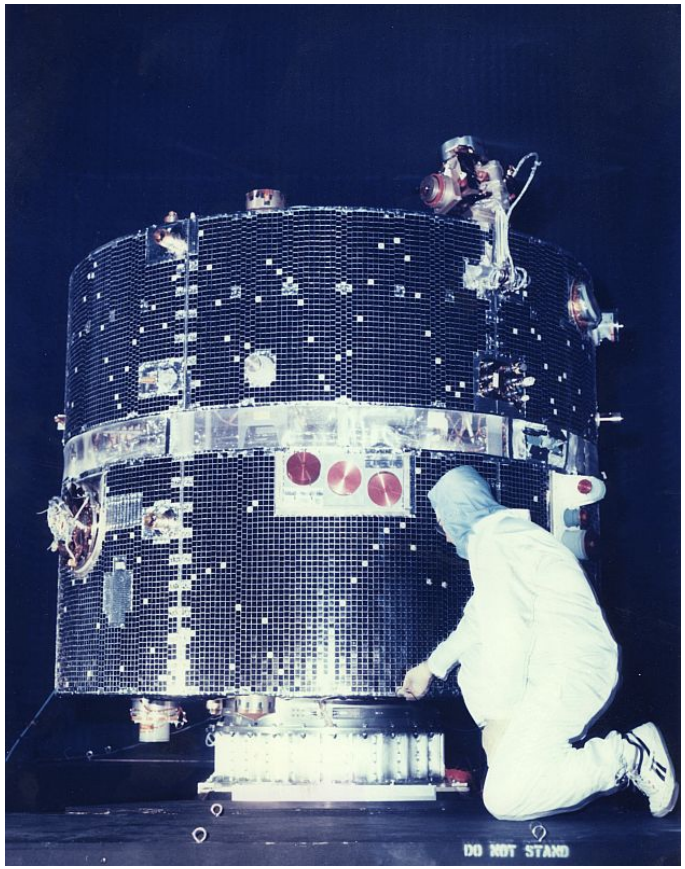


- Launched on November 1, 1994
- 25 years of continuous all sky observation!

Now in orbit near L1, up to 2.1 million km ($\sim$ 7 light s) from Earth.

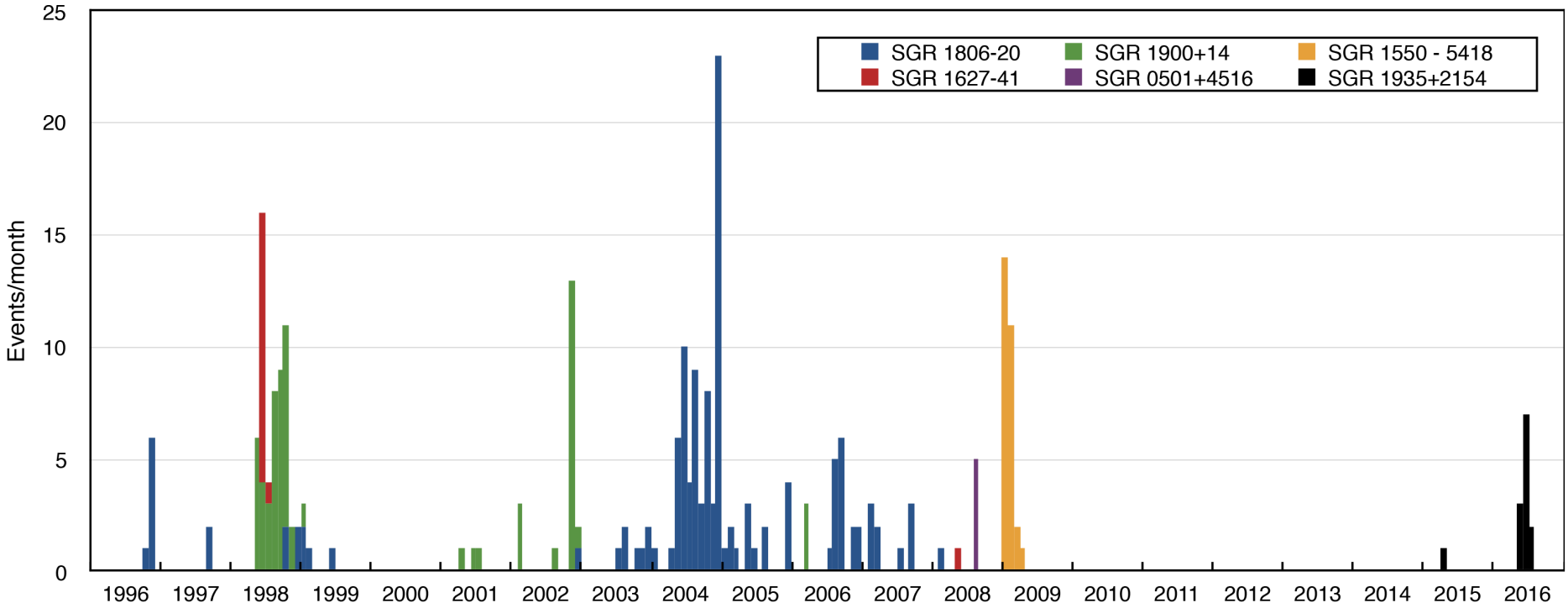


Konus-Wind experiment



- Two NaI(Tl) detectors
- 4π FoV, 20 keV - 15 MeV, $S_{eff} \sim 100 - 160$ cm^2
- KW operates in two modes:
  - "waiting"(continuous) mode (2.944 s resolution)
  - "burst"(triggered) mode (2 ms – 256 ms, from $T_0 - 0.512$ s to $T_0 + 230$ s)

All KW SGR triggers

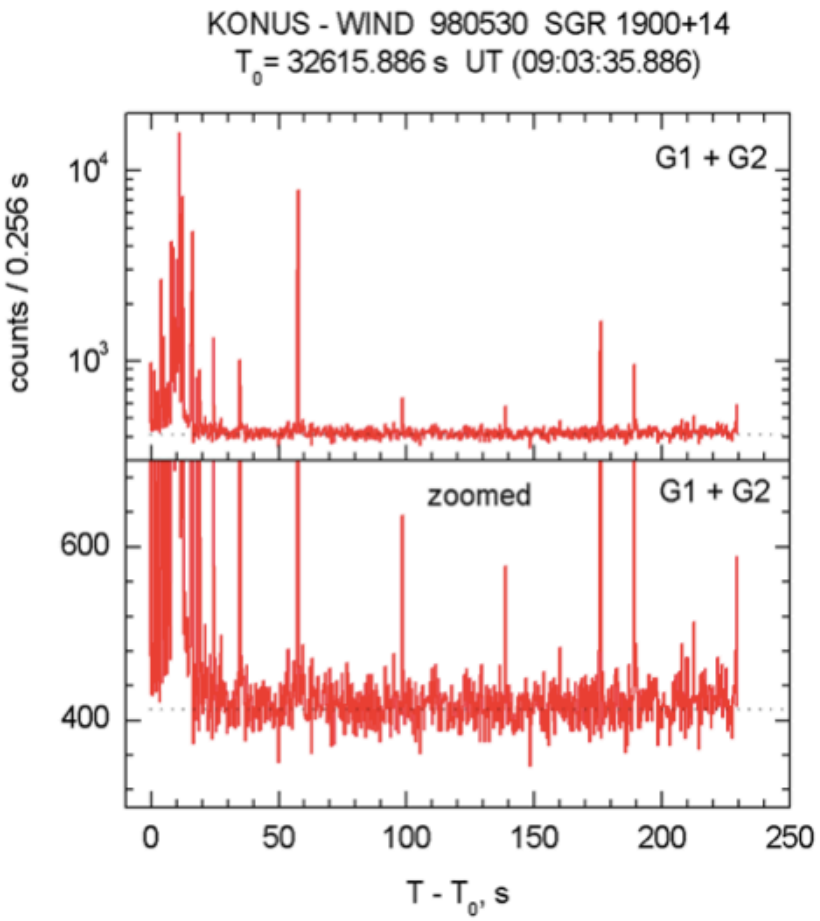


KW SGR detection statistics

Name	Type of bursts			Series	Total	Distance (kpc)	Proposed Associations
	Sb	Ib	GF				
SGR 1806-20	~ 88	~ 30	1	14	133	9 ± 2	W31, MC 13A, Star cluster
SGR 1900+14	~ 49	~ 6	1	10	66	12.5 ± 1.7	Star cluster
SGR 1627-41	~ 9	~ 2	0	3	14	11.0 ± 0.3	CTB 33, MC 71, SNR G337.00.1
SGR 0501+4516	5	0	0	0	5	~ 2	SNR G160.9+2.6*
SGR 1550-5418	~ 22	~ 3	0	3	28	6 ± 2	SNR G327.240.13
SGR 1935+2154	~ 10	~ 3	0	0	13	$\cdots$	SNR G57.2+0.8*

Note. — * This association is unconfirmed.

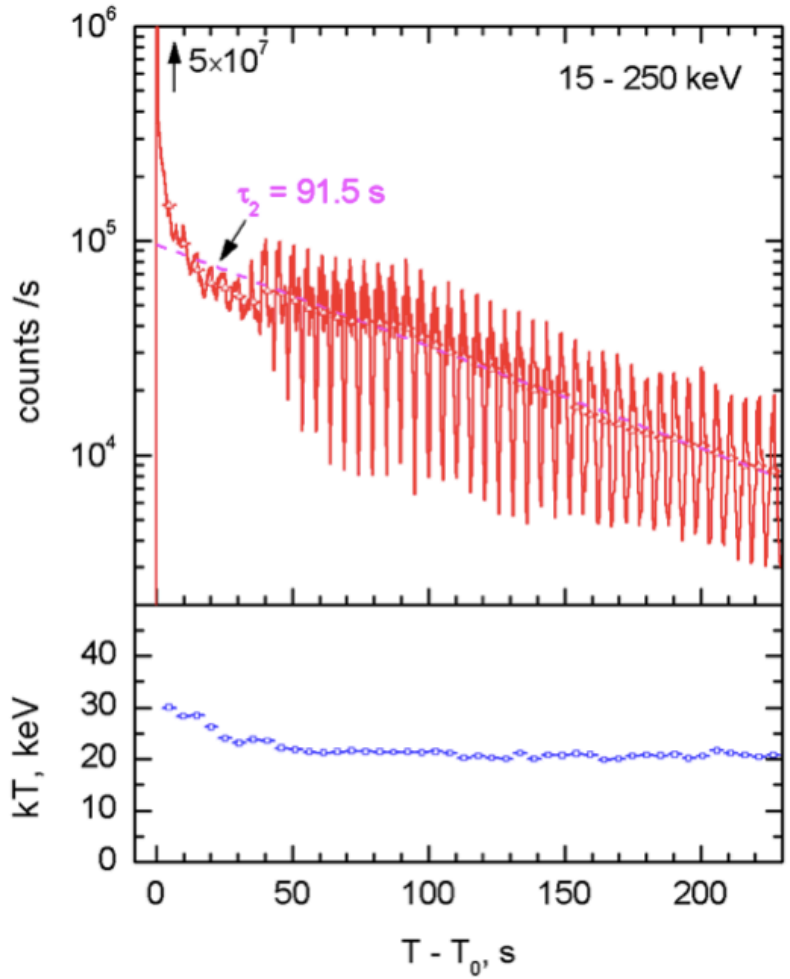
KW observation of SGR 1904+14 GF



Aptekar et al., ApJS (2001)

- 980530 burst "series"(cluster): multiple closely packed and partially overlapped bursts
- Duration > 250 s
  Fluence $> 5 \times 10^{-5}$ erg/cm^2
  $E_{tot} \sim 1.1 \times 10^{42}$ erg
- The series appeared three months before the GF

KW observation of SGR 1904+14 GF

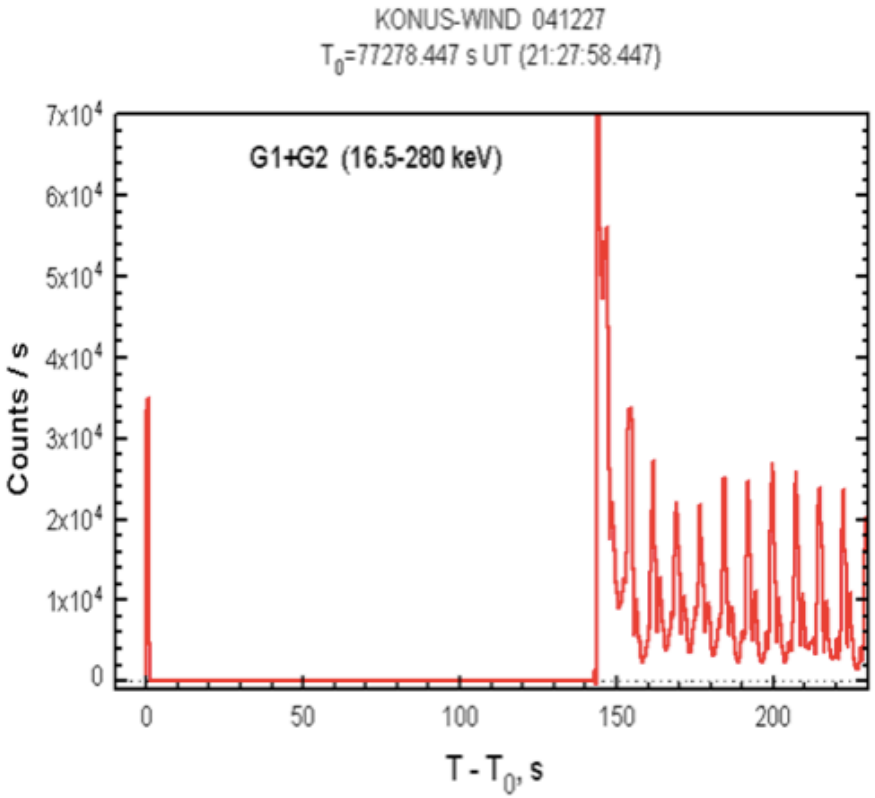


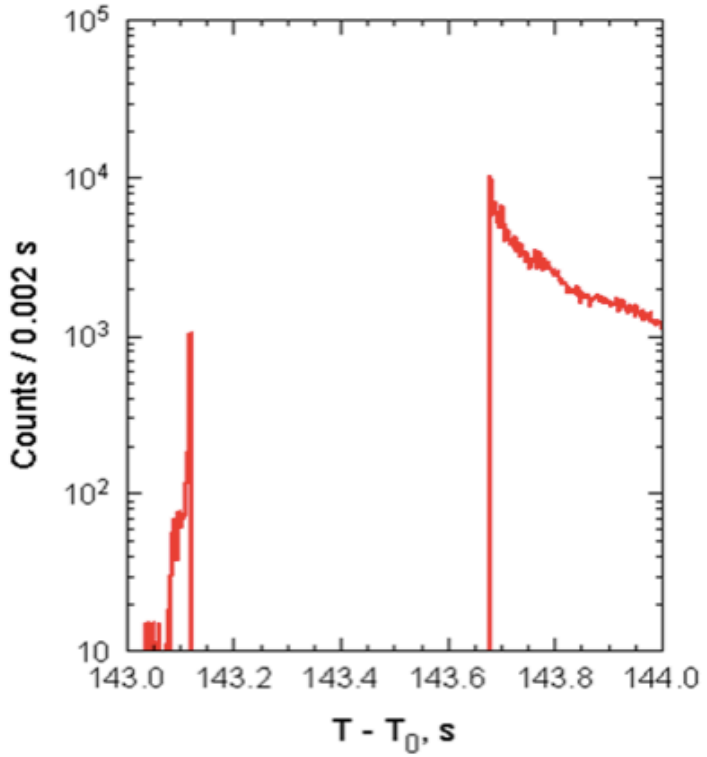
Hurley et al., Nature (1999);
Mazets et al., Ast. Lett. (1999)

- SGR 1900+14 Giant Flare on 1998 Aug 27 ∼20 yrs after the March 5 event
- Giant, hard initial pulse saturated the KW detectors for ∼200 ms. $E_{tot} > 6.8 \times 10^{43} d_{10}^2$ erg (Mazets et al., 1999) $E_{tot} \sim 1.9 \times 10^{44} d_{10}^2$ erg (Tanaka et al., 2007)
- The energy emitted in the soft pulsating tail was similar to that of the March 5 flare

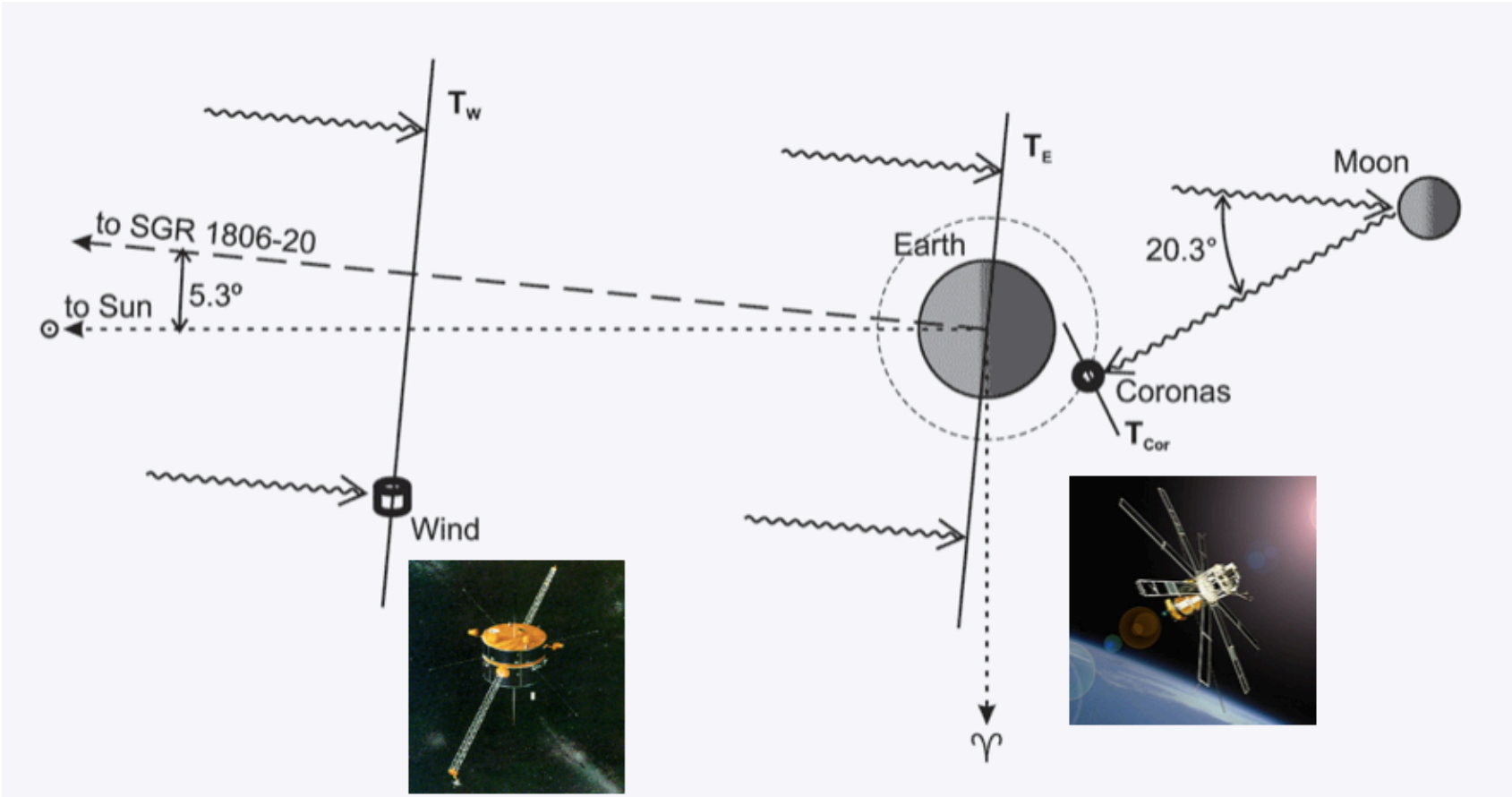
SGR 1806-20 Giant Flare on 2004 Dec 27

- 3rd in history and the most powerful GF yet
- Detected by 6 spacecraft
- full detector saturation for $\sim$ 500 ms

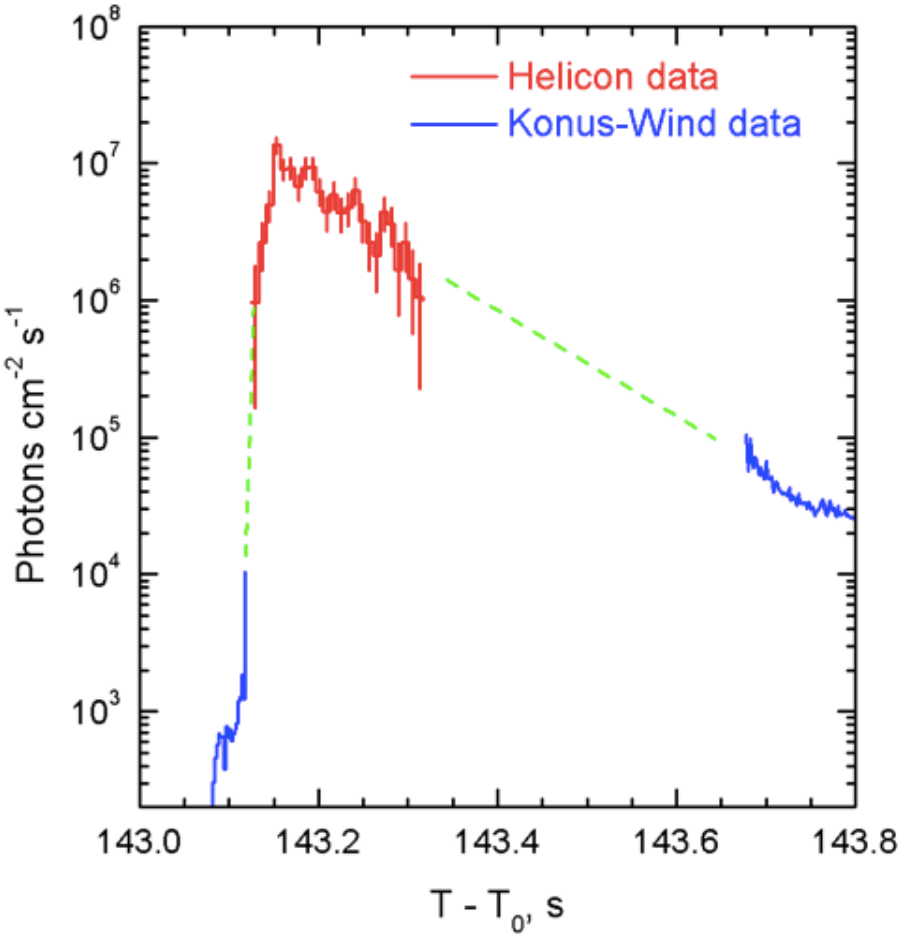




KW and Helicon (CORONAS-F) simultaneous observations of GF from SGR 1806-20 on December 27, 2004 (Frederiks et al., Ast. Lett., 2007)



Reconstructed light curve of the initial pulse

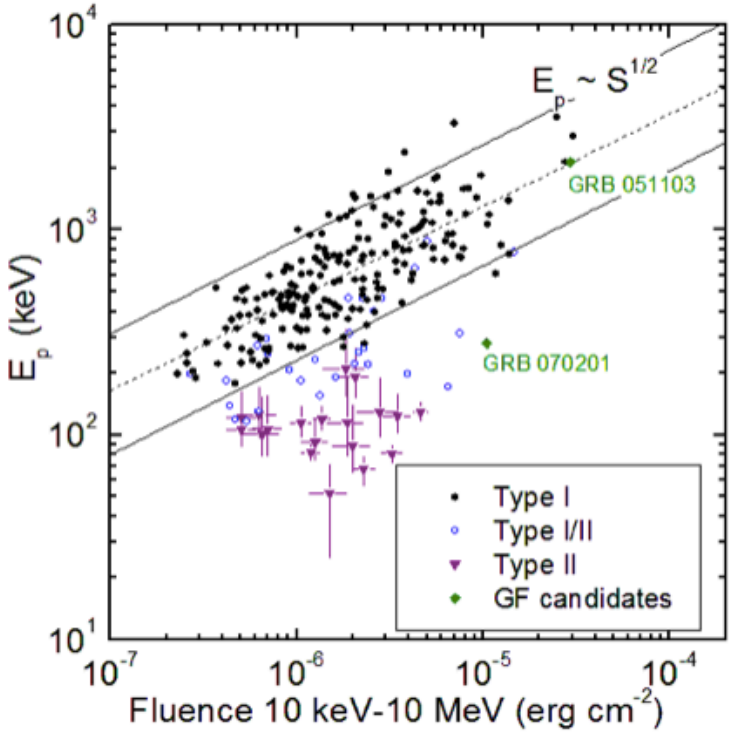


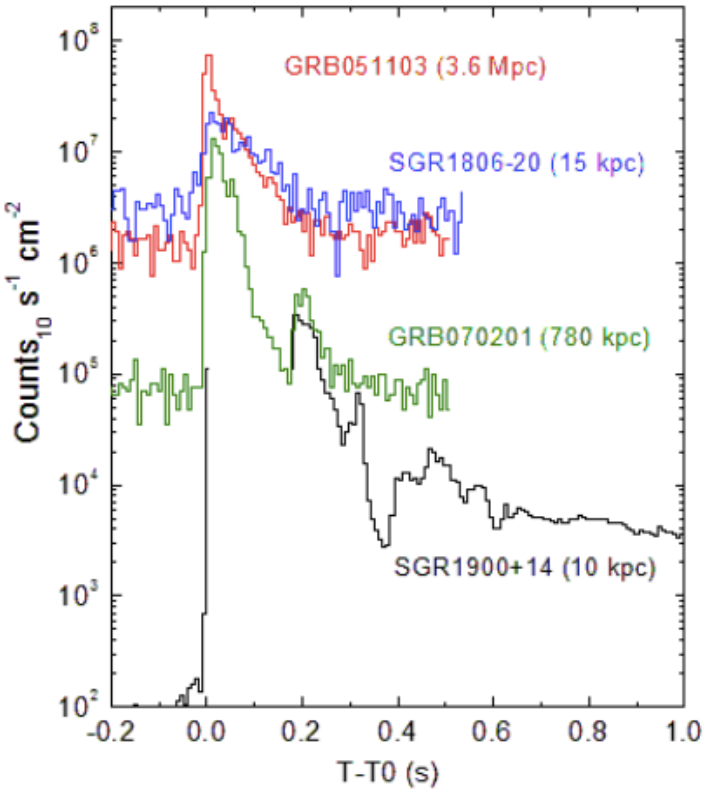
Frederiks et al., Ast. Lett. (2007)

- $E_{tot} = 2.3 \times 10^{46}$ erg; $L = 3.5 \times 10^{47}$ erg/s
- The GF is ~ 100 times brighter than of SGR 1900+14 GF
- The pulsating tail energetics was similar to that of the two previous GFs
- Due to the enormous luminosity of the initial pulse, GFs can be detected from SGRs in nearby galaxies.

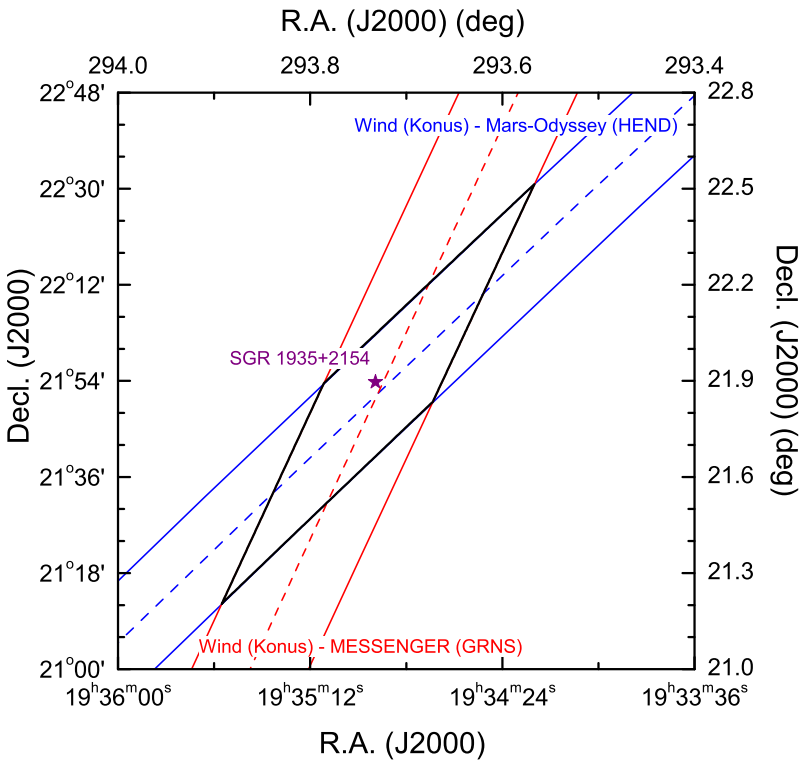
KW observation of extragalactic SGR GFs

- Two extragalactic GF candidates have been detected, so far: GRB 051103 and GRB 070201
- Search in well localized KW short GRBs yield no other GF candidates (Svinkin et al., 2015)
- Only GRB 070201 is an outlier in hardness-intensity distribution of short GRBs (Svinkin et al., 2016)





The first observation of an IF from SGR 1935+2154

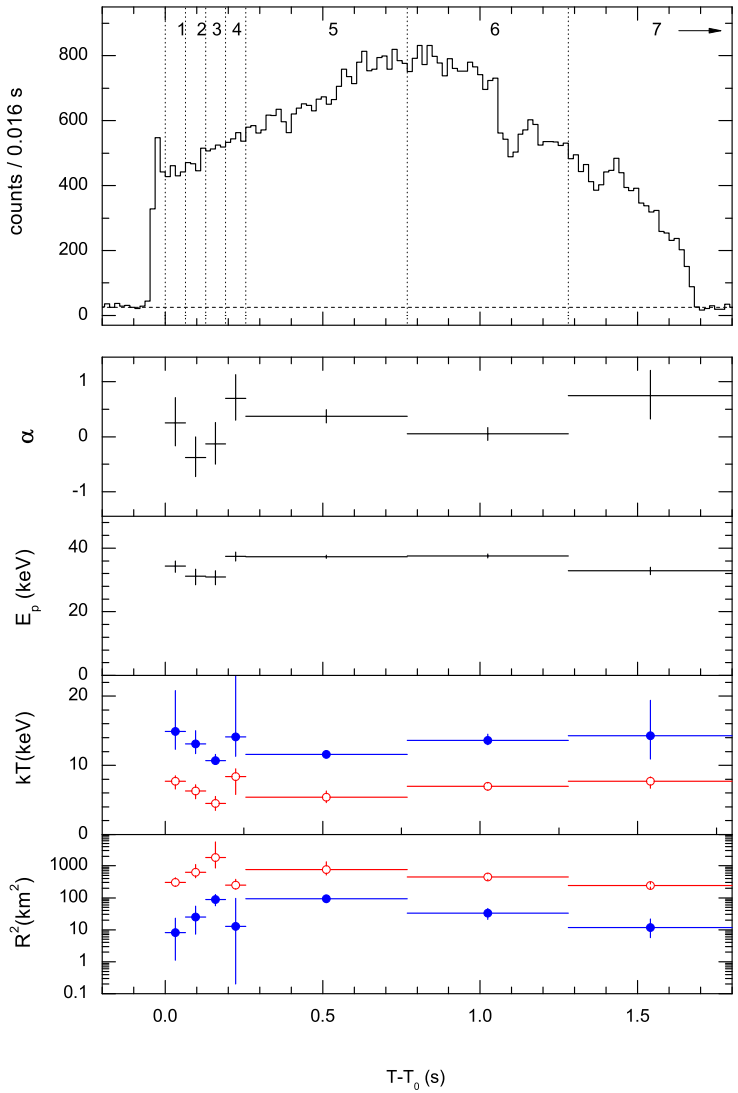


Burst was detected by four IPN experiments:

- *INTEGRAL* SPI-ACS,
- Konus *Wind*,
- *MESSENGER* GRNS,
- *Mars-Odyssey* HEND

the position of SGR 1935+2154 lies inside the error box, 1.97 arcmin from its centre.

The first observation of an IF from SGR 1935+2154



Triggered KW on 2015 April 12

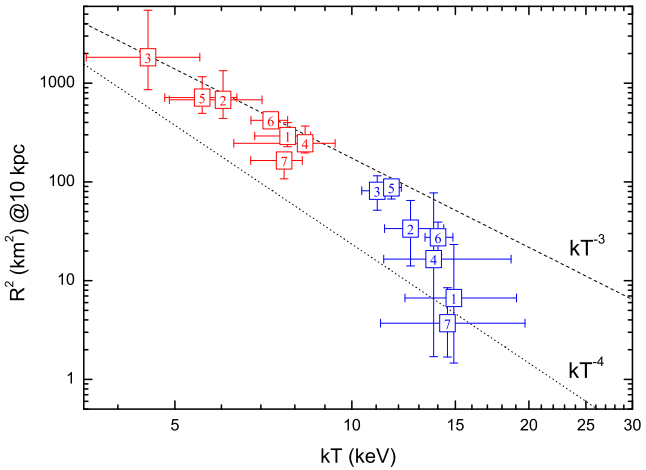
The burst light curve shows a single, very bright pulse with $T_{100} \sim 1.742$ s.

$$T_{90} = 1.412 \pm 0.016 \text{ s}$$
$$T_{50} = 0.654 \pm 0.016 \text{ s}$$

$$f_{cpl}(E) \propto E^{\alpha} e^{-(2+\alpha)E/E_{peak}}$$

$$f_{bb}(E) \propto E^2 / \left[(kT)^4 \left(e^{E/kT} - 1 \right) \right]$$

The first observation of an IF from SGR 1935+2154



magnetic Eddington luminosity formula (Paczynski,1992)

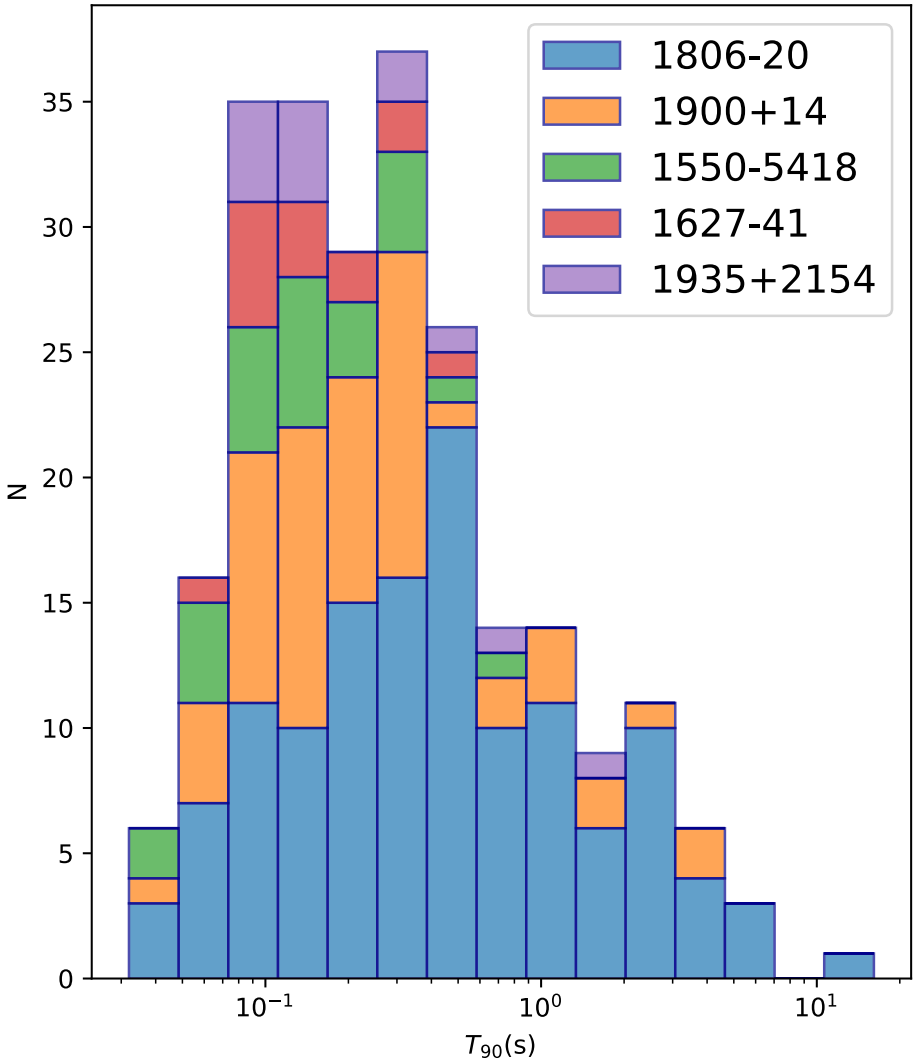
$$L_{Edd,B} \approx 2\times10^{40} \left(\frac{B}{B_{QED}}\right)^{4/3} \left(\frac{R}{R_{NS}}\right)^{2/3}$$

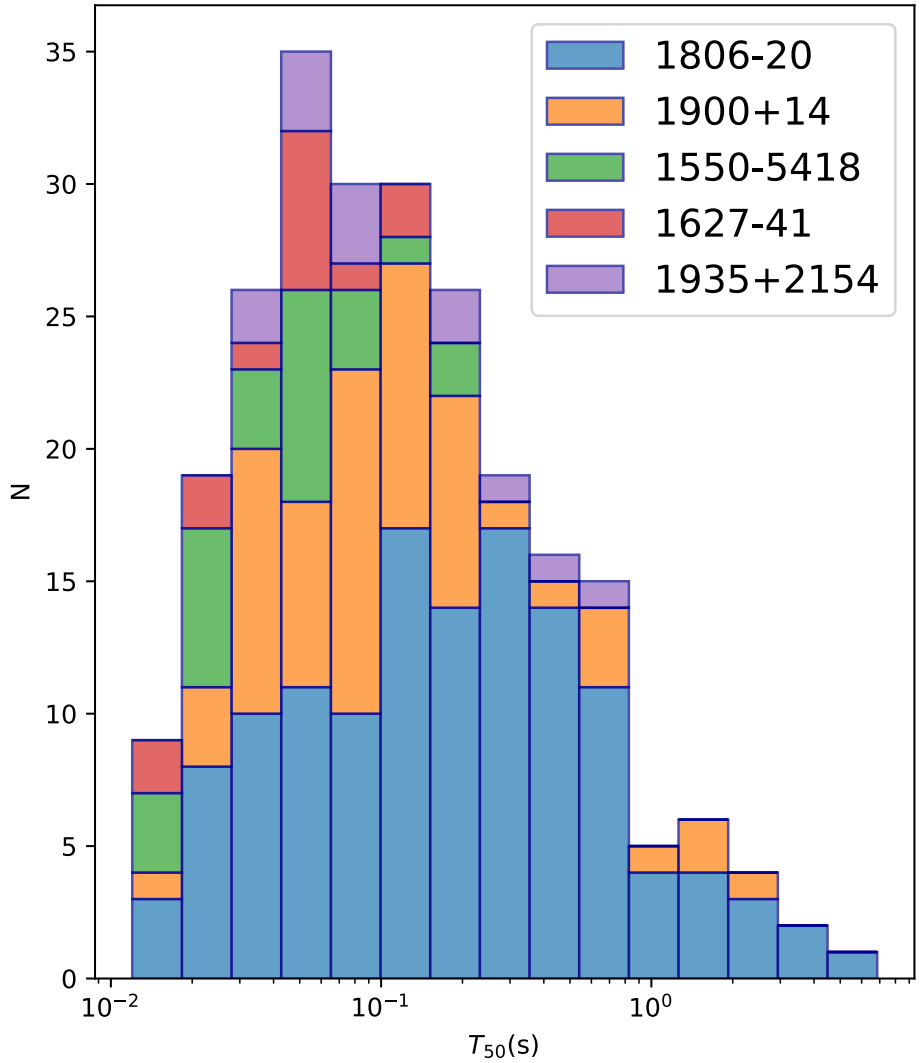
$$\left(\frac{d}{\mathrm{kpc}}\right) \simeq 0.4\times \left(\frac{F_{max}}{10^{-5}\,\mathrm{erg\ cm^{-2}\,s^{-1}}}\right)^{-1/2} \left(\frac{kT_{break}}{\mathrm{keV}}\right)^{5/4} \left(\frac{B_{surf}}{10^{14}\,\mathrm{G}}\right)^{1/4} \left(\frac{R_{NS}}{10\,\mathrm{km}}\right)^{5/8}$$

$B_{surf} \sim 2.2\times10^{14}$ G, $kT_{break} \sim 12-15$ keV $\rightarrow$ d$\sim 7.4-9.8$ kpc

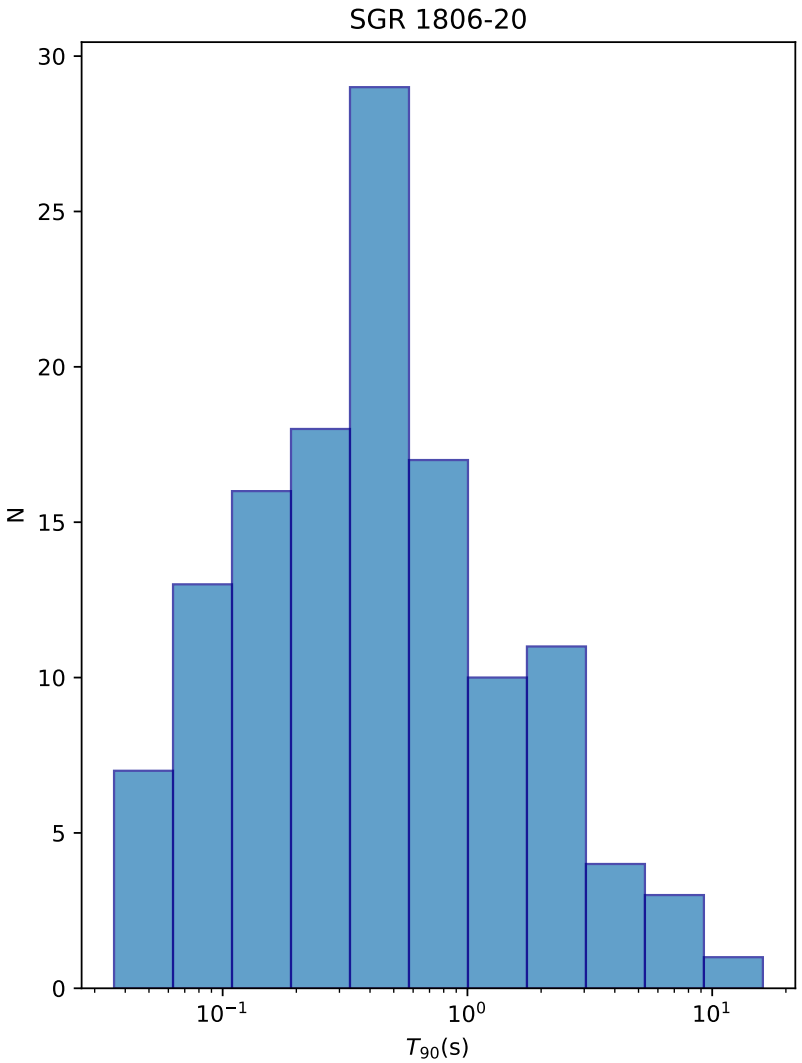
Assuming isotropic emission at 9.1 kpc: $E_{tot} \sim 3.3\times10^{41}$ erg, $L_{max} \sim 3\times10^{41}$ erg/s.

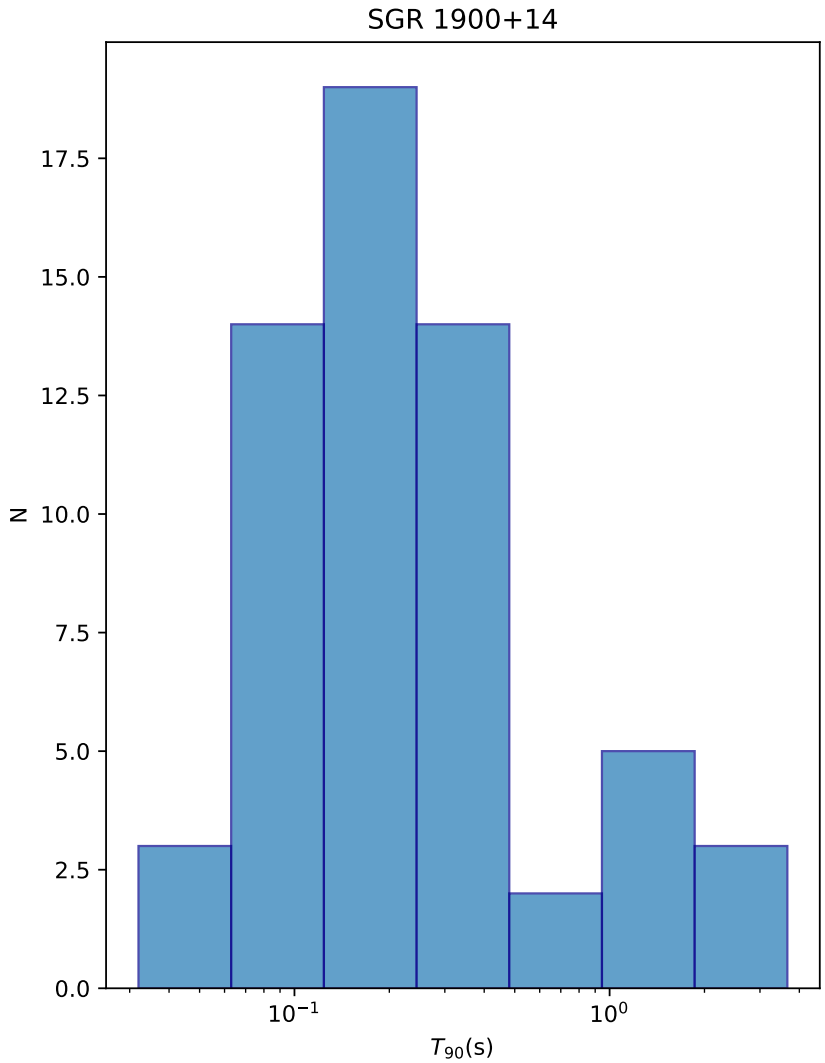
KW SGR Temporal properties



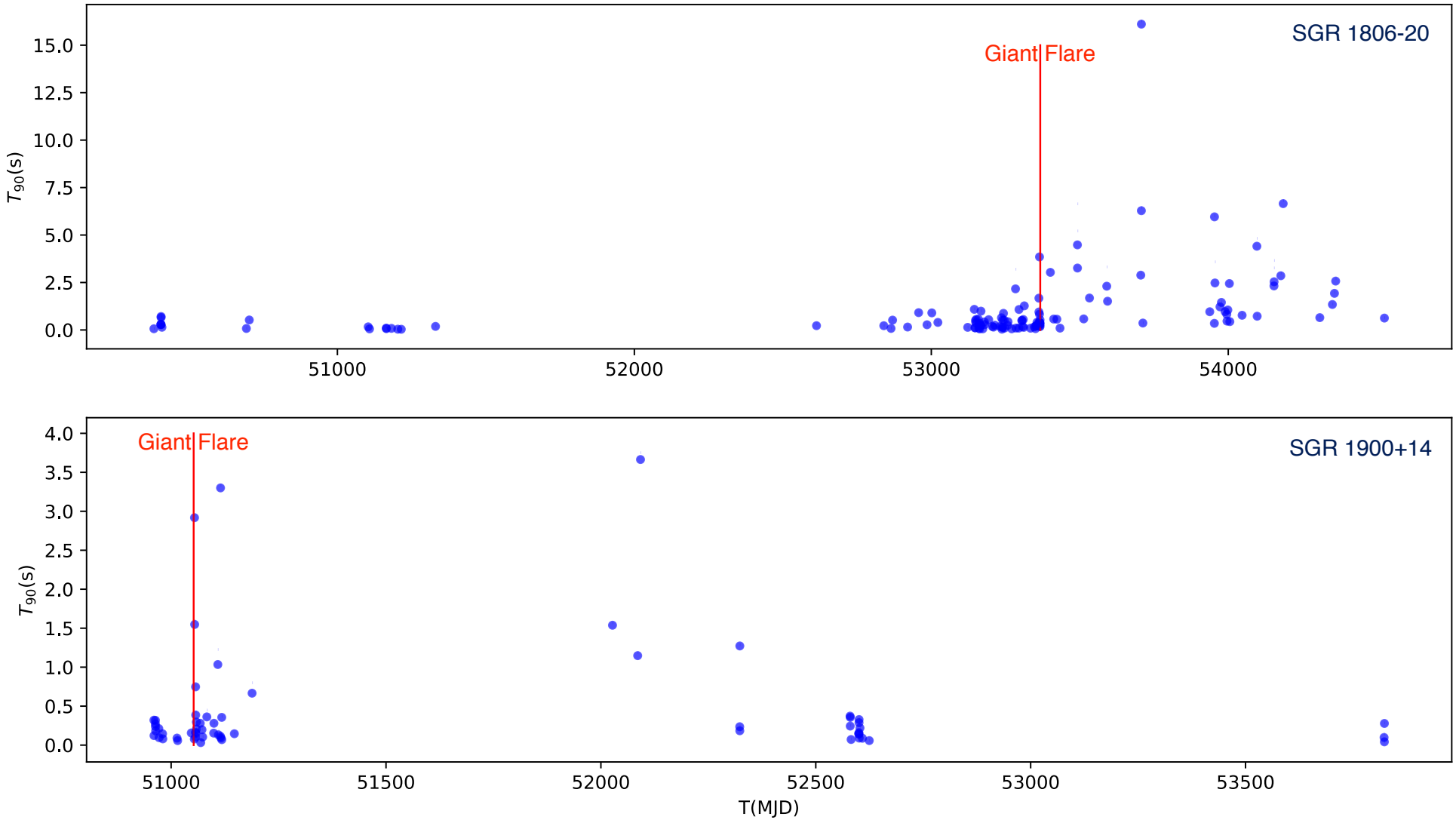


KW SGR Temporal properties

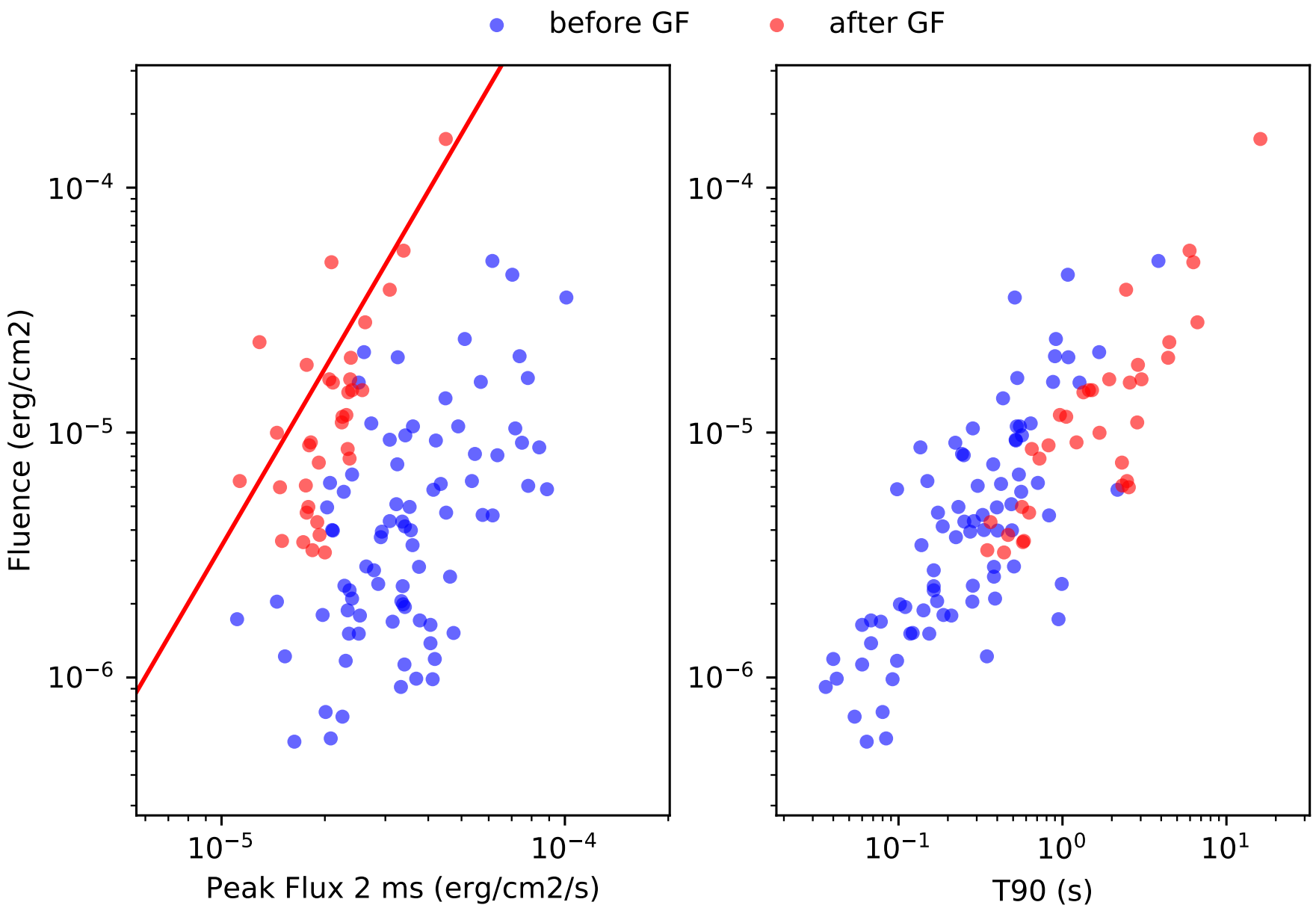




KW SGR Temporal properties



SGR 1806-20 ultra-long bursts



- the CPL model, parametrized as E_p:

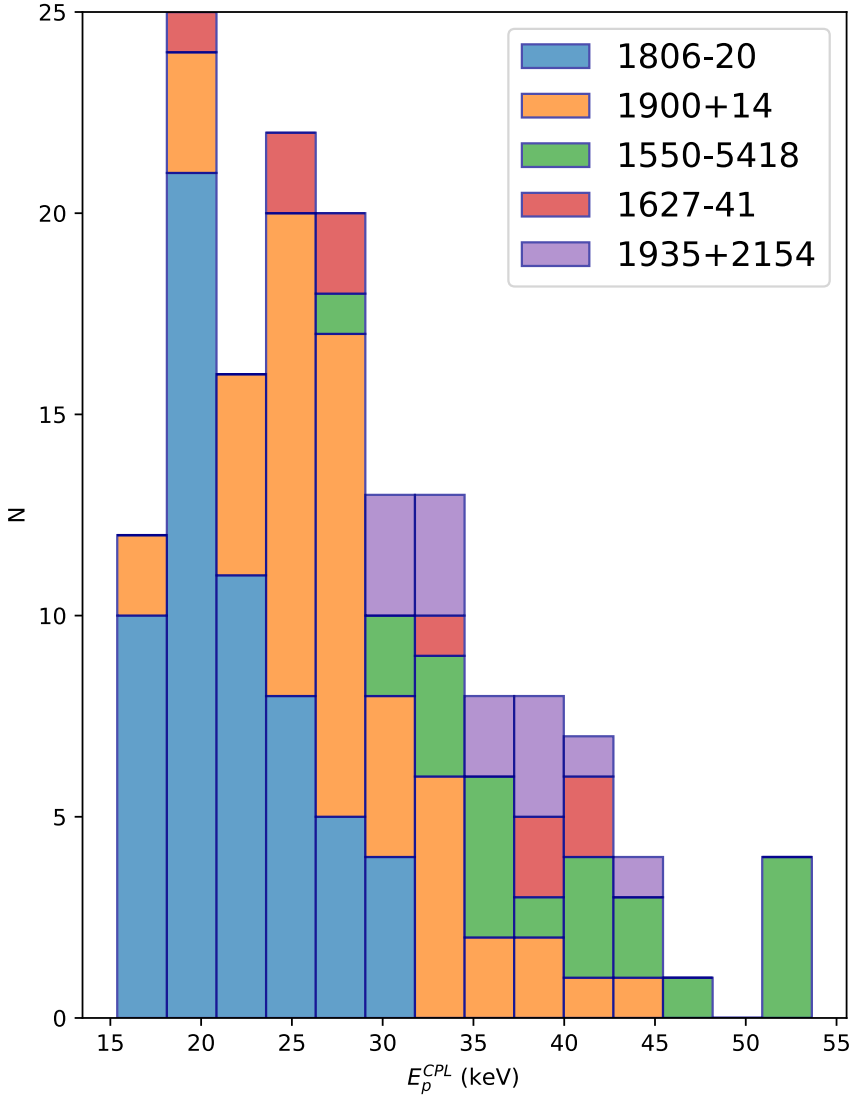
$$f(E) \propto E^{\alpha} \exp(-(2+\alpha)E/E_p),$$

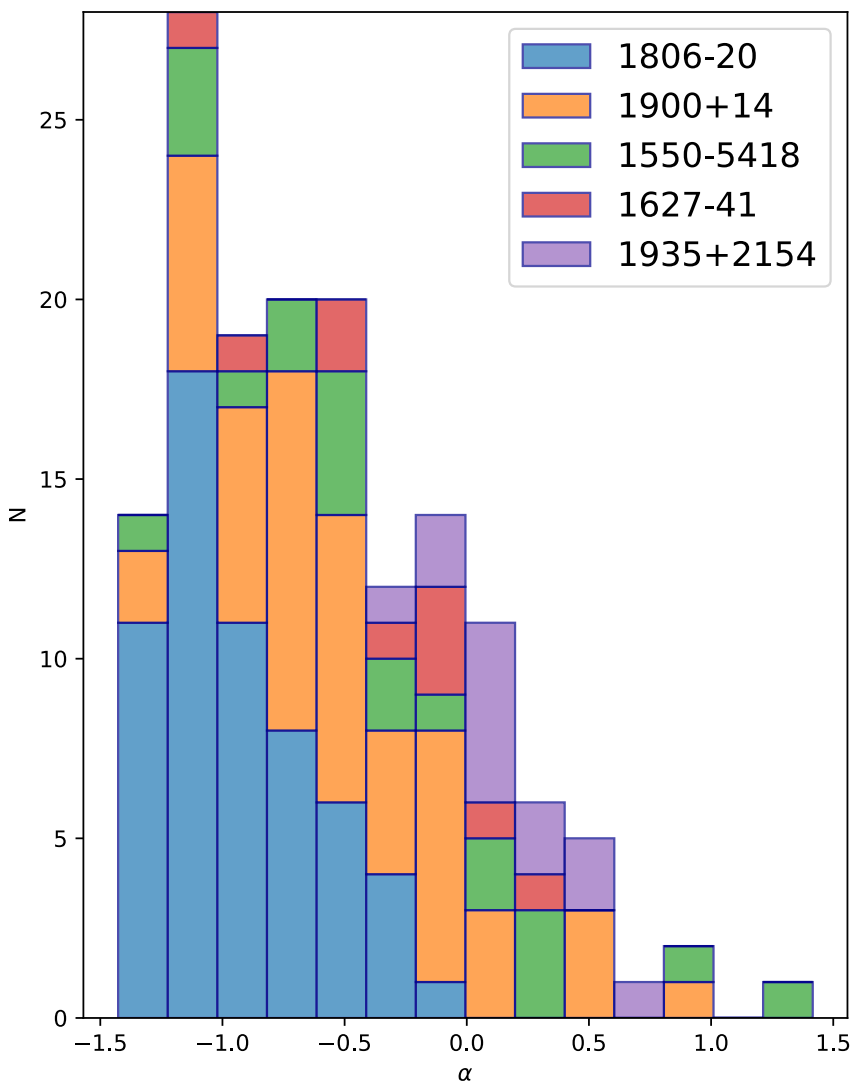
where α is the power-law photon index and E_p is the peak energy in the νF_ν spectrum

- a sum of two BB functions with the normalization proportional to the surface area (2BB).

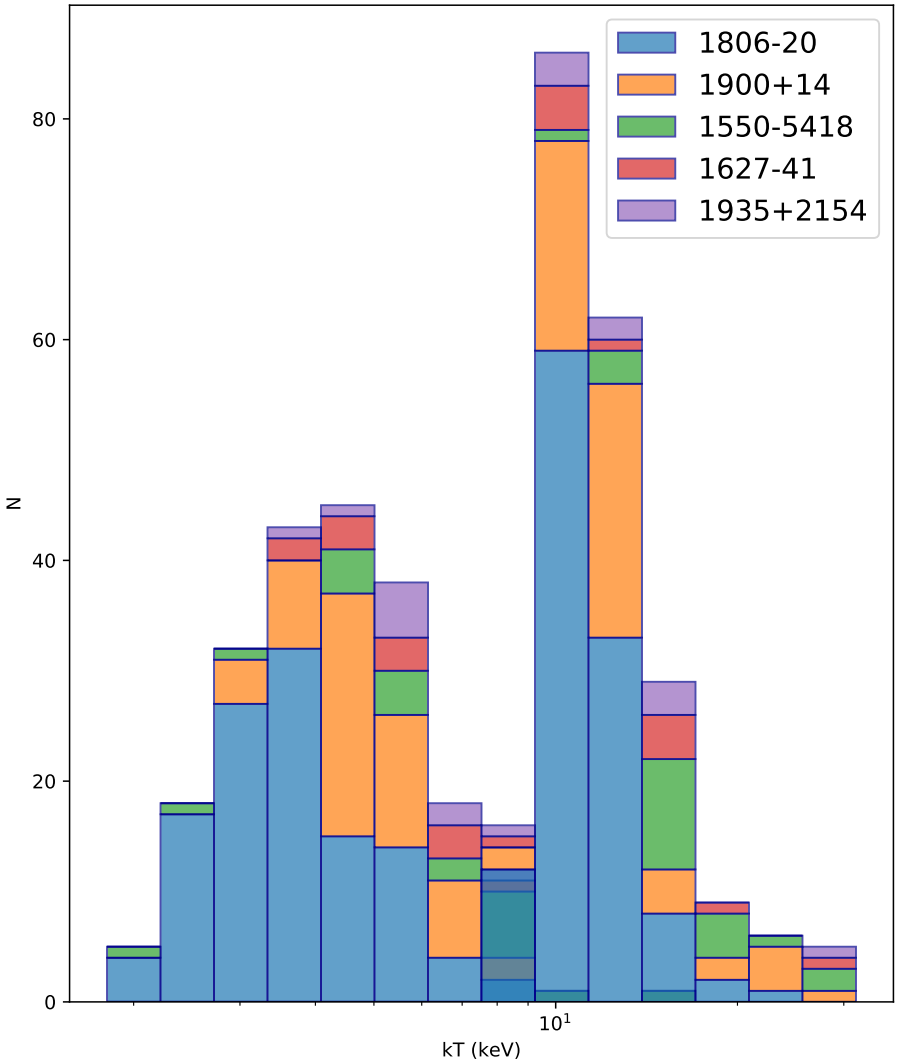
- the OTTB model

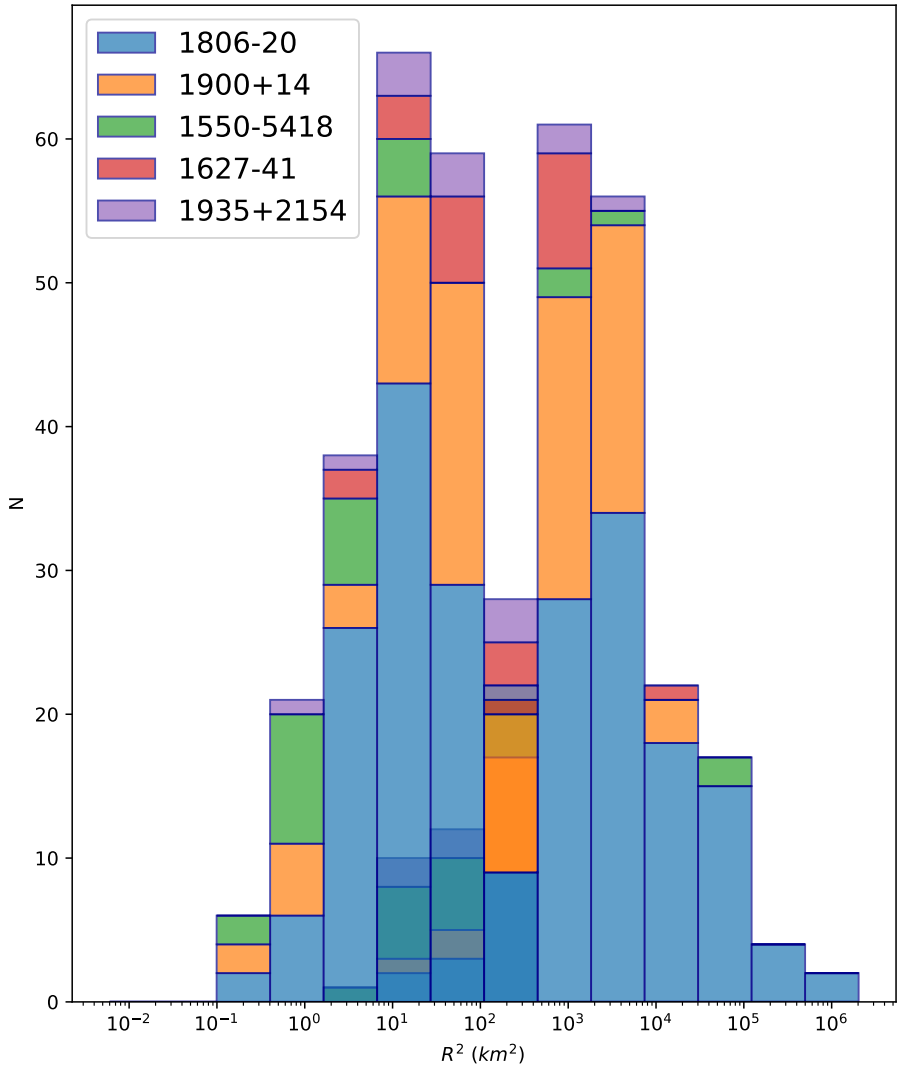
Spectral properties: CPL model



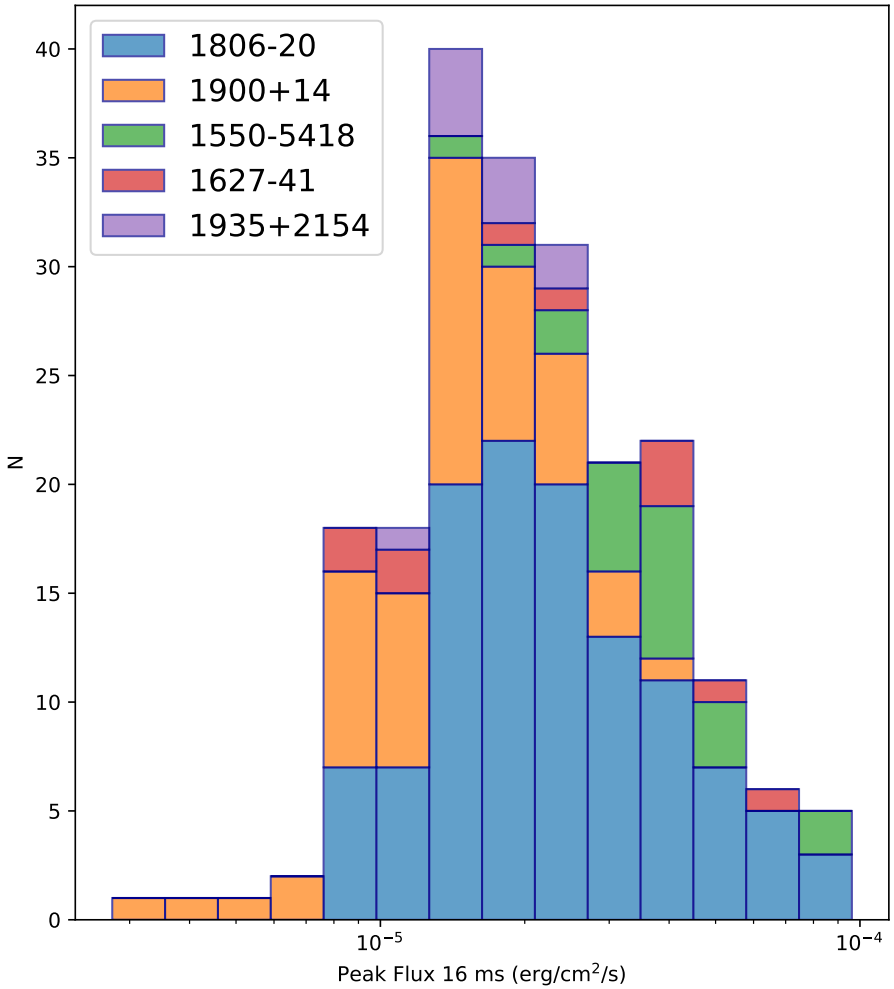


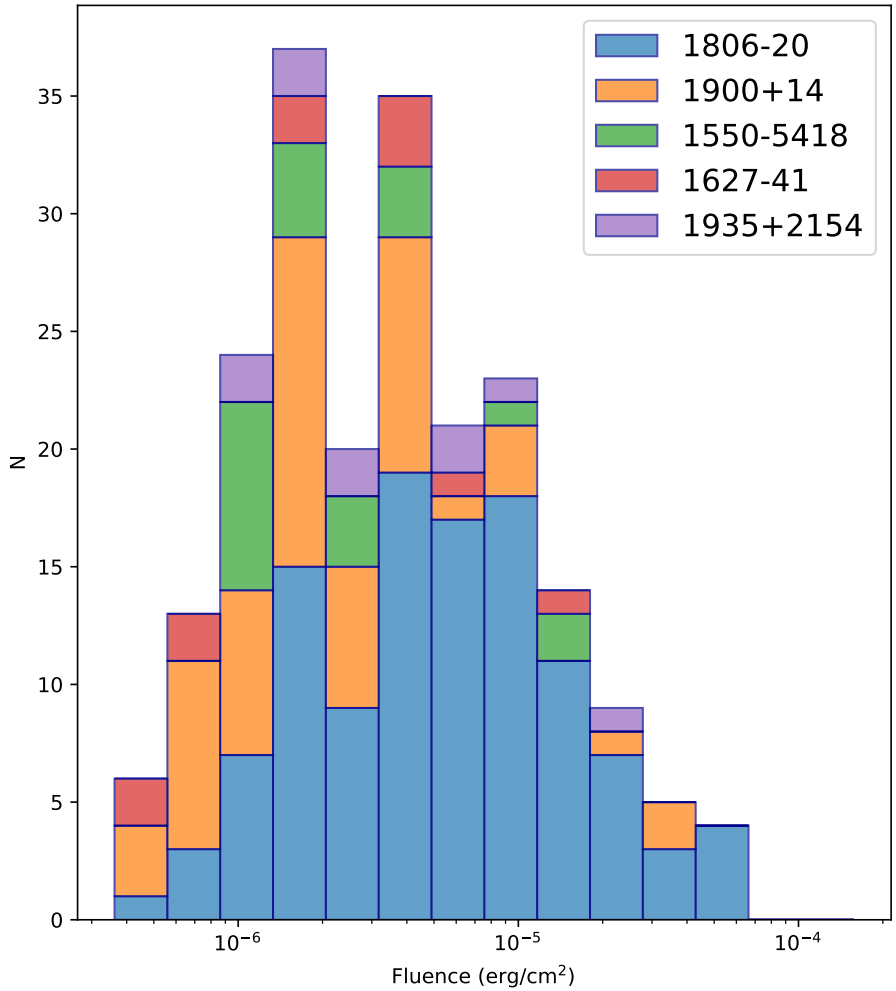
Spectral properties: 2BB model



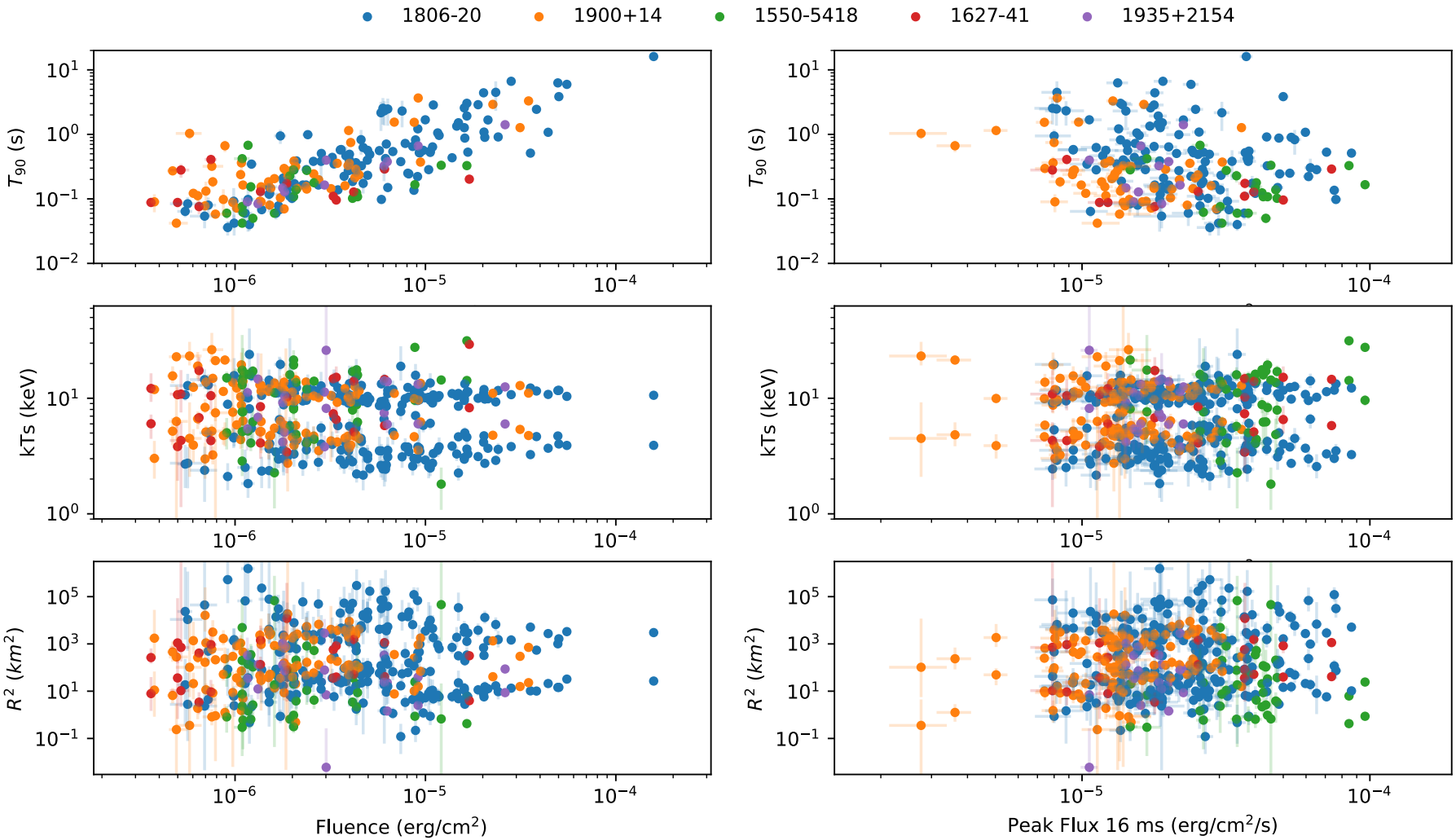


Burst energetics



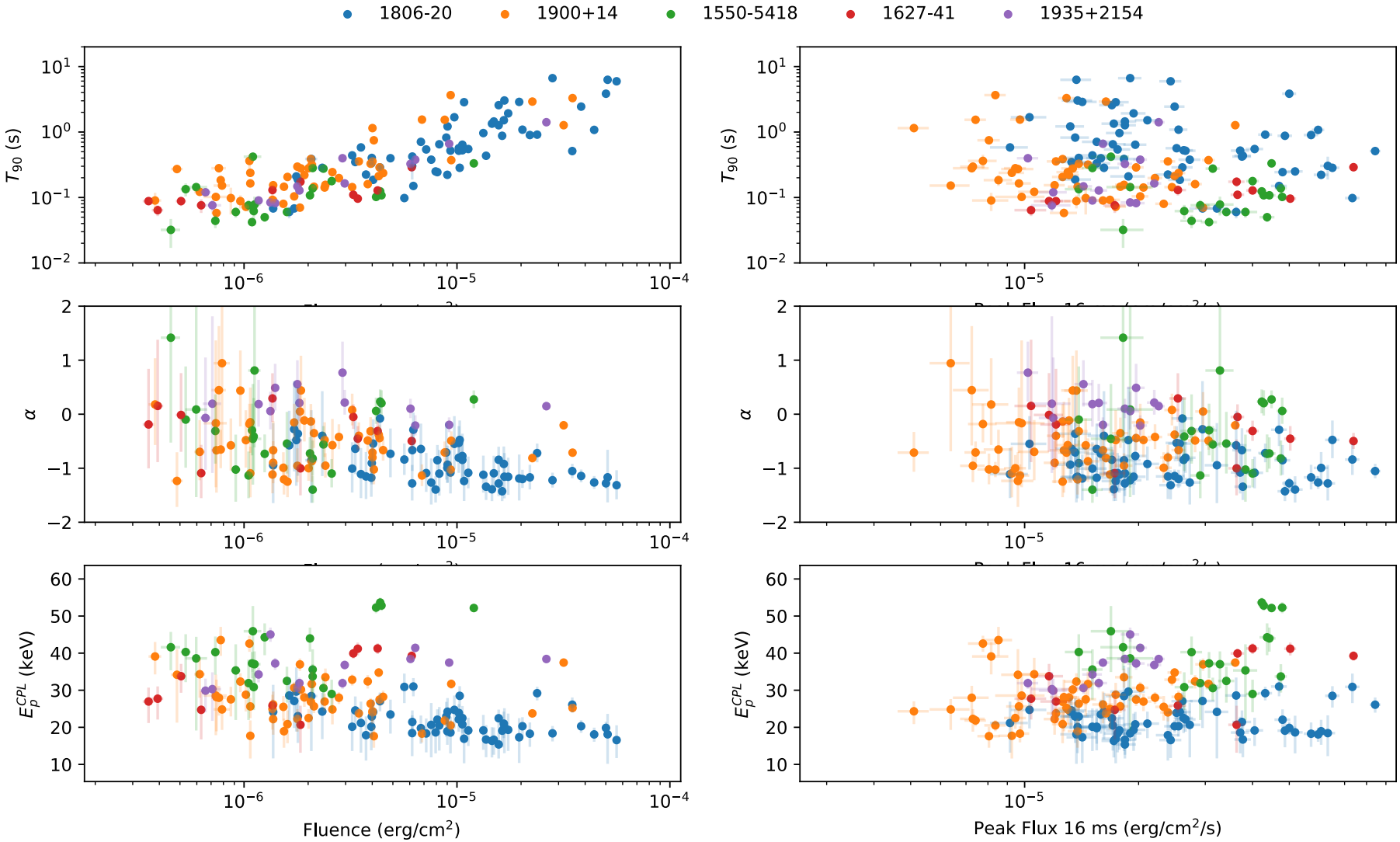


All KW SGR triggers

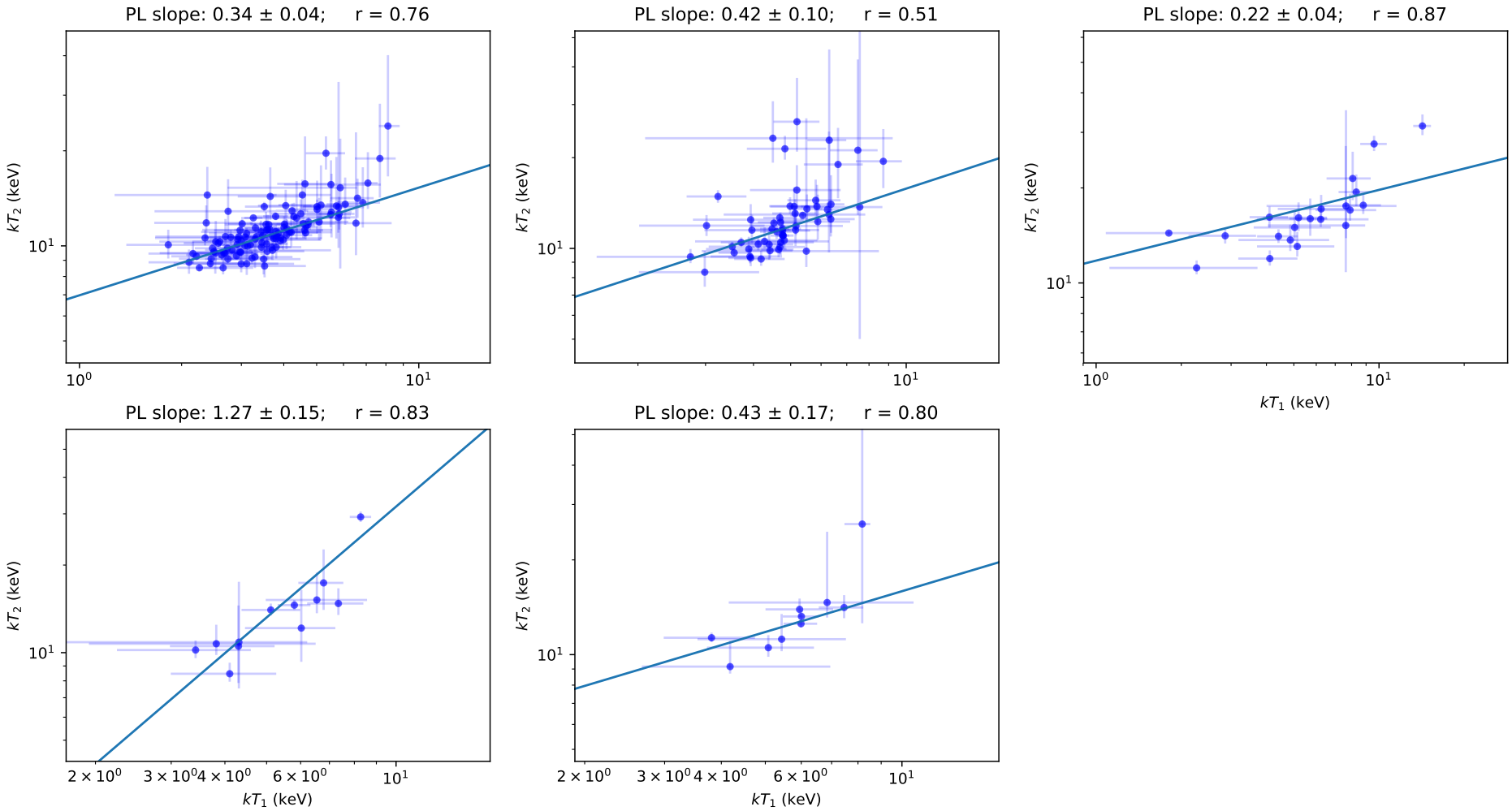


Energetic Correlations: CPL

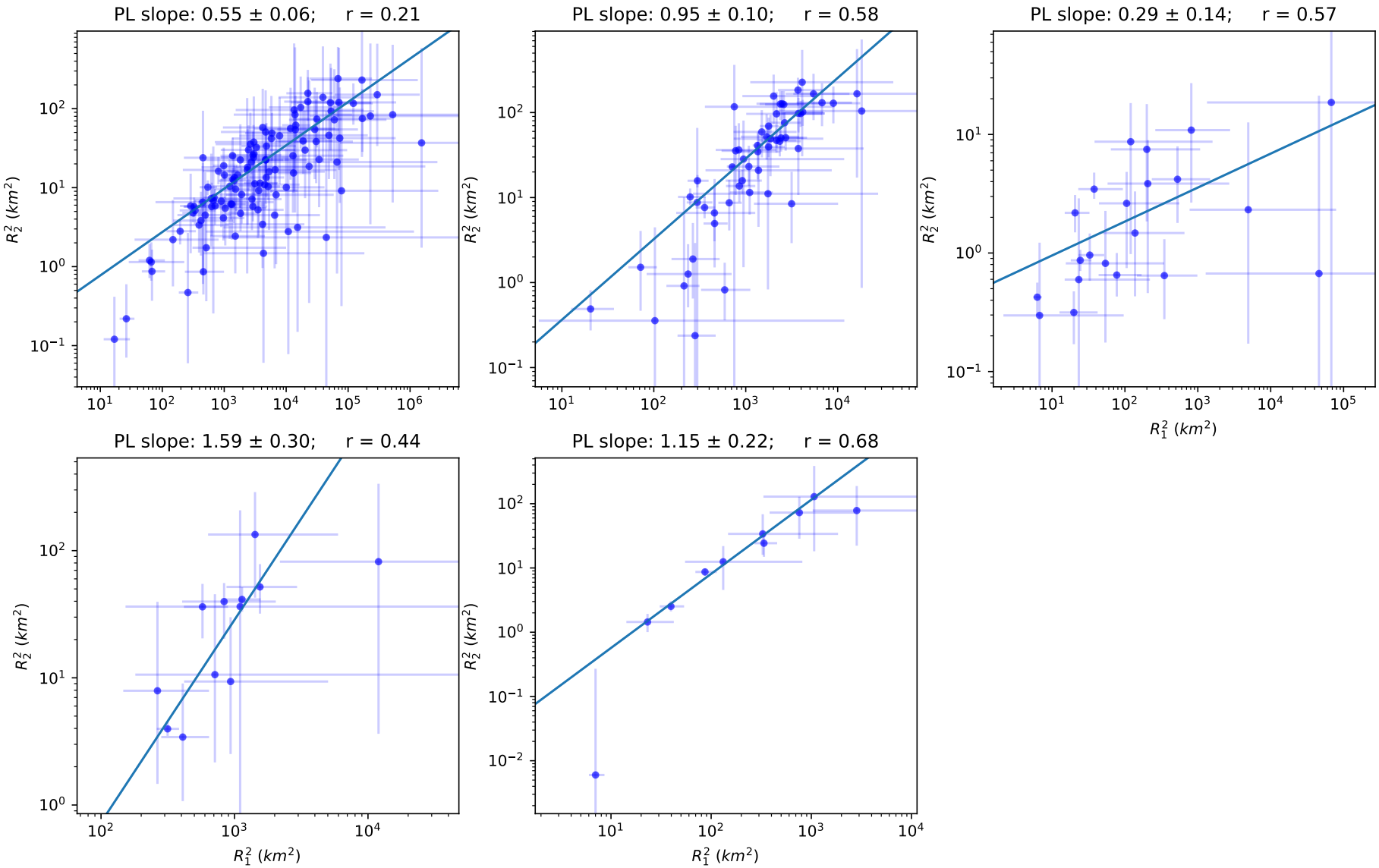
All KW SGR triggers



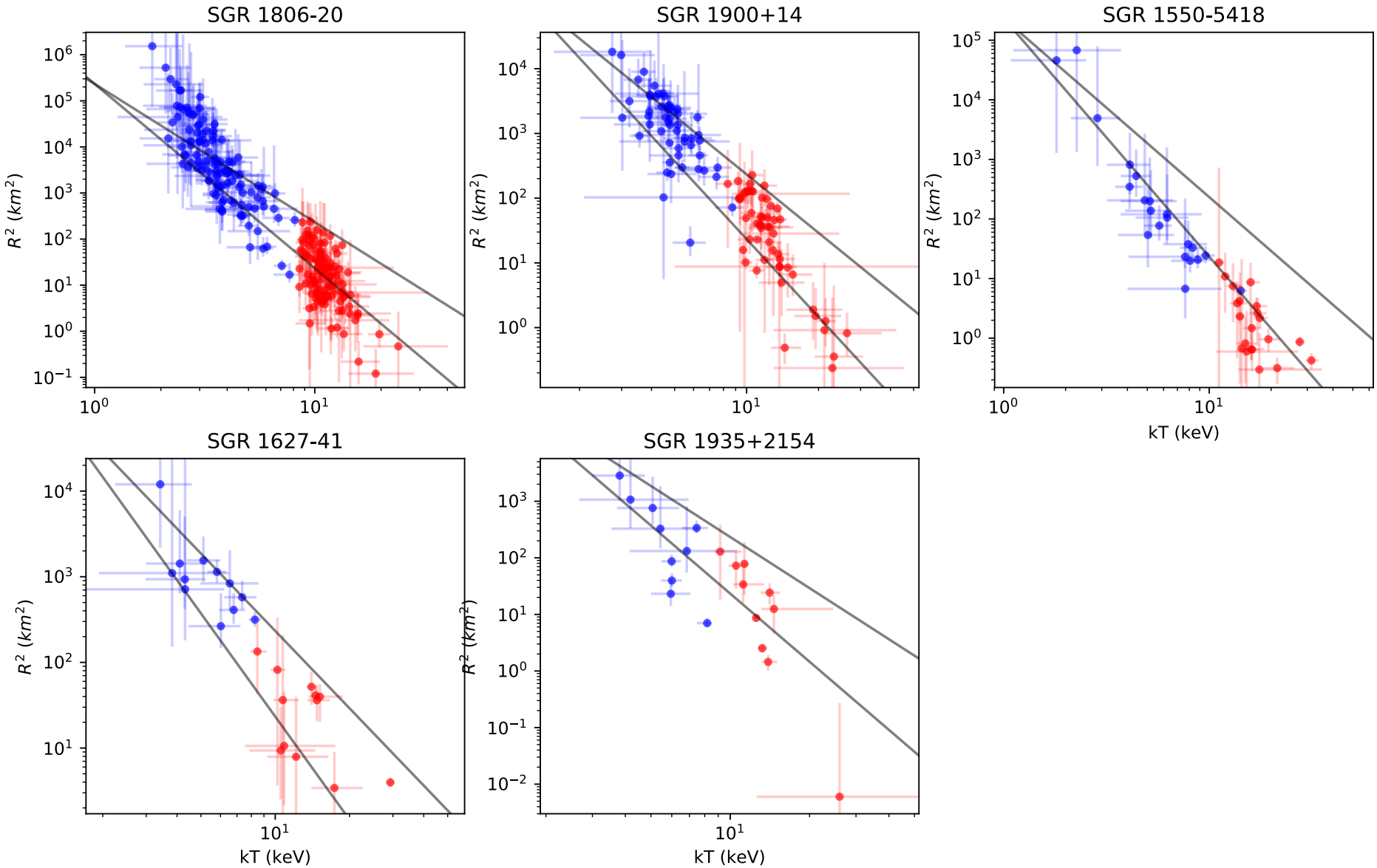
Parameter Correlations: kTs



Parameter Correlations: R^2s



Parameter Correlations: kT vs R^2



Summary

- SGR 1806-20, with the greatest number of IF, have a longer average $T_{90} \sim 1$ s compared to ~ 0.3 s for the rest
- KW-measured SGR spectra (20-200 keV range) are equally well described by both CPL and 2BB models
- with the CPL model, we find E_p value distributions peak between 20 and 40 keV
- The kTs and Rs we find for the 2BB model are similar among SGRs:

$$\text{low-kT} \sim 3 - 7 \text{ keV}, \; R_{low-kT} \sim 18 - 120 \text{ km}$$
$$\text{high-kT} \sim 11 - 17 \text{ keV}, \; R_{high-kT} \sim 1 - 7 \text{ km}$$

Name	E_p (keV)	α
SGR 1806-20	21.7 ± 3.9	-0.93 ± 0.3
SGR 1900+14	27.8 ± 5.9	-0.51 ± 0.48
SGR 1627-41	32.0 ± 7.4	-0.31 ± 0.43
SGR 1550-5418	39.9 ± 7.7	-0.31 ± 0.6
SGR 1935+2154	35.7 ± 4.5	0.19 ± 0.27

Name	kTs (keV)	$Rs(km)$
SGR 1806-20	3.8 ± 1.2 , 11.4 ± 2.3	111 ± 156 , 4.8 ± 3.2
SGR 1900+14	4.9 ± 1.2 , 12.9 ± 3.9	41.9 ± 25.6 , 6.4 ± 3.9
SGR 1627-41	5.5 ± 1.5 , 14 ± 5.2	34.8 ± 23 , 5.5 ± 2.8
SGR 1550-5418	6.2 ± 2.8 , 16.9 ± 4.7	34.6 ± 67 , 1.6 ± 1.0
SGR 1935+2154	5.8 ± 1.3 , 13.6 ± 4.4	18.5 ± 14 , 4.8 ± 3.5

Summary

- 2BB temperatures are positively correlated for all SGRs, and same is true for their emission areas
- all SGRs showed a similar trend: the area of low-kT BB decreases with kT at a slower pace then 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.

Thank you!

Parameter Correlations: temperatures; Time-Resolved