30 years of Konus-*Wind*: experiment overview and some recent results

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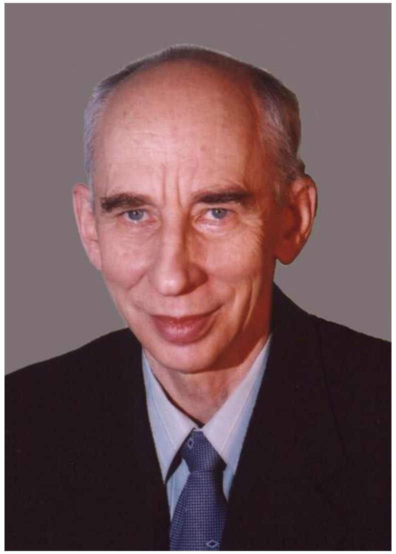
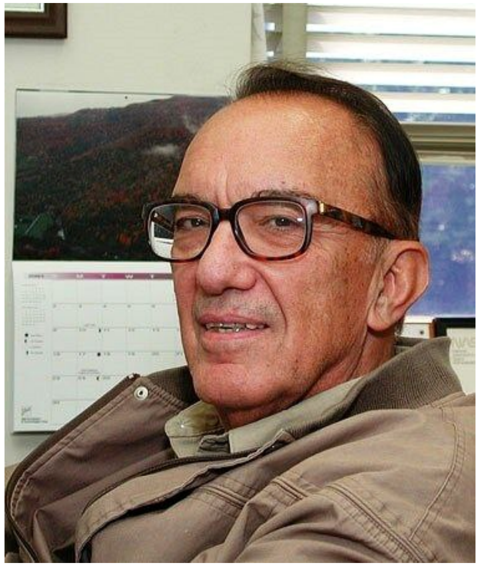
HEACOSS-2024

Joint Russian-US Konus-*Wind* experiment

- Started with the launch of the Russian gamma-spectrometer Konus onboard the NASA GGS-WIND spacecraft on November 1, 1994:

  almost 30 years of continuous operation!
- Goal: GRB, SGR, and Solar flare studies



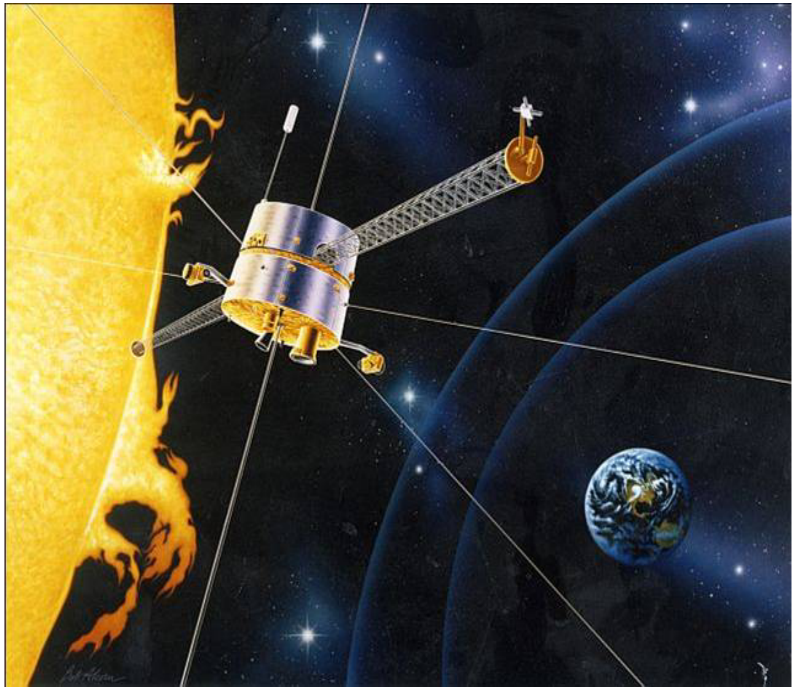


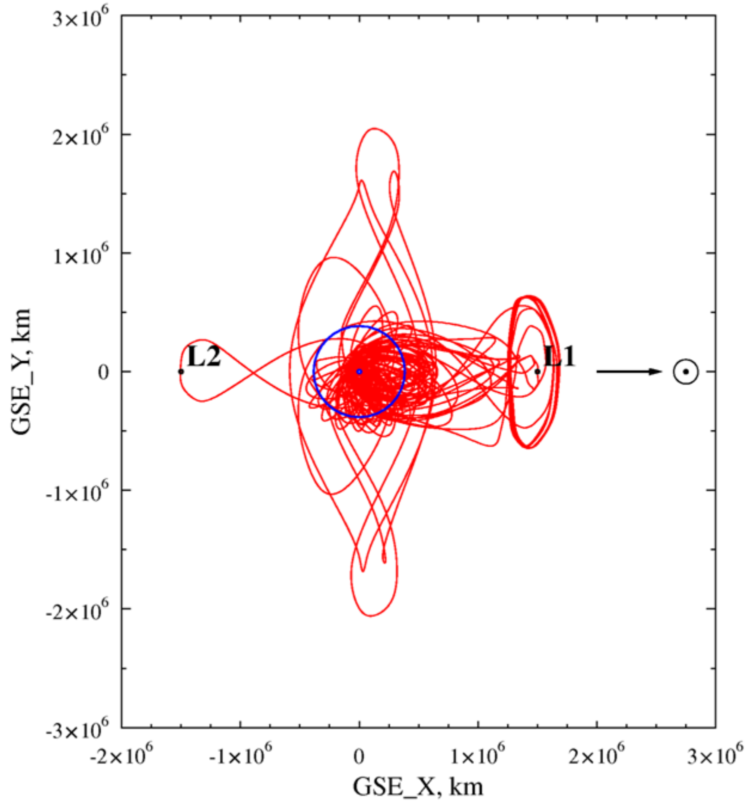
- **The first PIs**:

  Eugeny Mazets (Ioffe) and Thomas L. Cline (NASA GSFC)

The *WIND* Spacecraft

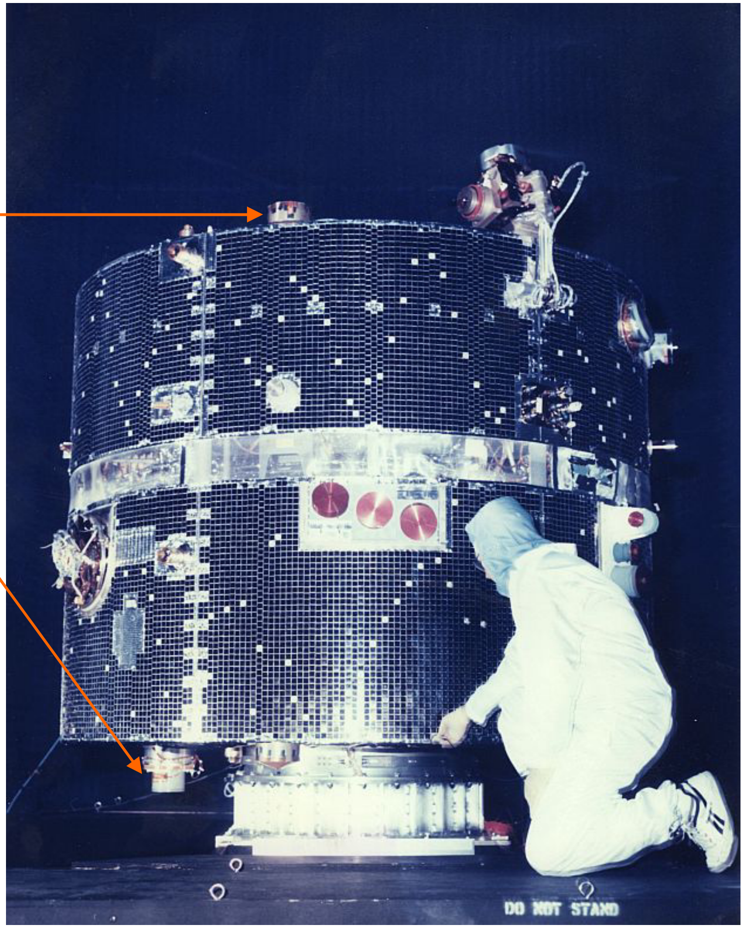
- Part of the NASA Global Geospace Science (GGS) initiative, “a solar wind workhorse”
- Since 2004, WIND is in orbit **near L1, up to 2.1 million km (～7 lt s) from Earth**
- Stable particle background + no Earth occultation
- The Wind mission provides an excellent opportunity for both Solar and GRB science





The Konus-*WIND* Instrument (KW)

- Gamma-ray spectrometer aimed at transient studies
- Designed and manufactured at the Ioffe Institute
- Weight ~20 kg, power consumption < 10 W
- Two **NaI** detectors (75x130 mm), each 2π FOV
- **Be** entrance window, lead glass back shielding
- Fully duplicated electronic systems



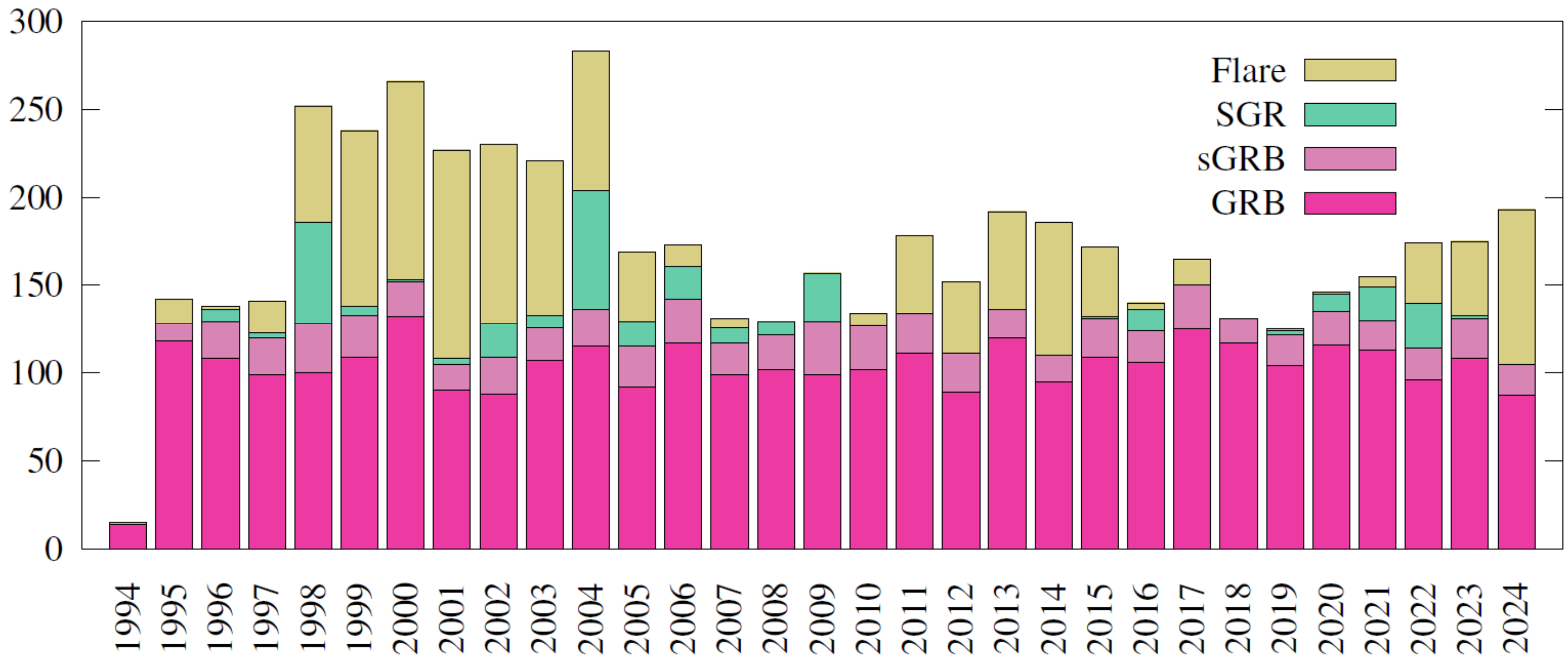
Advantages

- Very stable background, no Earth or planet occultation
- Continuous all-sky monitoring (4π FOV)
- Triggers on almost all bright events (**>~10^{-6} erg cm^{-2} s^{-1}**)
- Waiting mode (WM) sensitivity **~10^{-7} erg cm^{-2} s^{-1}**
- Wide energy band (~20 keV – 15 MeV)
- Hi-res light curves (from 2 ms)

Limitations

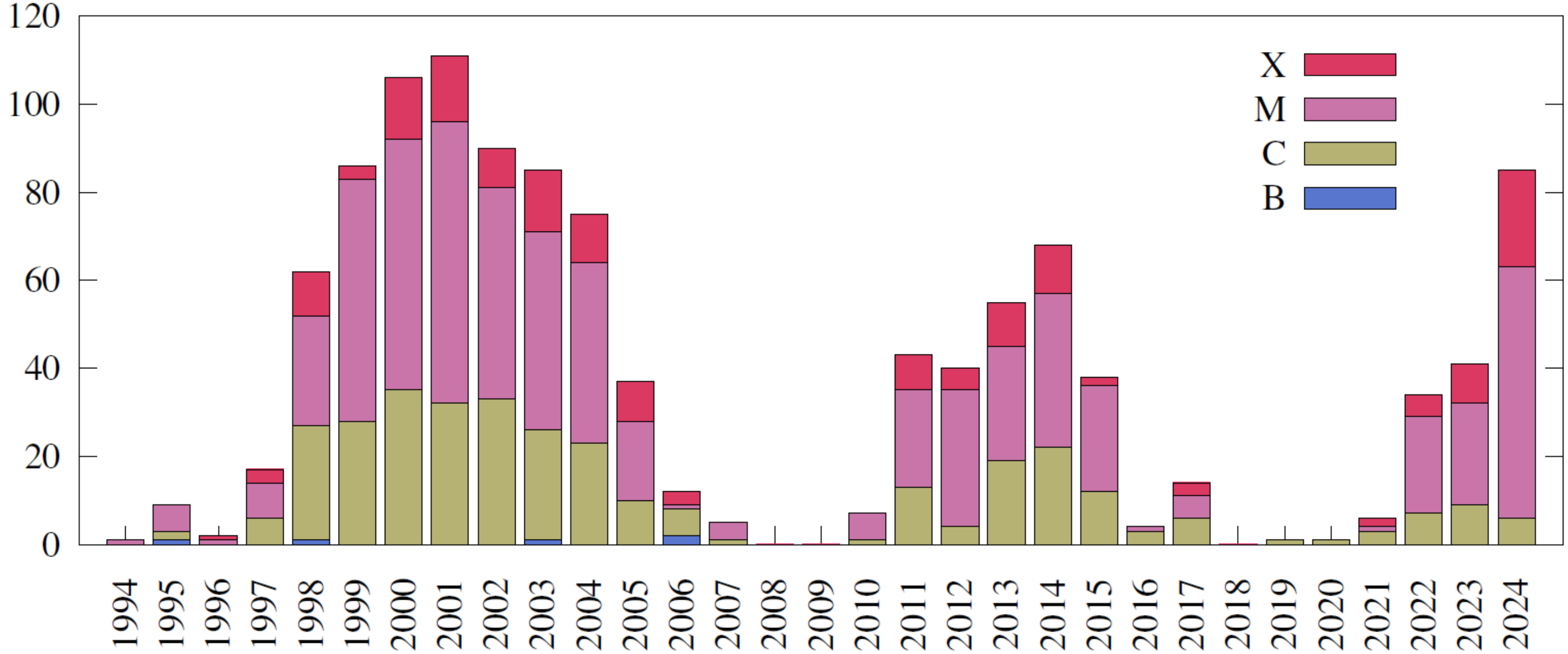
- Very low telemetry rate (55 bits/s)
- Data delays (typically one downlink session / day)

Konus-*Wind* trigger statistic since 1994



- ~ 4000 triggered GRBs (> 100 GRBs/yr), one the largest GRB samples
- > 600 short GRBs (~15%), one of the largest samples
- > 20 ultra-long GRBs, the largest sample so far
- > 350 GRBs with known redshifts ($0.04 \leq z \leq 9.4$)
- > 300 bright SGR (magnetar) flares, ~40 “intermediate” and 2 Giant SGR Flares
- > 1000 IPN localisations (>10 IPN catalogs)

KW observations of Solar Flares

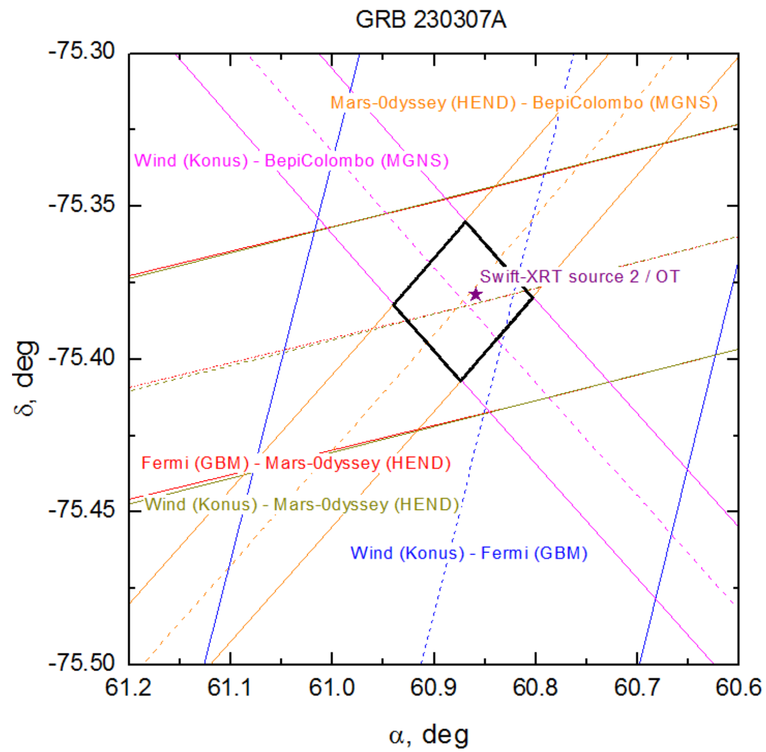


Konus-Wind advantages in the solar flare studies:

- Continuous observations of the Sun in hard X-rays, duty cycle ~95%,
- More than two full 11-yr solar cycles have been covered by the observations, more than 1100 solar triggers, many thousand flares detected in the WM
- The KW Solar Flare Database: http://www.ioffe.ru/LEA/sun.html

Konus-Wind and the Interplanetary Network (IPN)

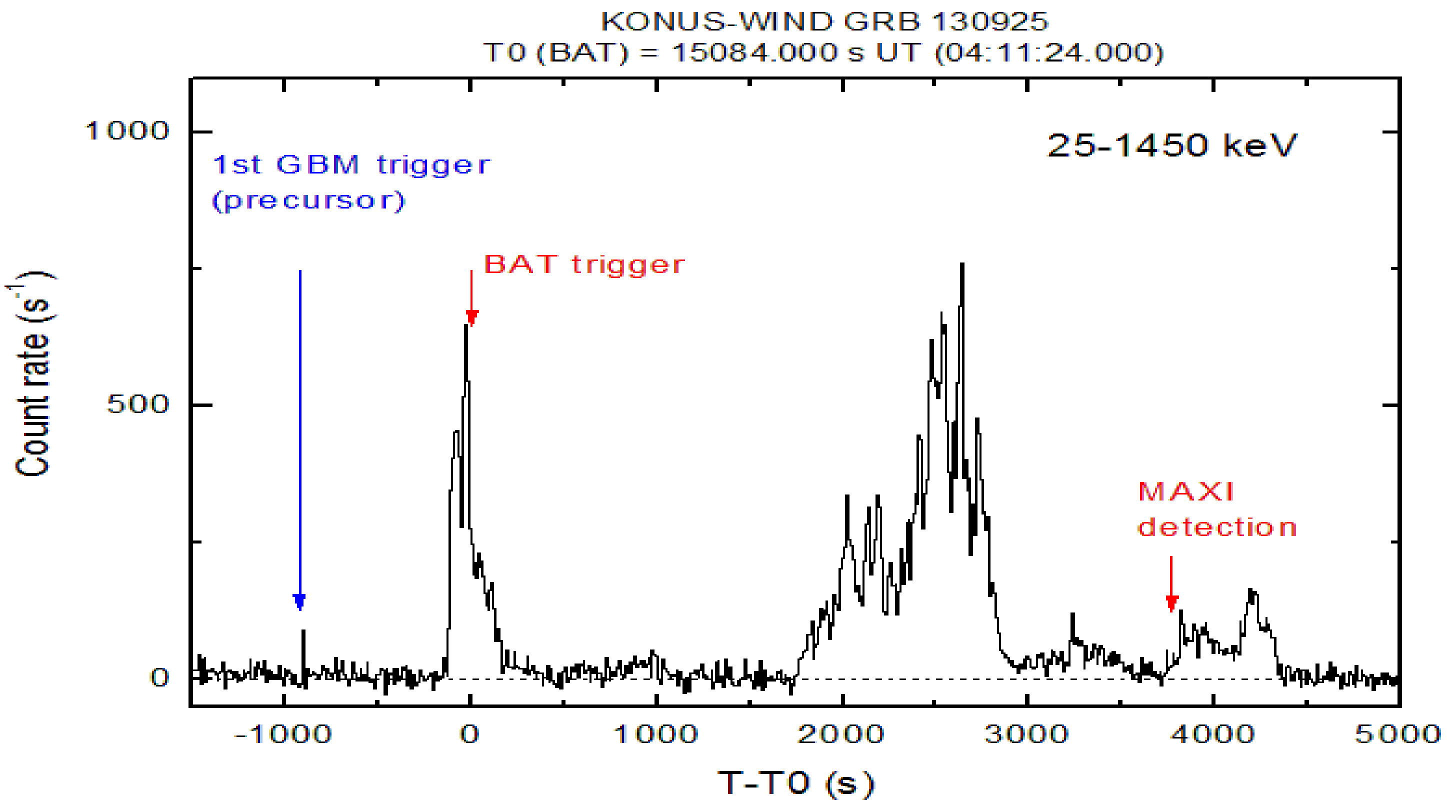
- The current 3rd Interplanetary Network (IPN) of gamma-ray detectors operates since 1990 г.
- Now comprises >10 spacecraft
  Fermi, Swift, and other low-orbit; INTEGRAL (high-orbit up to 0.5 lt s); Wind (up to 7 lt s), Mars-Odyssey (1200 lt s), and BepiColombo (on the way to Mercury)
- IPN provides uninterrupted monitoring of the whole sky with the sensitivity of ~10^{-6} erg cm^{-2} (~1 ph cm^{-2})
- KW has the best time resolution and sensitivity among the distant s/c that allows allowing building narrow (~10 arcmin) annuli with low-Earth s/c
- IPN (and Konus) publish up to ~50 localization GCNs per year, with the box areas down a few sq. arcmin (e.g. GRB 230307A)



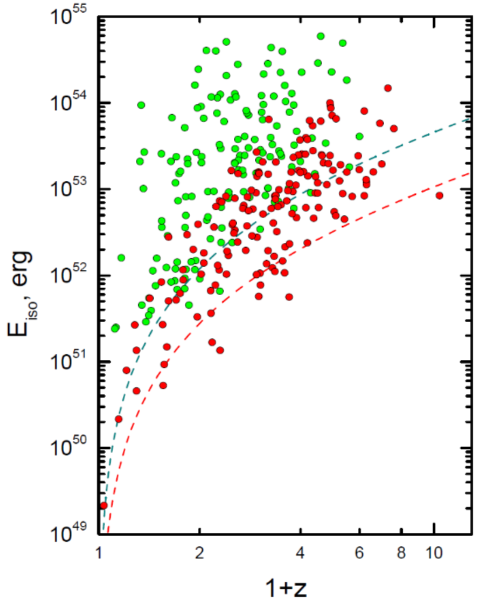
Ultra-long (u-long) GRBs

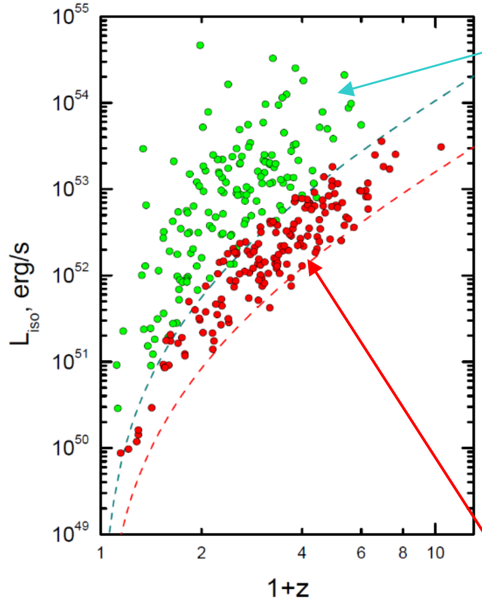
Extremely rare class of GRBs with durations > 1 ks, about two dozen reported so far.

In the WM, KW provides an excellent opportunity to observe prompt emission of u-long GRBs **for their whole duration** and constrain their spectra and fluences in the wide energy band (20-1500 keV).



KW GRBs with known redshifts





Of ~500 GRBs with known redshifts since 1997:

- 166 bright GRBs triggered KW ($0.1 \leq z \leq 5$)

  (catalog: Tsvetkova et al. ApJ 2017) :

  - 14 short/hard + 152 long/soft

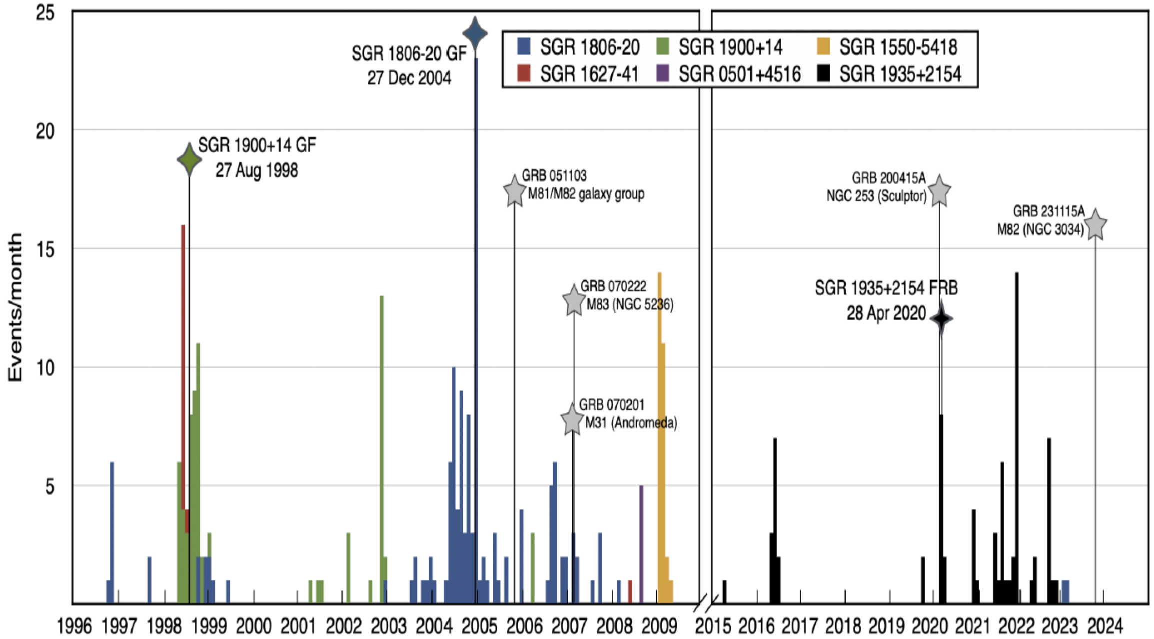
  - 32 GRBs with reliable jet breaks (collimation!)

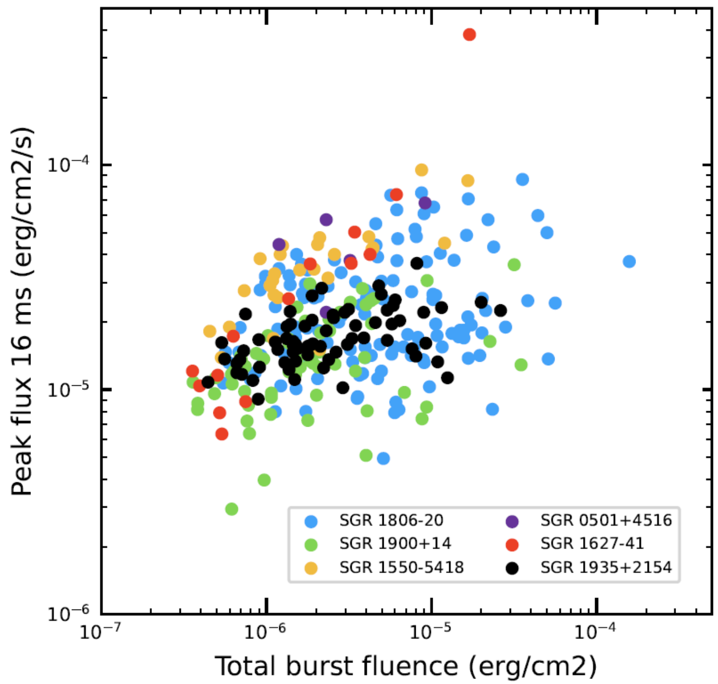
  - knowing z, rest-frame GRB energy and spectrum may be constrained directly from the KW data (20 keV-15 MeV)

- + ~200 weaker GRBs were detected by KW in the waiting mode (20-1500 keV, 3-ch)

  For 172 Swift GRBs ($0.04 \leq z \leq 9.4$) we were able to constrain broadband spectra, fluences, and peak fluxes and from joint KW + *Swift*/BAT analysis (Tsvetkova et al. ApJ 2021)

SGR (magnetar) flares

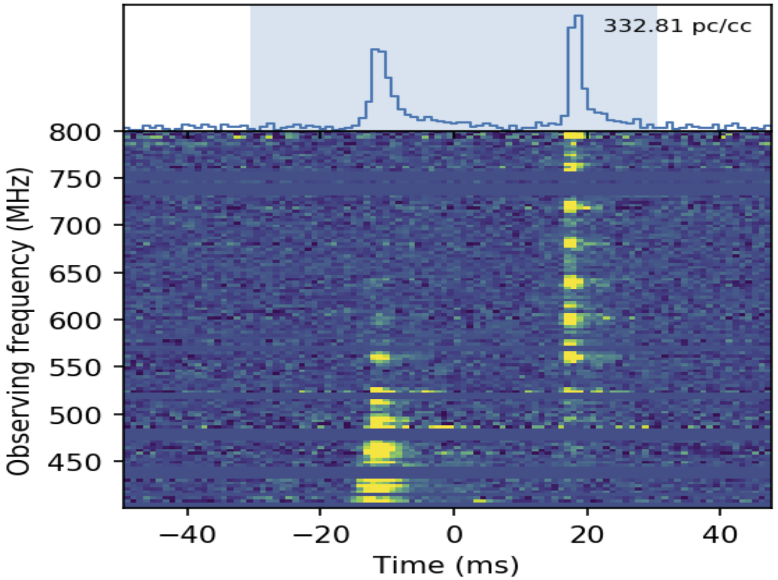




- >300 rather bright, short SGR bursts from 8 sources (T<1 s, E_{tot} ~ 10^{38}-10^{40} erg)
- > 40 ‘intermediate’ flares (T~1-30 s, E_{tot} ~ 10^{40}-10^{43} erg)
- 2 Magnetar Giant Flares (T>100 s, E_{tot} ~ 10^{44}-10^{46} erg, L_{peak} ~ 10^{46}-10^{47} erg/s)

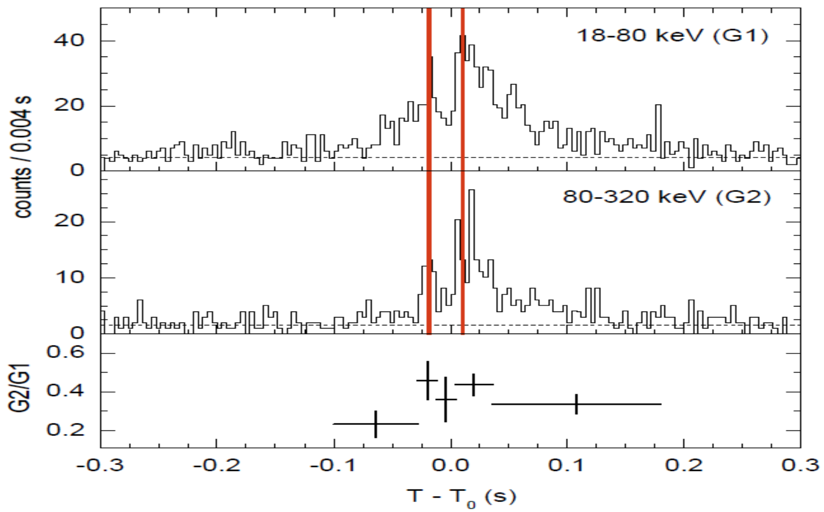
SGR/FRB event of April 28, 2020

- Powerful, FRB-like radio burst was detected by CHIME/FRB (CHIME collabaration 2020) and STARE2 (Bochenek et al., 2020), the CHIME/FRB localization is consistent with then active Galactic magnetar SGR 1935-2154 – the first Galactic FRB!
- A short, hard X-ray flare was detected simultaneously by INTEGRAL-ISGRI, KW, Insight-HXMT, and SuperAGILE (Mereghetti et al. 2020, Ridnaia et al. 2021, Li et al. 2021, Tavani et al. 2021) and localized to the direction to SGR 1935-2154
- The arrival time of two bright FRB peaks is consistent, within ~4 ms, with two main peaks in the KW X-ray light curve, thus confirming their common origin



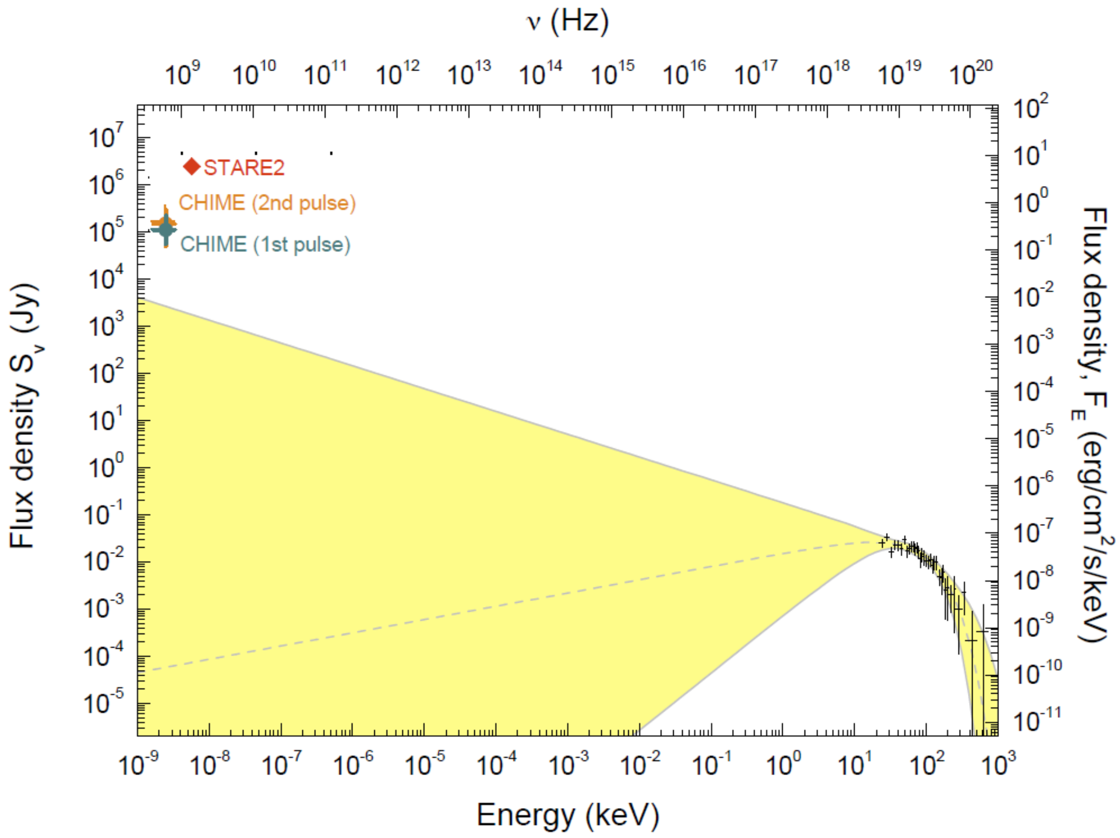
CHIME collab. Nature 2020

Konus-Wind (hard X-rays)



Ridnaia et al. Nat. Astr. 2021

SGR/FRB 200428 spectrum and energy



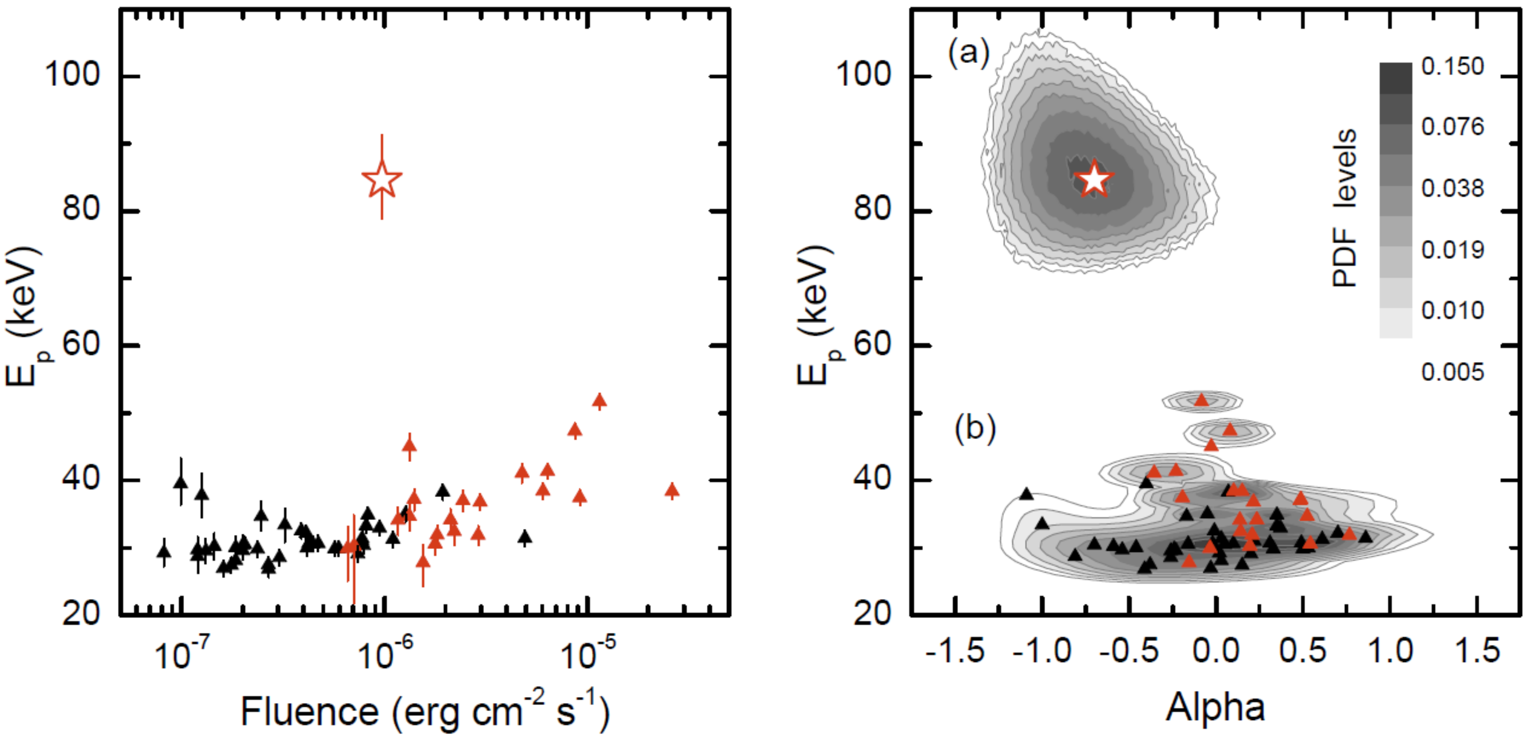
KW: CPL Model with $\alpha = -0.72$ and $E_p = 85$ kev

- For the first time for this source, the emission in a short flare was detected up to beyond ~250 keV
- The KW spectrum can be described by a **CPL with α~-0.72, Ep~85 keV**
- The broadband (radio- to X-rays) spectrum is inconsistent with a single PL
- The flare energy (20-500 keV) in X-rays is **Ex~1.2x10^{40} erg** and the peak luminosity is **Lx~1.1x10^{41} erg/s**
- The derived **Lr/Lx ~ 10^{-5} – 10^{-3}** and **Er/Ex ~ 10^{-6} – 10^{-5}**

(Ridnaia et al. Nat. Astr. 2021)

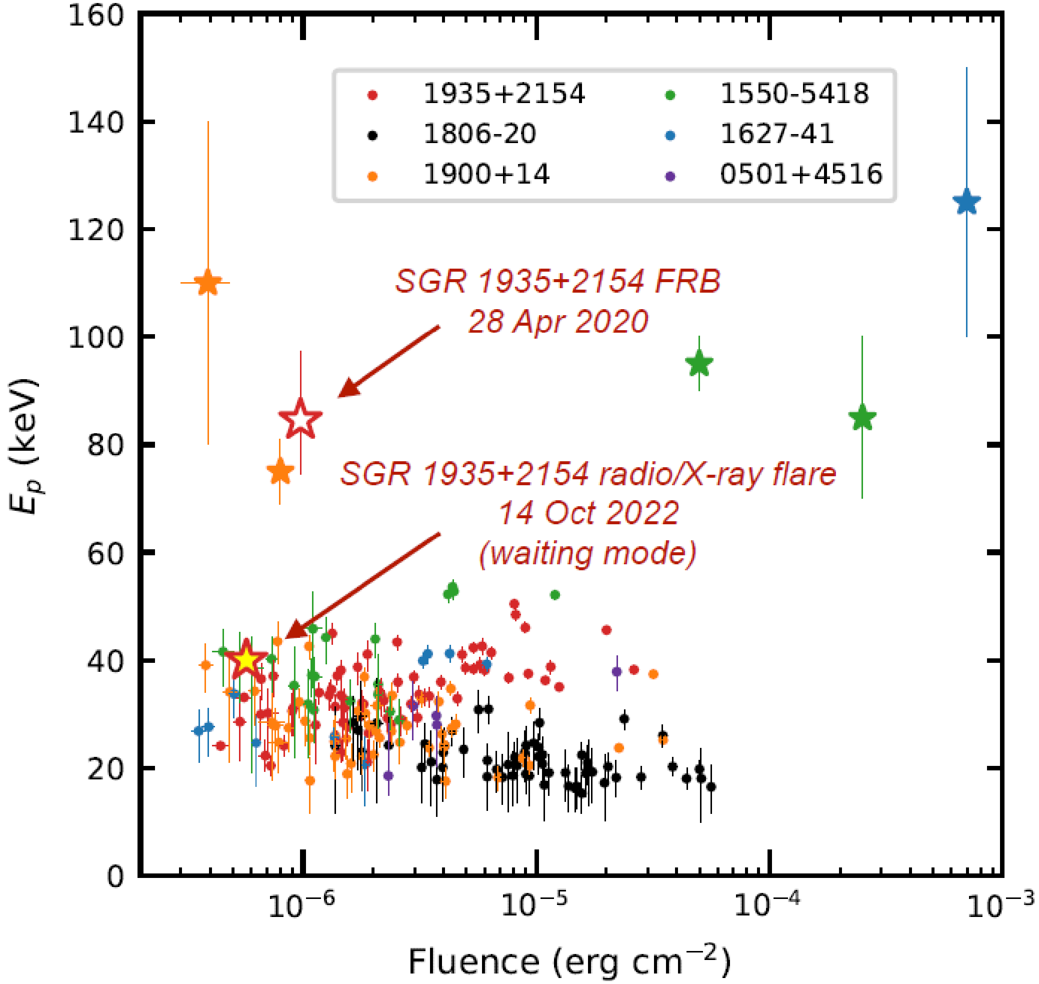
Peculiar hardness of SGR/FRB 200428

- The X-ray fluence of the flare and the CPL photon index are typical of SGR 1935+2514 bursts
- The spectral harness (Ep~85 keV) of the flare is inconsistent with the SGR 1935+2514 flare population (P_{chance}~10^{-10})



Ridnaia et al. 2021

Very hard SGR flares



Ridnaia et al. 2021

- Of ~300 bright, short X-ray flares from eight magnetars, 6 KW events have anomaluosly-hard (Ep>60 keV) spectra.
- The rate of such flares is estimated from the KW data to **~0.04/year/magnetar**
- The rate of FRBs, similar in Eradioradio-emitted energy with FRB 200428 is estimated to **0.007-0.04)/year/magnetar** (CHIME collaboration, 2020)
- => Peculiarly-hard X-ray bursts and bright, FRB-like magnetar flares may be closely related!
- Oct 14, 2022 – the 2nd radio/X-ray flare from SGR 1935+2154, with Sr ≥ 20 kJ s, Sx ~5x10^{-7} erg cm^{-2}, and a typical X-ray spectrum hardness (Ep~40 keV).

  (CHIME: ATel #15681, KW: ATel #15686)

Peculiar SGR/FRB 200428

nature astronomy

LETTERS

https://doi.org/10.1038/s41550-020-01265-0

Check for updates

A peculiar hard X-ray counterpart of a Galactic fast radio burst

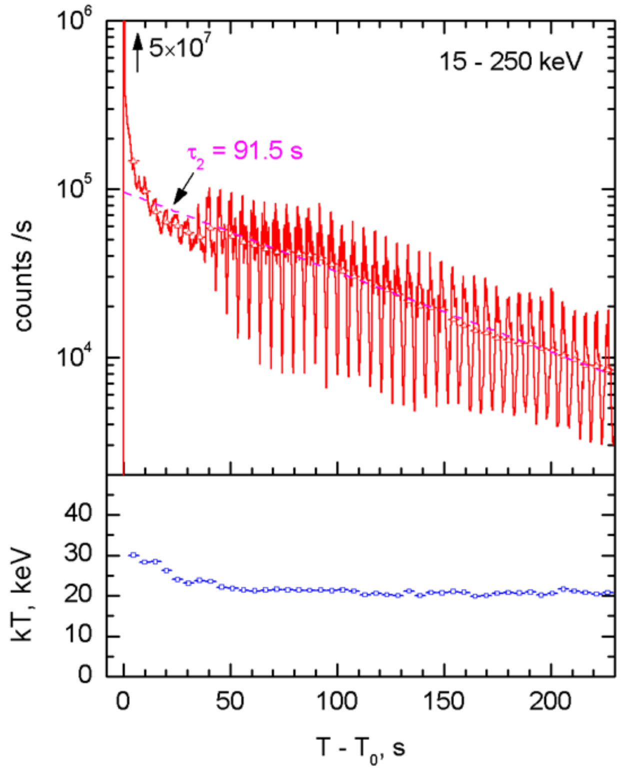
A. Ridnaia[1] ✉, D. Svinkin[1], D. Frederiks[1], A. Bykov[1], S. Popov[2,3], R. Aptekar[1], S. Golenetskii[1], A. Lysenko[1], A. Tsvetkova[1], M. Ulanov[1] and T. L. Cline[4]

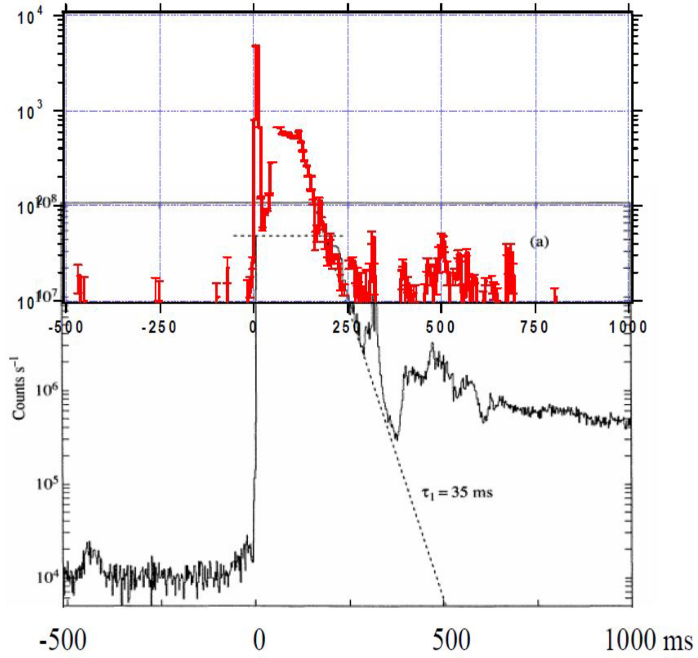
Fast radio bursts (FRBs) are bright, millisecond-scale radio flashes of unknown physical origin[1]. Young, highly magnetized, isolated neutron stars—magnetars—have been sug-

distance of 10 kpc in this Letter. Since its discovery, SGR 1935+2154 has been one of the most burst-prolific magnetars[21,22]. During the recent activation (which started in April 2020), it exhibited multiple

More details in Ridnaia et al. Nat Astr 5, 372 (2021)

Magnetar Giant Flares (MGFs)



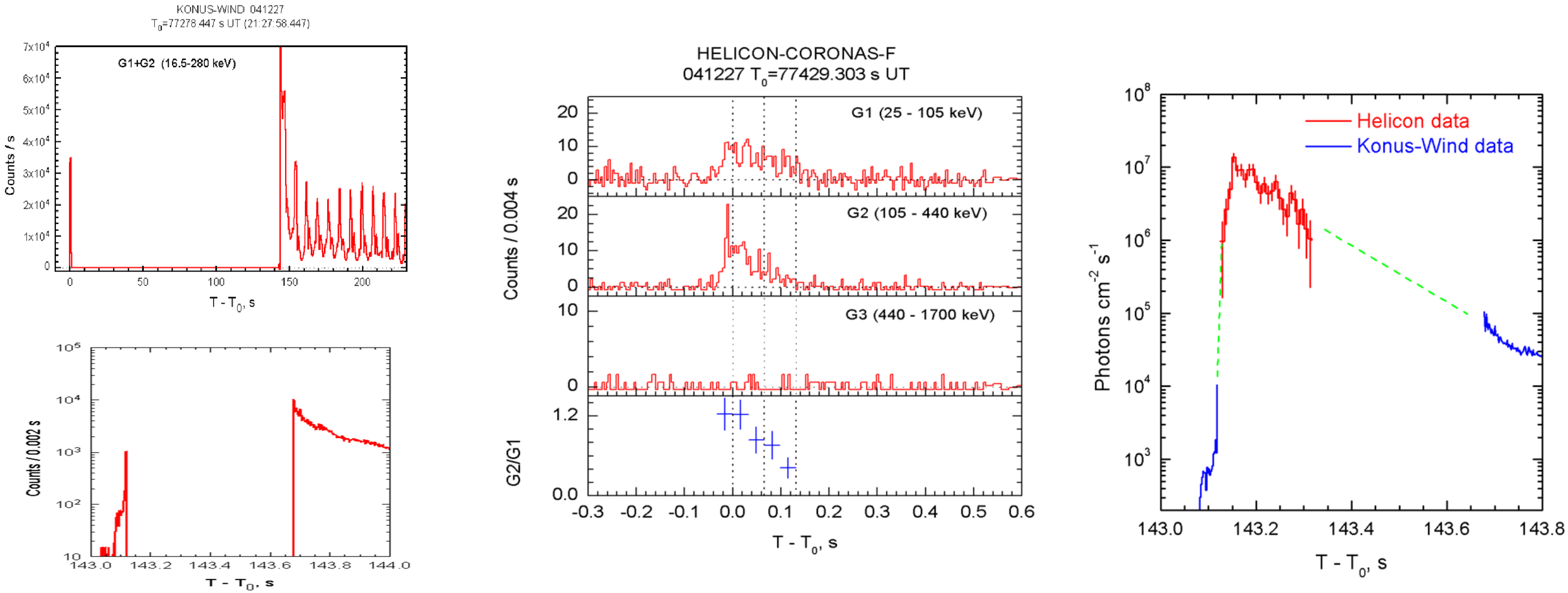


GEOTAIL-LEP
(Tanaka+2006,07)

Konus-WIND
(Mazets+1999)

- SGR 1900+14 GF (August 27, 1998) - the first GF after the famous March 5, 1979 event (SGR 0526-66 @ LMC, Mazets+1979)
- Giant, hard-spectrum initial pulse + soft pulsating tail
- E_{tot} ~ $4x10^{44}$ erg, L_{peak} ~ $2x10^{46}$ erg/s

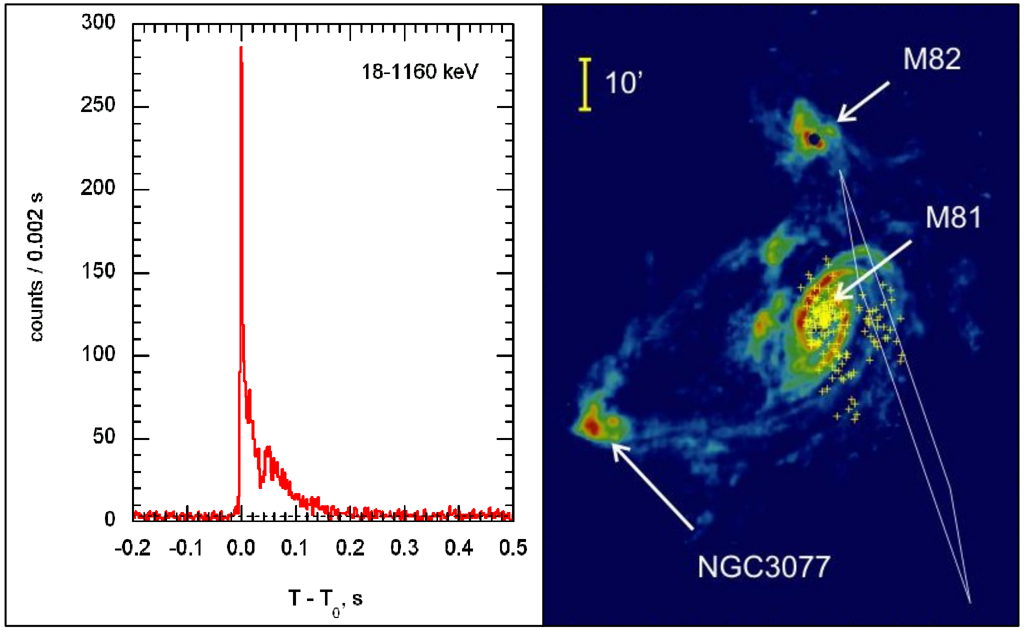
SGR 1806-20 “Superflare” (December 27, 2004)



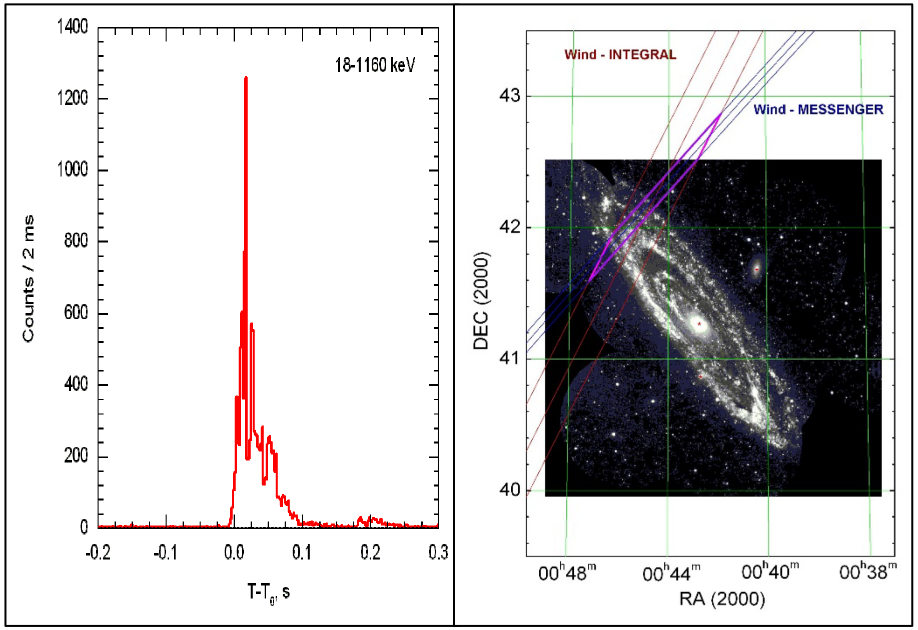
Frederiks et al. 2007a

- 3^{rd} in history and the most powerful Galactic MGF to date
- As for the August 27, 1997 GF, KW was fully saturated for ~500 ms in the initial pulse
- Helicon/*CORONAS-F* detected the GF initial pulse reflected from the Moon
- From joint KW+Helicon analysis: E_{tot} ~ 2x10^{46} erg, L_{peak} ~ 4x10^{47} erg/s

Short GRBs - extragalactic MGF candidates



GRB 051103 (Frederiks et al. 2007b)



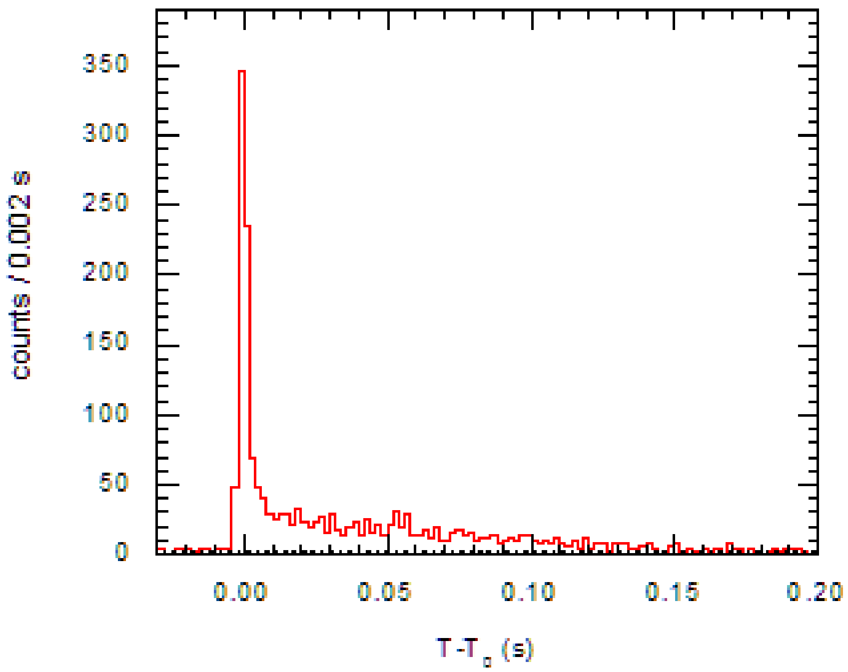
GRB 070201 (Mazets et al. 2008)

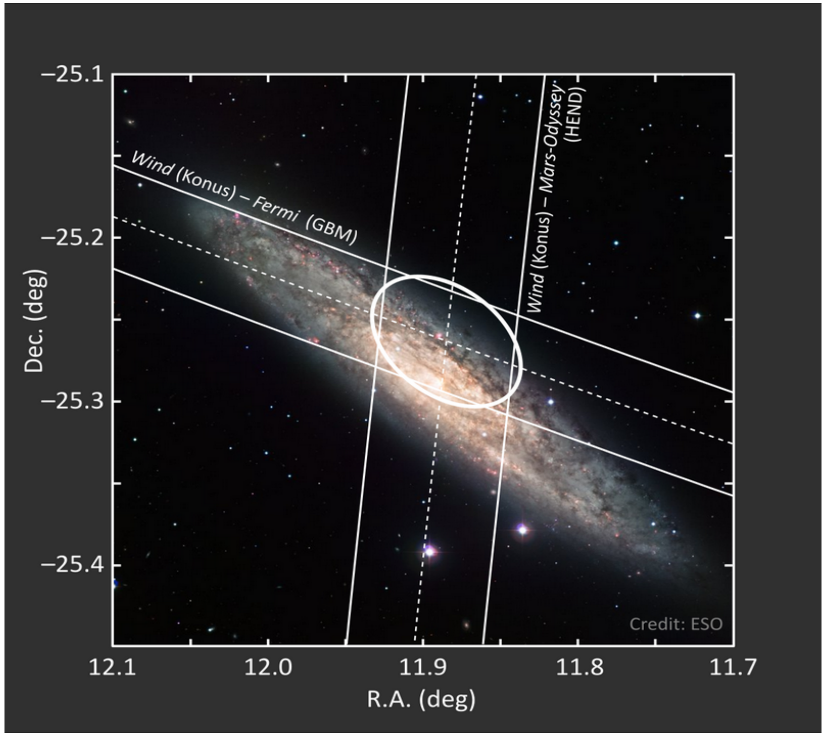
Original idea (Mazets & Golenetskii 1981) that some (if not all) short hard GRB are in fact distant Giant Flares was based on properties of the March 5, 1979 event. The superflare in SGR 1806-20 renewed the interest.

- GRB 051103 and GRB 070201 are extremely bright short events with sharp rise, dT ~150-200 ms and hard energy spectra, these characteristics of the events match the general pattern of a GF very closely
- For both bursts their IPN localization boxes overlap with starforming regions of nearby large spiral galaxies
- Assuming M81/82 and M31, respectively, the burst energies are close to that of initial pulses of known MGFs
- GRB 070201: weak extended tail (~100 s) with the energy comparable that of GF pulsating tails

Short GRB 200415A (NGC 253)

- Detected by five detectors (KW, Fermi-GBM, INTEGRAL-SPI/ACS, MO-HEND, ASIM)
- Localized by IPN to ~20 sq arcmin box overlapping the central part of NGC 253 at ~3.5 Mpc (P_{chance} ~5×10^{-6})

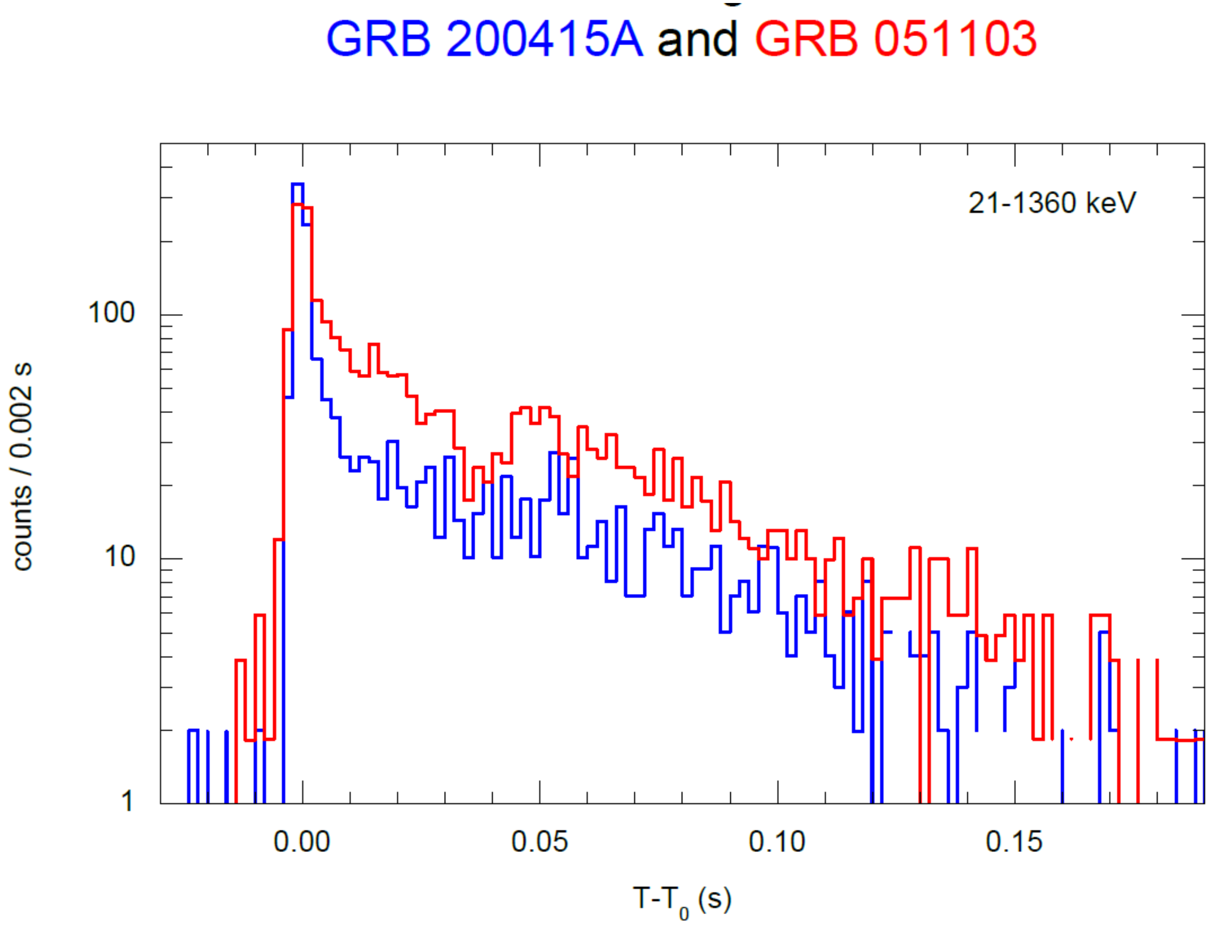




Svinkin et al. Nature 589, 211 (2021)

GRB 200415A

- The burst appeared to be a «twin” of GRB 051103 (in M81/M82 @~3.6 Mpc) !
- Fast (~2 ms) rise to the short (4 ms) initial spike + nearly exponential decay, T~200 ms



(Svinkin et al. 2021)

GRB 051103 (M81/M82) and GRB 200415A (NGC 253)

The Initial spike

- Rise time ~2 ms, duration ~4 ms
- E_p ~1.2 MeV,
- Contrib. to the total fluence ~45% (~13%)
- L_{iso}~1.4 (1.8) ×10^{48} erg/s

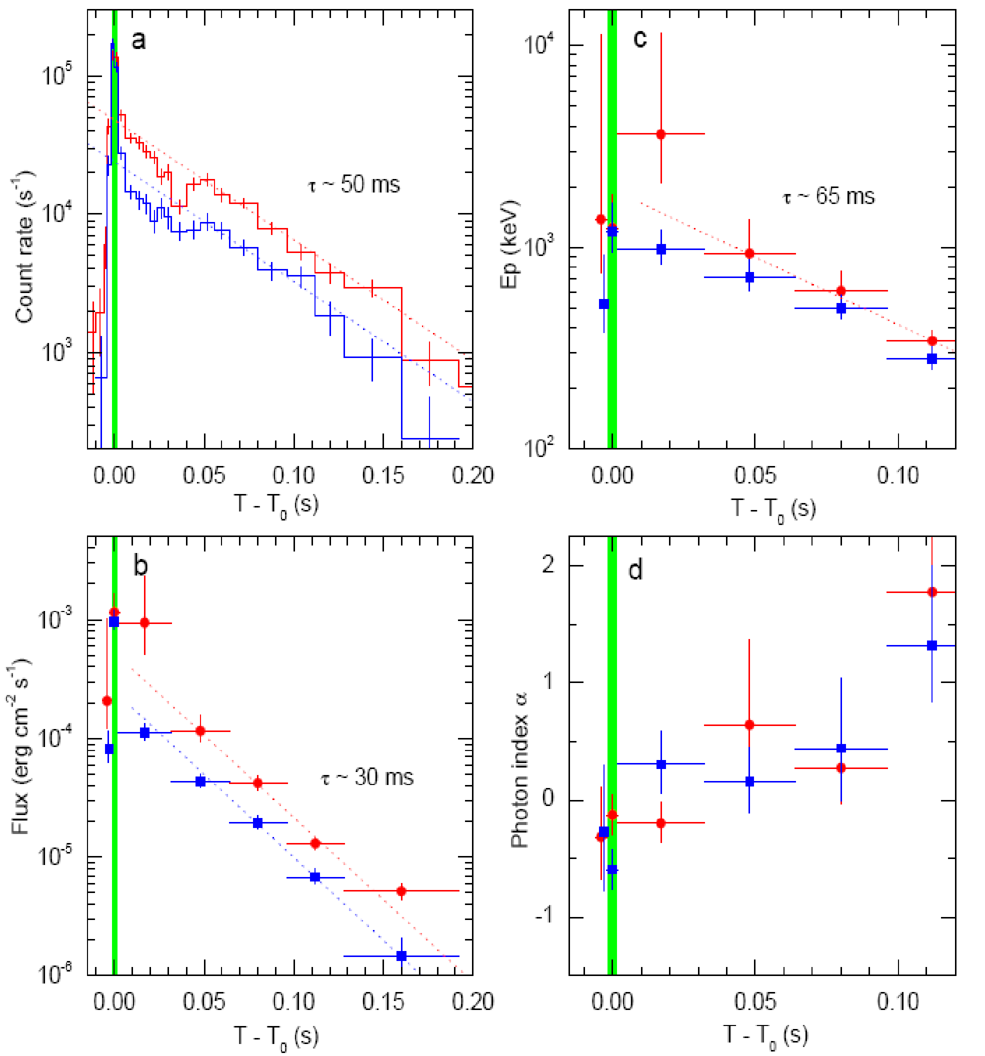
The decaying part

- Starting ~T_0+30 ms both E_p and energy flux decay exponentially
- After ~T_0+100 ms the spectrum evolves to blackbody (kT~ 70 keV, R~20-40 km)

Time-integrated spectrum (CPL+BB)

- CPL: E_p ~1080 / ~2690 кэВ, alpha ~ 0
- Total energy E_{iso} ~1.3 (~5.3) ×10^{46} erg
- BB contribution ~14% / ~9%

(Svinkin et al. 2021)



The nature of GRB 200415A and GRB 051103

- The first time when such unusual short bursts were detected, with very similar characteristics, and both are localized to the nearby galaxies at ~3.5 Mpc
- The combination of light curve structure, the emission hardness, and the flux evolution was never observed in hundreds of short GRBs
- The light curve properties (rise time, duration) and the emission hardness are similar to those of the initial pulses of the three known Galactic MGF
- The flare energies (Eiso~$(1\text{-}5)\times10^{46}$erg) are close to that of the SGR 1806-20 Superflare of December 27, 2004 (~2×10^{46}erg; Frederiks et al. 2007a)
- GW signal for GRB 051103 was excluded by LIGO up to d ~5.2 Mpc (Abadie et al. 2012)

- **GRB 200415A – the first reliable identification of an extragalactic MGF (eMGF)**
- **For the first time MGF initial pulse properties were derived from direct observations**
- **The population of «Superflares»:** SGR 1806-20 (041227), GRB 051103, GRB 200515A

GRB 200415A

Article

A bright γ-ray flare interpreted as a giant magnetar flare in NGC 253

https://doi.org/10.1038/s41586-020-03076-9

Received: 17 August 2020

Accepted: 2 November 2020

Published online: 13 January 2021

Check for updates

D. Svinkin[1]✉, D. Frederiks[1], K. Hurley[2], R. Aptekar[1], S. Golenetskii[1], A. Lysenko[1], A. V. Ridnaia[1], A. Tsvetkova[1], M. Ulanov[1], T. L. Cline[3], I. Mitrofanov[4], D. Golovin[4], A. Kozyrev[4], M. Litvak[4], A. Sanin[4], A. Goldstein[5], M. S. Briggs[6], C. Wilson-Hodge[7], A. von Kienlin[8], X.-L. Zhang[8], A. Rau[8], V. Savchenko[9], E. Bozzo[9], C. Ferrigno[9], P. Ubertini[10], A. Bazzano[10], J. C. Rodi[10], S. Barthelmy[3], J. Cummings[11], H. Krimm[12], D. M. Palmer[13], W. Boynton[14], C. W. Fellows[14], K. P. Harshman[14], H. Enos[14] & R. Starr[15]

Soft γ-ray repeaters exhibit bursting emission in hard X-rays and soft γ-rays. During the active phase, they emit random short (milliseconds to several seconds long), hard-X-ray bursts, with peak luminosities[1] of 10^{36} to 10^{43} erg per second. Occasionally, a giant flare with an energy of around 10^{44} to 10^{46} erg is emitted[2]. These phenomena are

More details in Svinkin et al. Nature 589, 211 (2021)

GRB 221009A (the BOAT)

The Astrophysical Journal Letters, 949:L7 (11pp), 2023 May 20 https://doi.org/10.3847/2041-8213/acd1eb

CrossMark

Properties of the Extremely Energetic GRB 221009A from Konus-WIND and SRG/ART-XC Observations

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Received 2023 February 26; revised 2023 April 30; accepted 2023 May 2; published 2023 May 18

The Astrophysical Journal Letters, 946:L31 (14pp), 2023 March 20 https://doi.org/10.3847/2041-8213/acc39c

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GRB 221009A: The BOAT

Eric Burns[1], Dmitry Svinkin[2], Edward Fenimore[3], D. Alexander Kann[4], José Feliciano Agüí Fernández[5], Dmitry Frederiks[2], Rachel Hamburg[6], Stephen Lesage[7,8], Yuri Temiraev[2], Anastasia Tsvetkova[2,9], Elisabetta Bissaldi[10,11], Michael S. Briggs[7,8], Sarah Dalessi[7,8], Rachel Dunwoody[12], Cori Fletcher[13], Adam Goldstein[13], C. Michelle Hui[14], Boyan A. Hristov[8], Daniel Kocevski[14], Alexandra L. Lysenko[2], Bagrat Mailyan[15], Joseph Mangan[16], Sheila McBreen[12], Judith Racusin[17], Anna Ridnaia[2], Oliver J. Roberts[13], Mikhail Ulanov[2], Peter Veres[7,8], Colleen A. Wilson-Hodge[14], and Joshua Wood[14]
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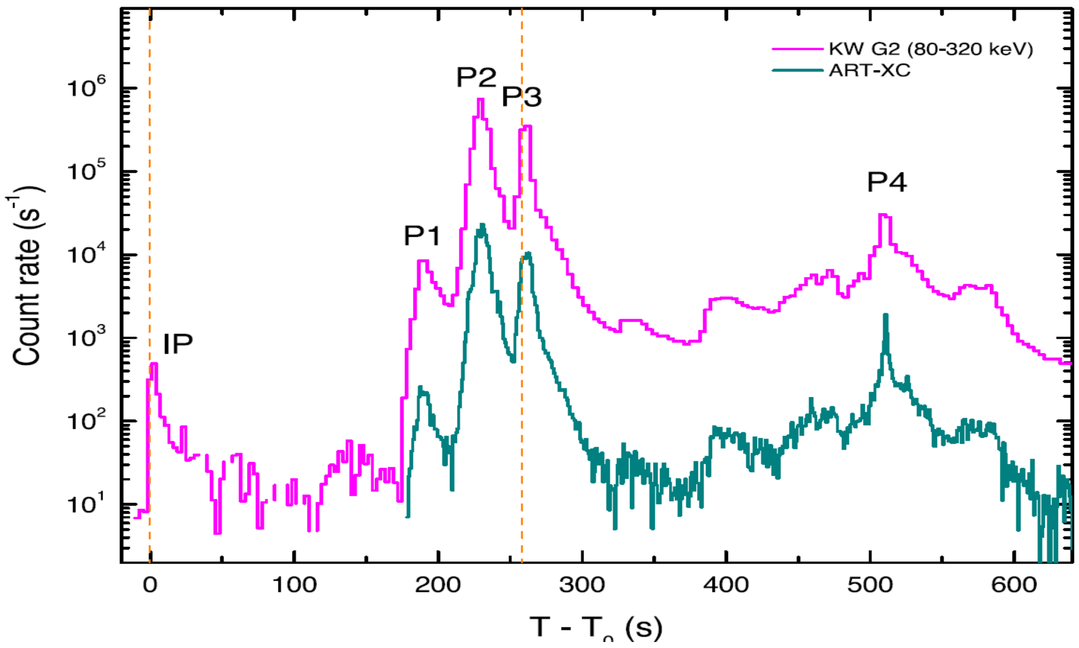
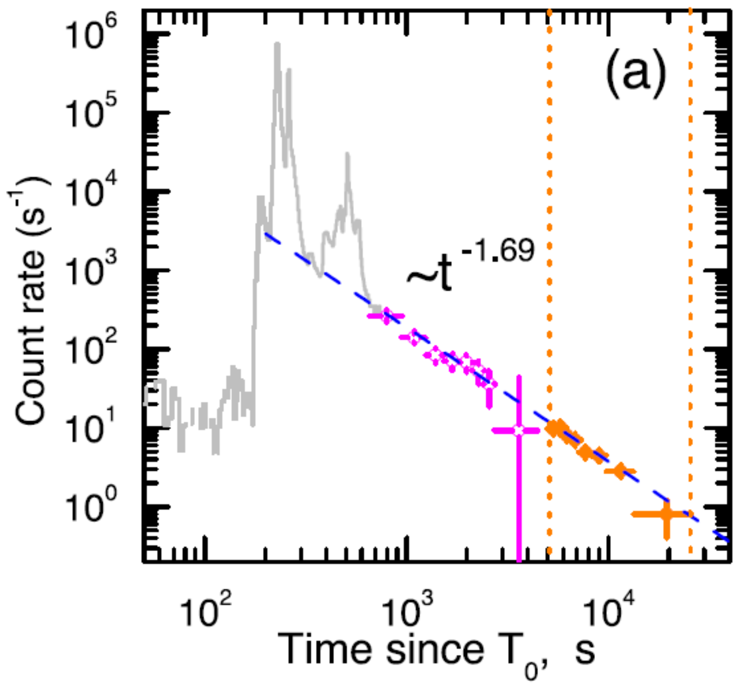
GRB 221009A (the BOAT)

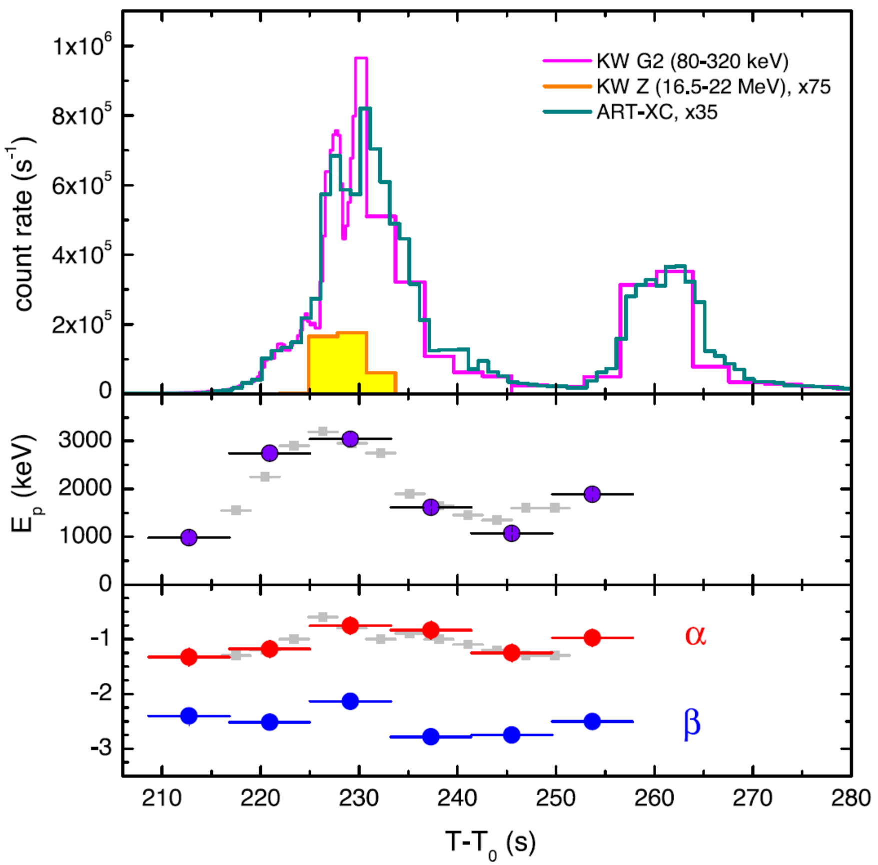




- The brightest and the most energetic GRB observed in > 50 years, a "once in 10^4 yrs" event (the BOAT, Burns et al. 2023)
- Observed by multiple spasecraft across the Solar system (and even by Voyager 1 !)
- Radio-to-TeV emission observed by space- and ground-based facilities
- Multi-peaked prompt emission lasted for ~600 s (seen by both KW and SRG/ART-XC)
- Gamma-ray afterglow (20-1220 keV) was observed by KW for ~25 ks

Frederiks et al. ApJL 949:L7 (2023)

GRB 221009A (the main peaks)



Frederiks et al. 2023

- The peak photon flux up to >10^4 cm^{-2} s^{-1} (Galactic MGFs – up to 10^5 - 10^6 cm^{-2} s^{-1})
- Saturated almost all GRB instruments (KW, Fermi/GBM, Insight-HXMT, GECAM, AGILE…)
- Using the methods developed for MGFs and powerful solar flares, we were able to reconstruct lc and spectra of the brightest part of the burst (P2 & P3) and were the first team to report the GRB energetics on arXiv (see also An et al. 2003 and Lesage et al. 2003)
- Burst parameters in the observer frame :

  Ep ~2.6 MeV (TI), ~3.0 MeV (at the peak)
  S ~ 0.22 erg cm^{-2} , F_{peak} ~ 0.031 erg cm^{-2} s^{-1}
  (both are the highest in > 50 years)

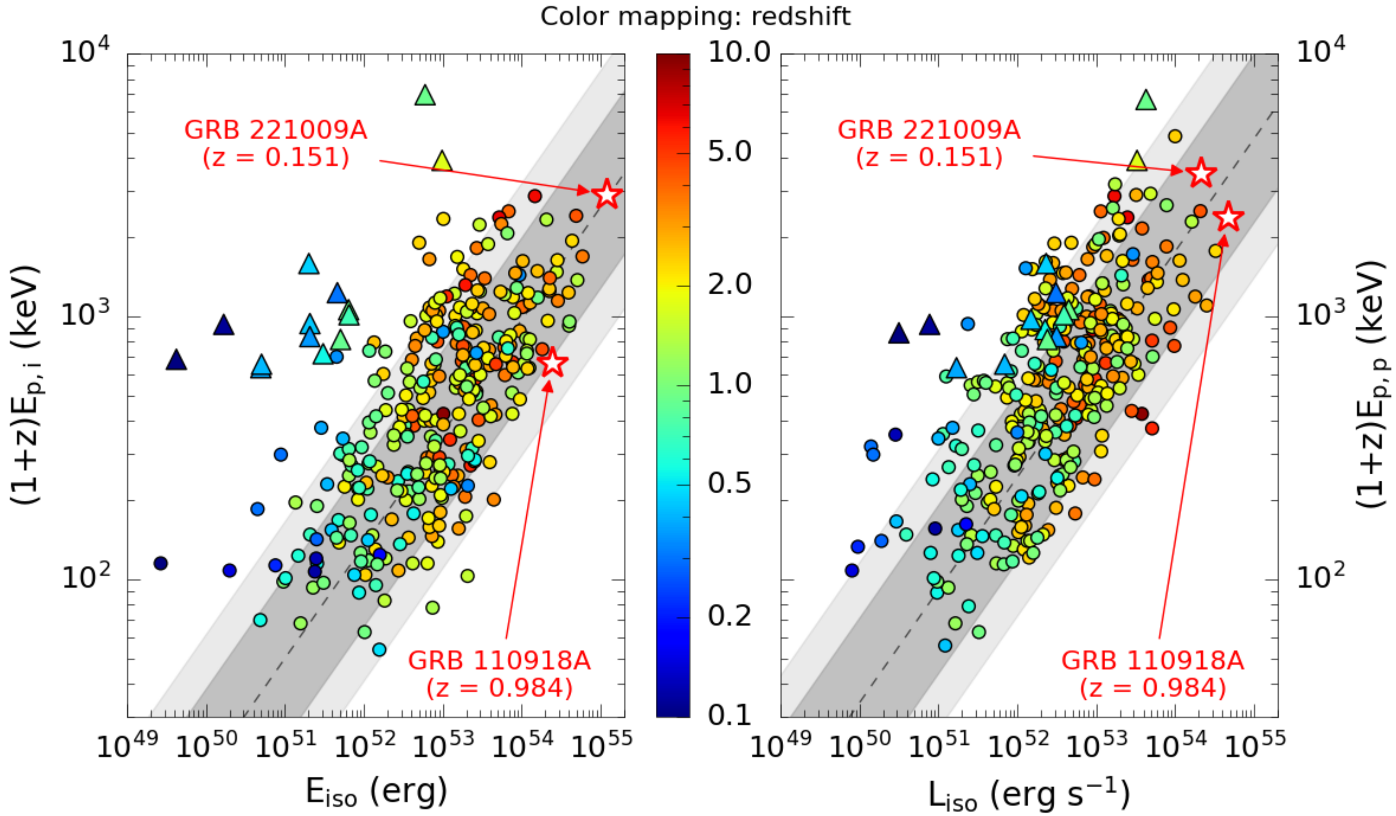
Pulse contribution to the total fluence:

IP (precursor) : 2.6 x 10^{-5} erg cm^{-2} (~0.01%)

P1+P2+P3: 0.21 erg cm^{-2} (~95%)

P4 : 0.01 erg cm^{-2} (~5%)

GRB 221009A (rest frame)

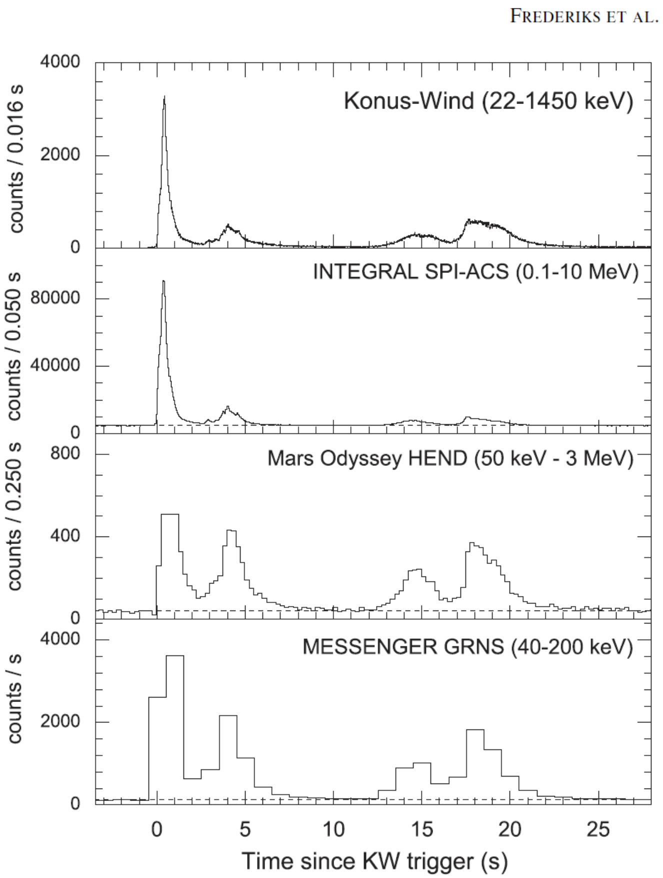


- Energetics in the rest frame (z=0.151):
  E_{iso}= 1.2×10^{55} erg, (> 6.5 solar rest mass), L_{iso} = 3.4×10^{54} erg s^{-1}

The burst fits perfectly both "Amati" and "Yonetoku" relations for > 300 KW long GRBs

Frederiks et al. 2023

GRB 110918A: the Ultraluminous burst



Frederiks et al. ApJ 779, 151 (2013)

GRB 110918A -

the most luminous GRB from the beginning of cosmological GRB era in 1997

- Localized by IPN to 2.6 sq. arc min box, missed by *Swift* and *Fermi* due to Earth occultation.
- Bright X-ray counterpart found was by *Swift*/XRT ~1.2 days after the burst and observed for 48 days

- Burst parameters, observer frame:

  ΔT ~30 s, $E_{p,max}$ ~4 MeV,
  S ~8×10^{-4} erg cm^{-2} and
  F_{peak} ~9×10^{-4} erg cm^{-2} s^{-1}

  GRB rest frame (z=0.984):
  $E_{iso}=2.1\times10^{54}$ erg,
  $L_{iso} = 4.8\times10^{54}$ erg s^{-1} (!),
  $\Theta_{jet}=1°.7 – 3.°4$, L_γ = ~ 5×10^{51} erg s^{-1}

KW catalogs and online databases

- **KW trigger database (event classifications, light curves, durations…), updated daily:**

  http://www.ioffe.ru/LEA/kw/triggers/index.html

- **GRBs with known reshifts (light curves, spectral fits, data tables) :**

  http://www.ioffe.ru/LEA/zGRBs/triggered/ (triggered bursts)

  http://www.ioffe.ru/LEA/zGRBs/part2/ (WM bursts)

- **KW Short GRB catalogs:**

  http://www.ioffe.ru/LEA/shortGRBs/Catalog/index.html

  http://www.ioffe.ru/LEA/shortGRBs/Catalog2/index.html

  http://www.ioffe.ru/LEA/shortGRBs/Catalog3/index.html

- **Short GRB IPN localizations:**

  http://www.ioffe.ru/LEA/ShortGRBs_IPN/index.html

- **KW-Sun, the solar flare database:**

  http://www.ioffe.ru/LEA/sun.html

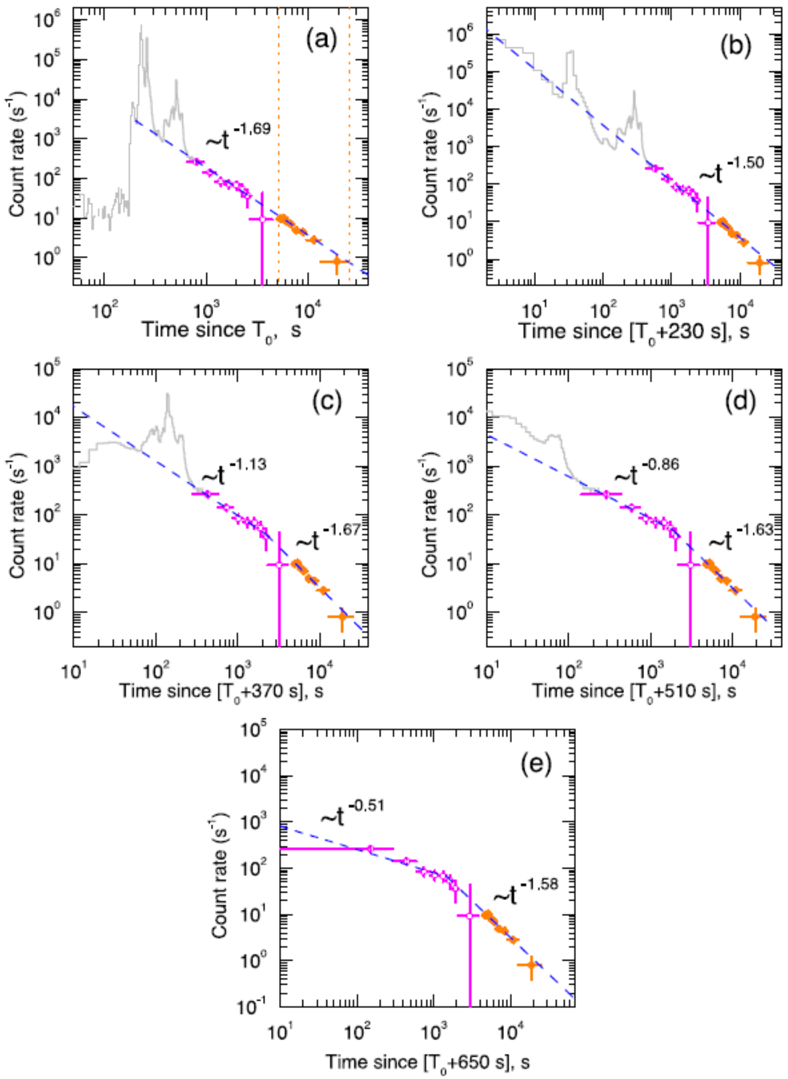
Conclusions

- For almost 30 years of operation Konus-Wind has been collecting important, often unique data on short, long, and u-long GRBs, SGR (magnetar) flares, Galactic and extragalactic MGFs, solar flares, and other transients
- The instrument provides excellent results in collaboration with many space-based missions (Swift, Fermi, INTEGRAL, MO, BepiColombo, Insight-HXMT, GECAM, EP …) and ground-based facilities
- The *Wind* spacecraft and the Konus instrument are both in a good health and we expect more exciting science with KW in the future!

Thank you!

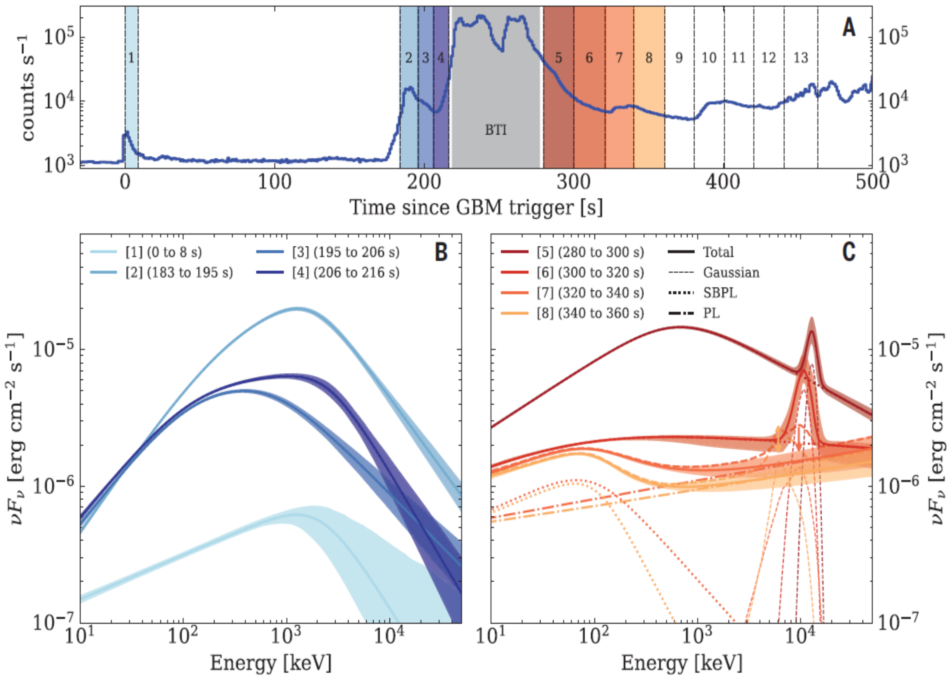
GRB 221009A (afterglow)

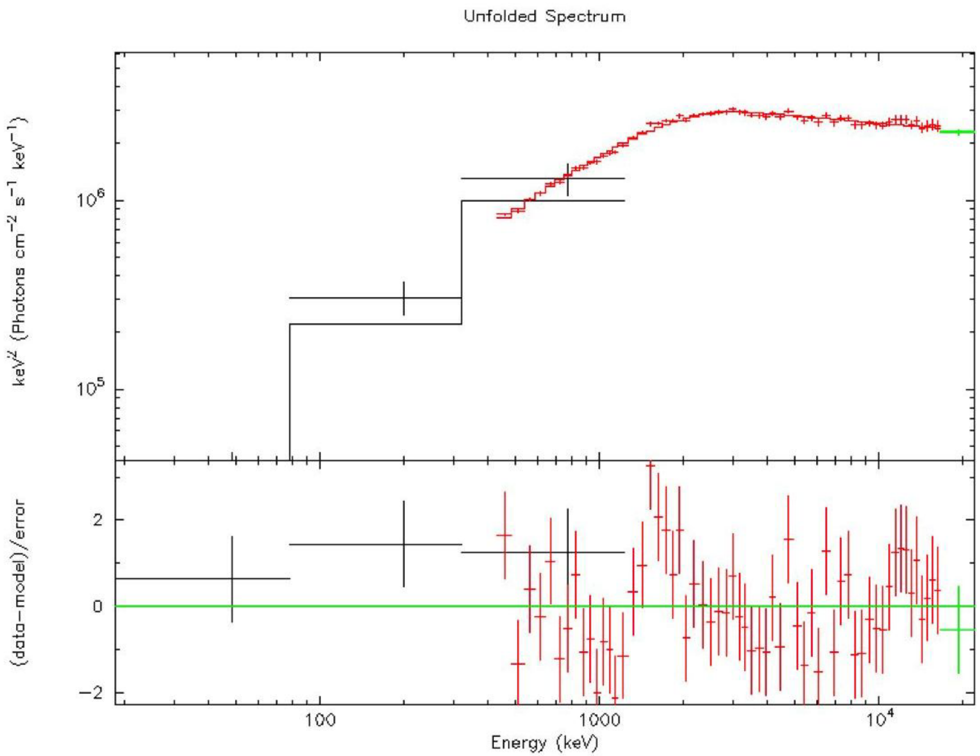
THE ASTROPHYSICAL JOURNAL LETTERS, 949:L7 (11pp), 2023 May 20 Frederiks et al.



Frederiks et al. (2023)

GRB 221009A (MeV line)





Fermi-GBM: 290 .. 320 s, > 6σ

E_{line} (14.4 – 6.) MeV

L_{line} (1 – 0.4)×10^{50} erg s^{-1}

Ravasio et al., Science 385, 452 (2024)

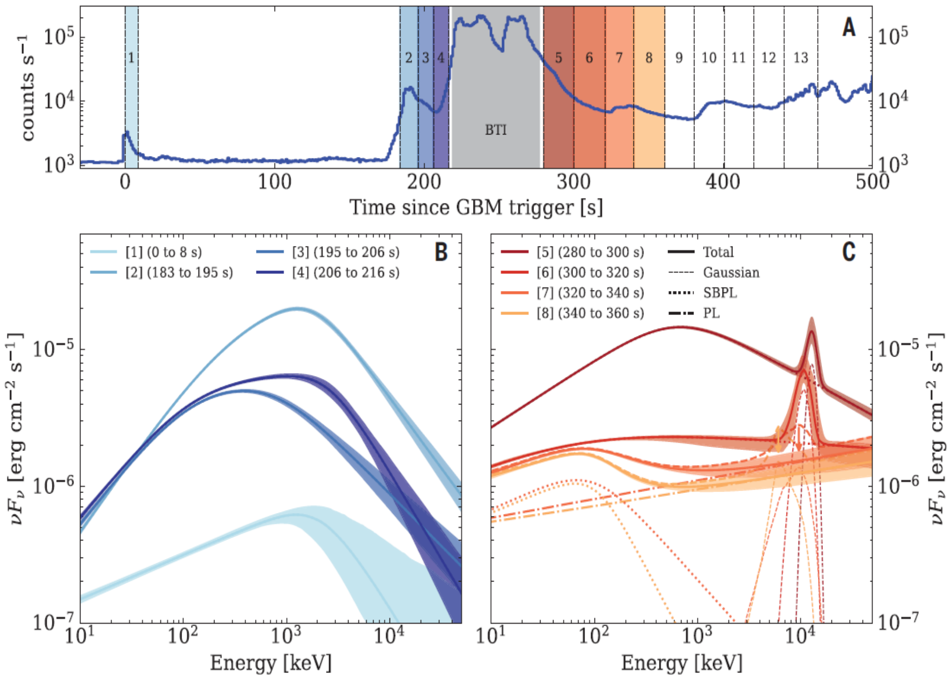
KW: 225 .. 233 s (< 2σ)

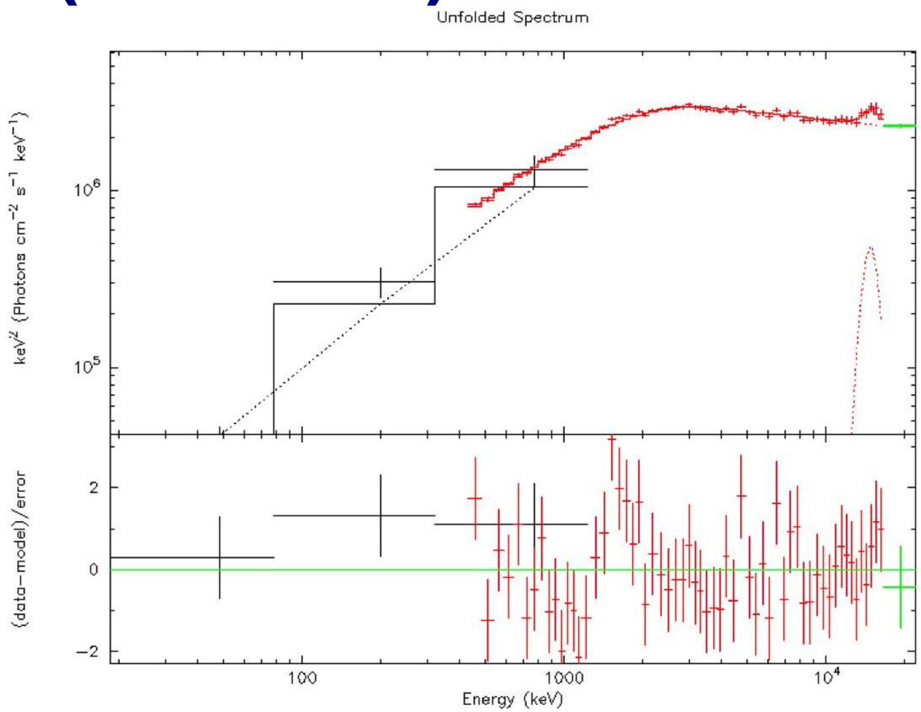
E_{line} ~ 14.7 MeV

L_{line} ~ 9×10^{51} erg s^{-1}

Frederiks et al. (2023)

GRB 221009A (MeV line)





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