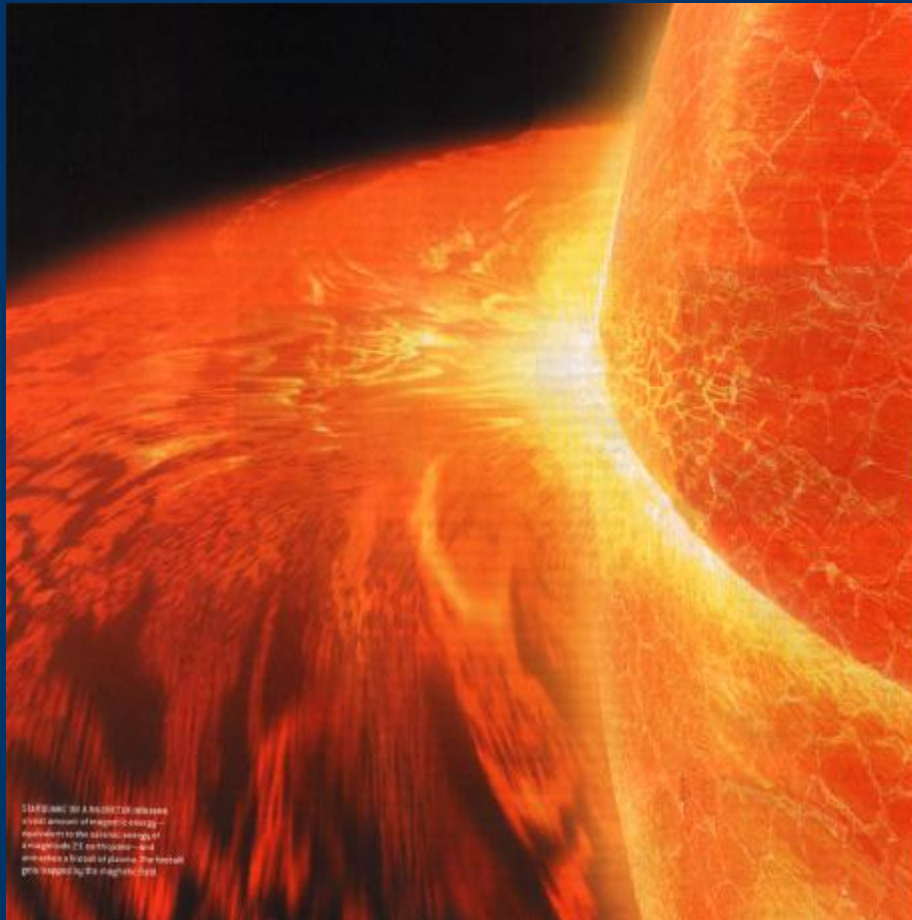
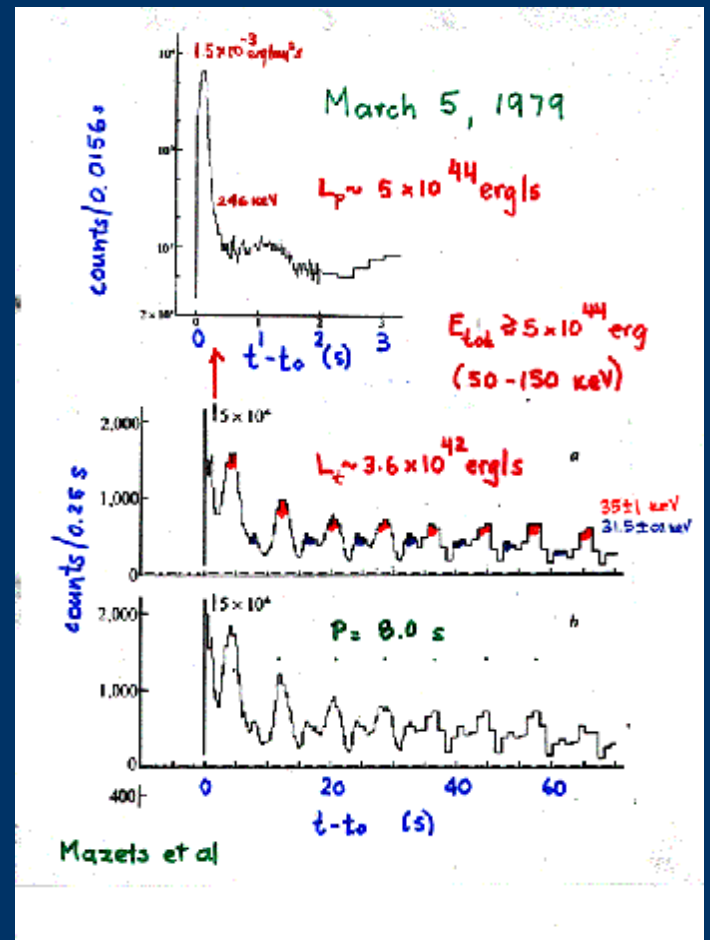


Soft Gamma Repeaters (SGRs)



MAGNETARS

STARS ARE OF A MASSIVE MASS
 emit amount of magnetic energy
 equivalent to the kinetic energy of
 a hydrogen 21 centimeter line
 emission at every second. The total
 energy is released by the magnetar field.





Soft Gamma Repeaters (SGRs)



Goddard
Flight
Space
Center

Giant Flares in Soft Gamma Repeaters (Konus-Wind and Helicon - Coronas-F summary)

*A.F.Ioffe Physico-Technical Institute,
St.Petersburg, Russia*

*NASA Goddard Space Flight Center,
Greenbelt, Maryland, USA*



Soft Gamma Repeaters (SGRs)



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Konus-Wind Summary

Joint Russian-American experiment on US GGS-WIND spacecraft

Launch: November 1, 1994

Konus-Wind instrument switched on:
November 11, 1994

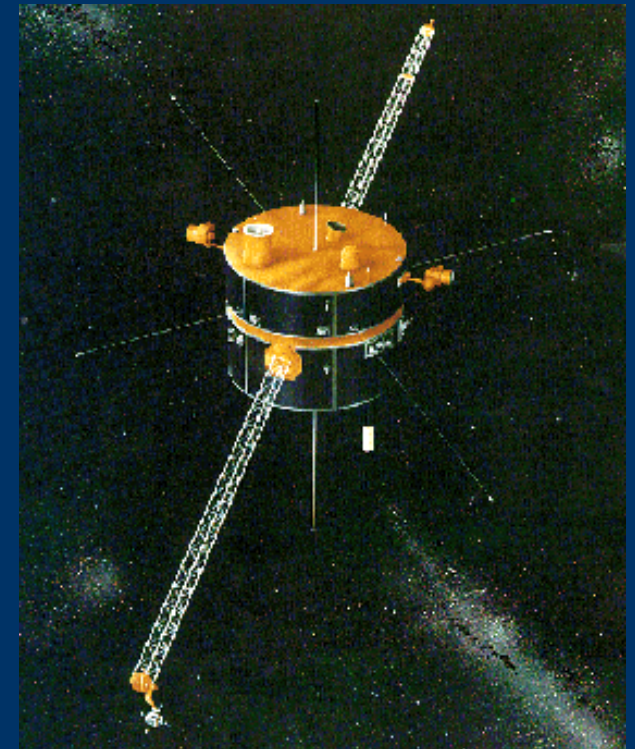
Orbit: beyond the magnetosphere of the Earth

Observations:

November 11, 1994 – December 18, 2004 (3689 days)

Gamma ray bursts total >2500

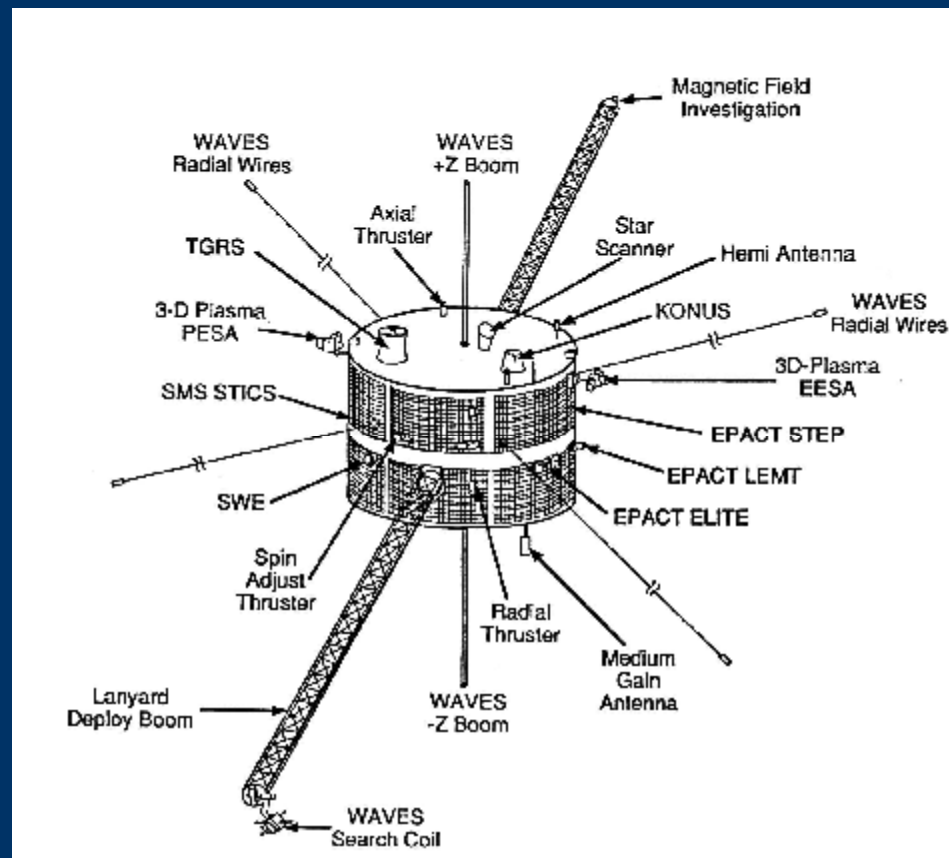
- Burst mode >1450
- Background mode >1150
- Solar flares >750
- SGR bursts >300



Soft Gamma Repeaters (SGRs)



Wind Instruments

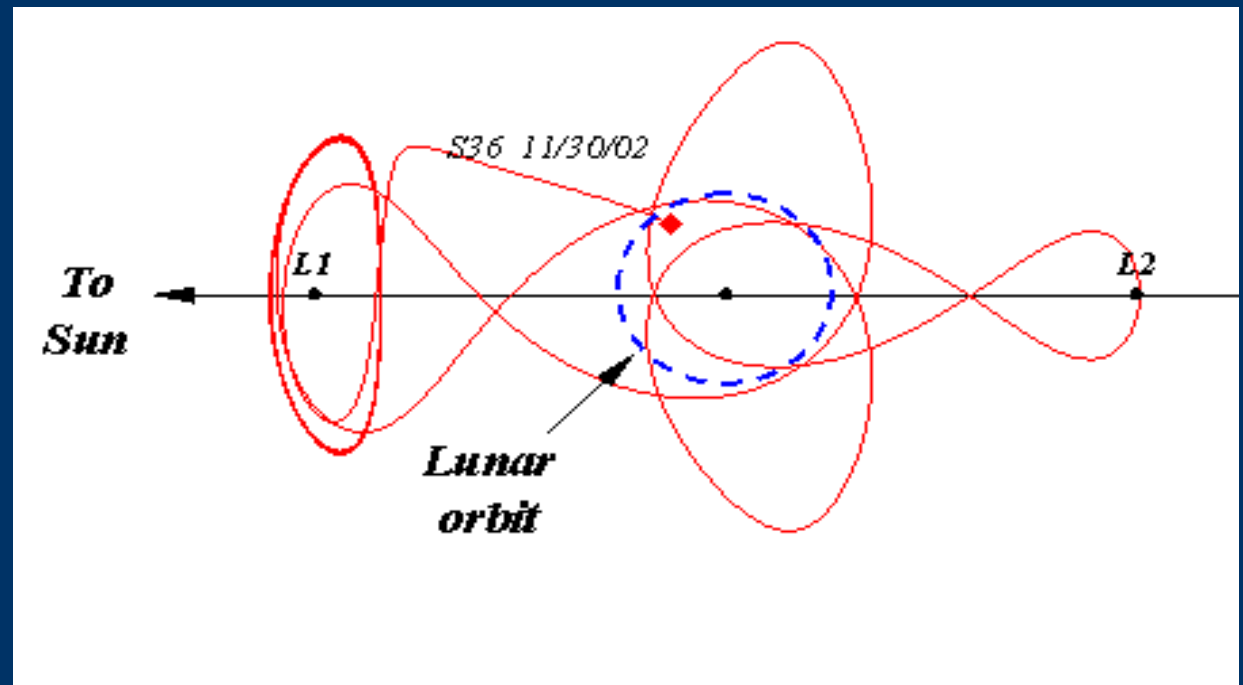


Wind trajectory

Wind trajectory
during
extended
mission

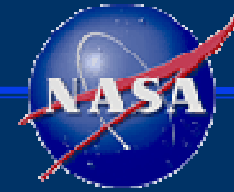
L1 excursion →
L2 excursion
→ L1 Lissajous
orbit (2002-
2008+)

XY (ecliptic plane) projection





Soft Gamma Repeaters (SGRs)



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Konus-Wind Gamma-Ray Burst Experiment on US GGW-Wind spacecraft

- Two detectors S1 and S2:
NaI(Tl) 13 cm diameter, 7.5 cm height, 12.5 cm Be window.
Located on opposite faces of spacecraft, observing correspondingly the southern and northern celestial hemispheres
- Burst mode:
Time history analyzer: resolution 2ms – 256 ms, total duration 230s

12 – 50 keV	4096 ch
50 – 200 keV	4096 ch
200 – 770 keV	4096 ch



Soft Gamma Repeaters (SGRs)



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Center

Instrument description (ii)

- Pulse Height analyzer: accumulation time 64ms – 8.192 s,
duration 79 – 492 s

PHA1 12 – 770 keV 63 ch quasilog scale

PHA2 0.2 – 10 MeV 63 ch quasilog scale

- Background mode: accumulation time 1.47 – 2.94 s

Count rate:

12 – 50 keV

50 – 200 keV

200 – 770 keV

> 10 MeV



Soft Gamma Repeaters (SGRs)



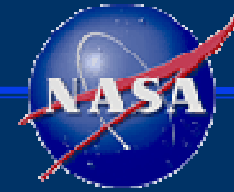
Goddard
Flight
Space
Center

Helicon-Coronas-F

- Coronas-F is a Russian solar observatory that was launched on 2001 July 31 on near-Earth orbit (inclination 82°). S/c is stabilized by rotation with axis directed to Sun.
- Helicon is a gamma-ray spectrometer (20keV-15MeV). Two detectors identical to Konus-Wind, observed solar and anti-solar hemispheres.



Soft Gamma Repeaters (SGRs)



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Space
Center

SGR history

- 5 March 1979 – giant flare from **SGR 0526-66** detected by Konus experiment on Venera-11, 12
- End of March 1979 – 3 short, soft bursts were detected by Konus from **SGR 1900+14**
- **SGR 1806-20** – 1983 (Prognoz 9, ICE, SMM)
- **SGR 1627** – 1998 (BATSE, Konus-A, Konus-W, Ulysses)
- **SGR 1801-23** – two bursts were detected on 1997 June 29 (BATSE, Konus-A, Konus-W, Ulysses)



Soft Gamma Repeaters (SGRs)



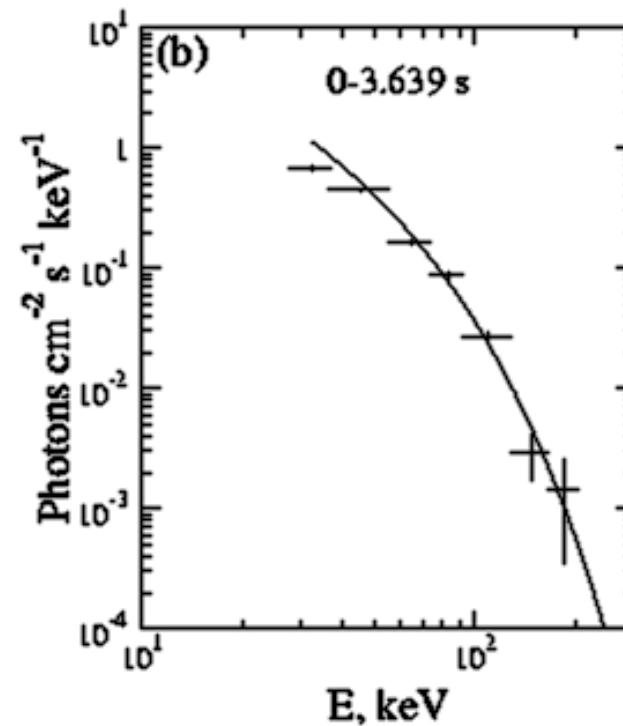
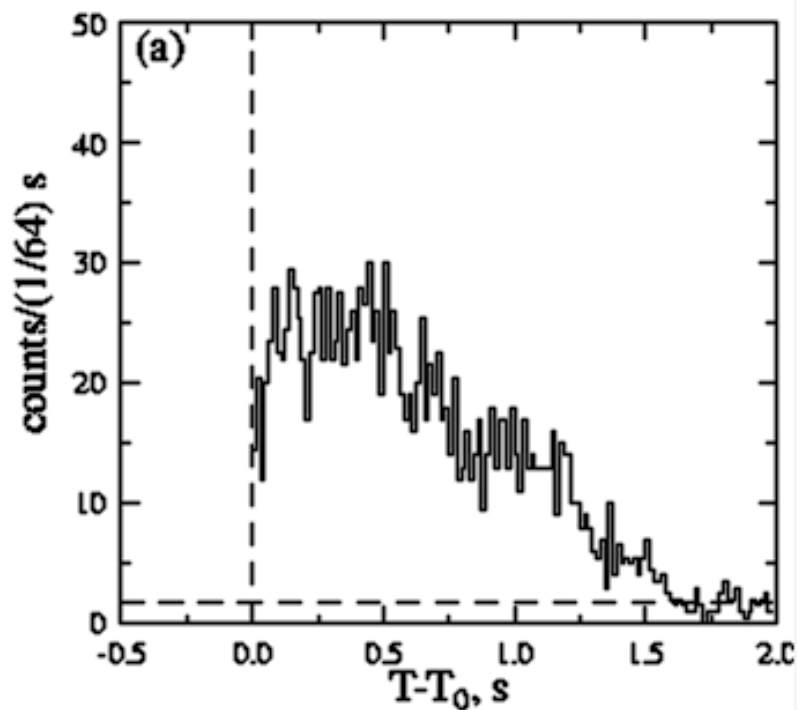
Goddard
Flight
Space
Center

SGR observational summary (i)

- «Active» and «Quiet» states
- Recurrent bursts:
 - duration $\sim 0.1-1$ s;
 - energy release $\sim 10^{38}-10^{41}$ erg,
 - Spectra can be described by **OTTB** model
[$dN/dE \sim E^{-1} \exp(-E/kT)$] for $E > 20$ keV;
 $kT \sim 15 \div 30$ keV

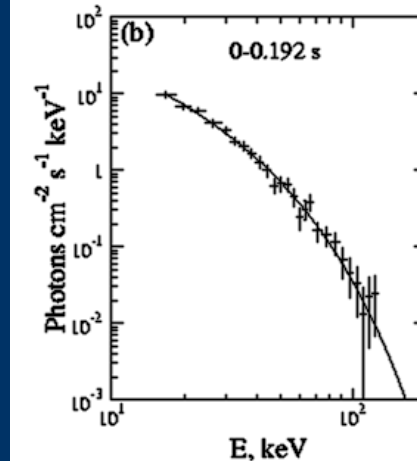
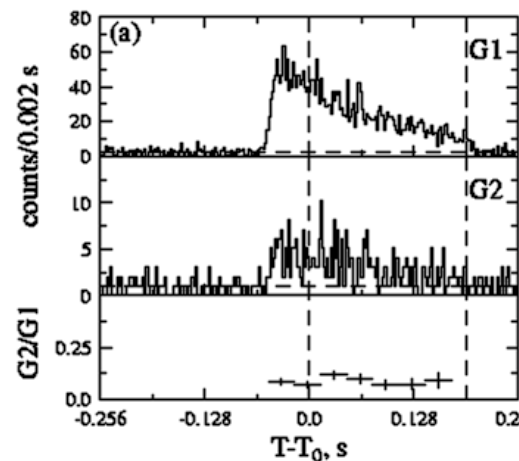
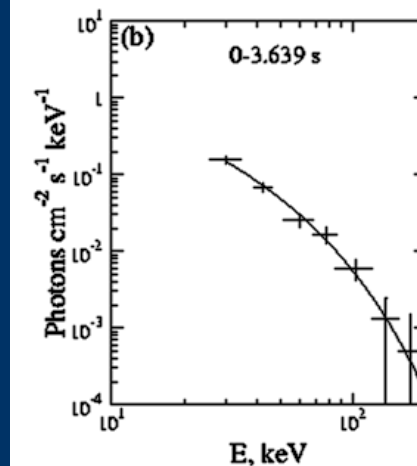
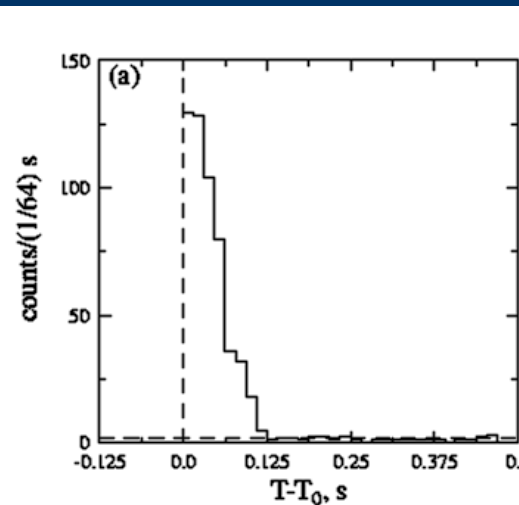
SGR 0526-66

- Burst 790306 detected from SGR 0526-66 by Konus on Venera-11



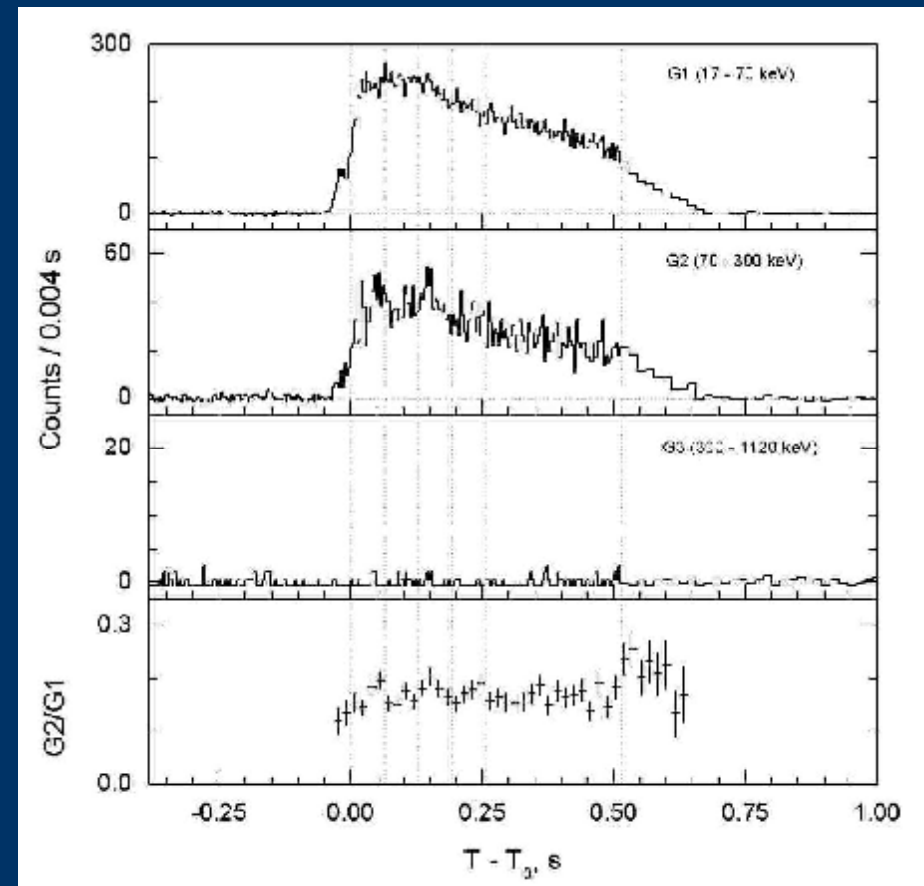
Konus-Wind observations of SGR 1900+14

- Burst 790324 - the first burst detected from SGR 1900+14 by Konus on Venera-11
- Burst 980902b – a typical burst from SGR 1900+14 detected by Konus-Wind



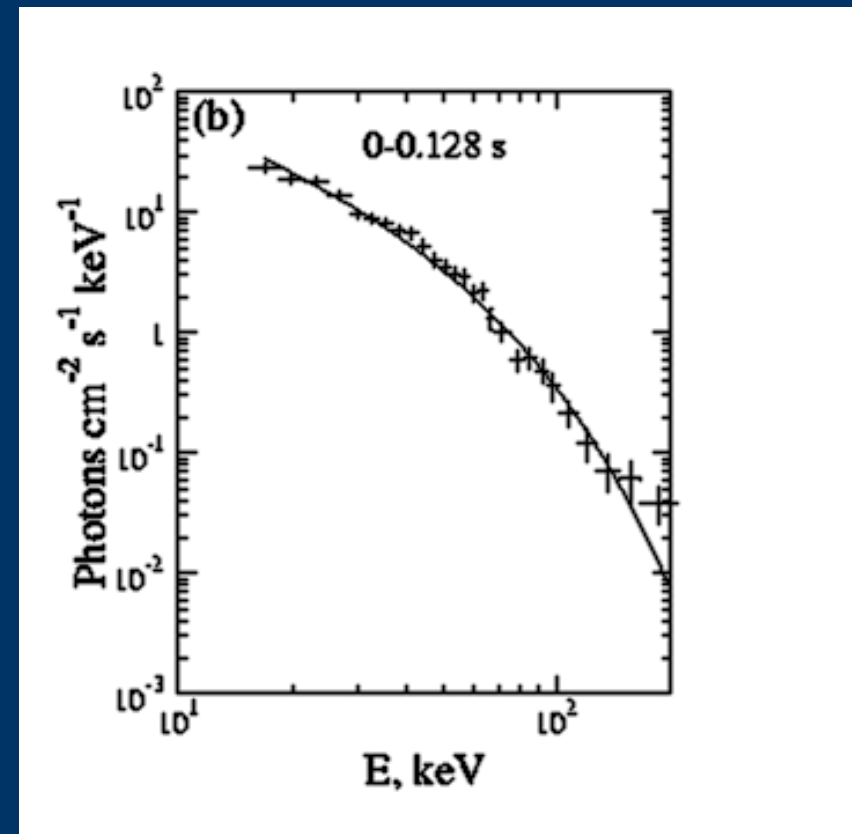
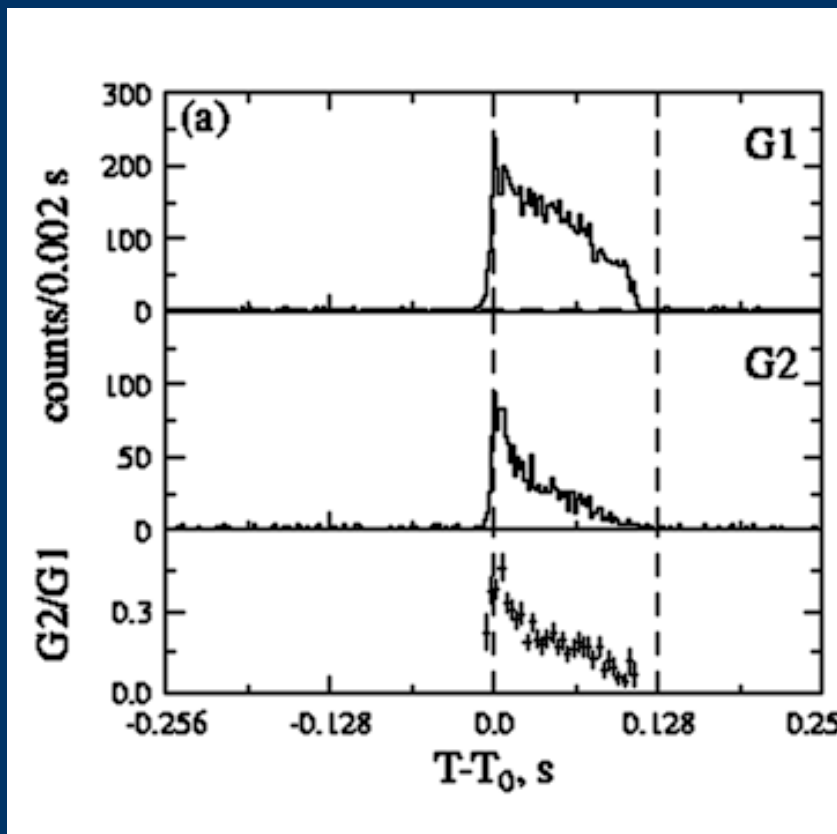
SGR 1806-20

- Burst 040828 – one of the most intense burst (both in peak flux and fluence) detected by Konus-Wind from this SGR.



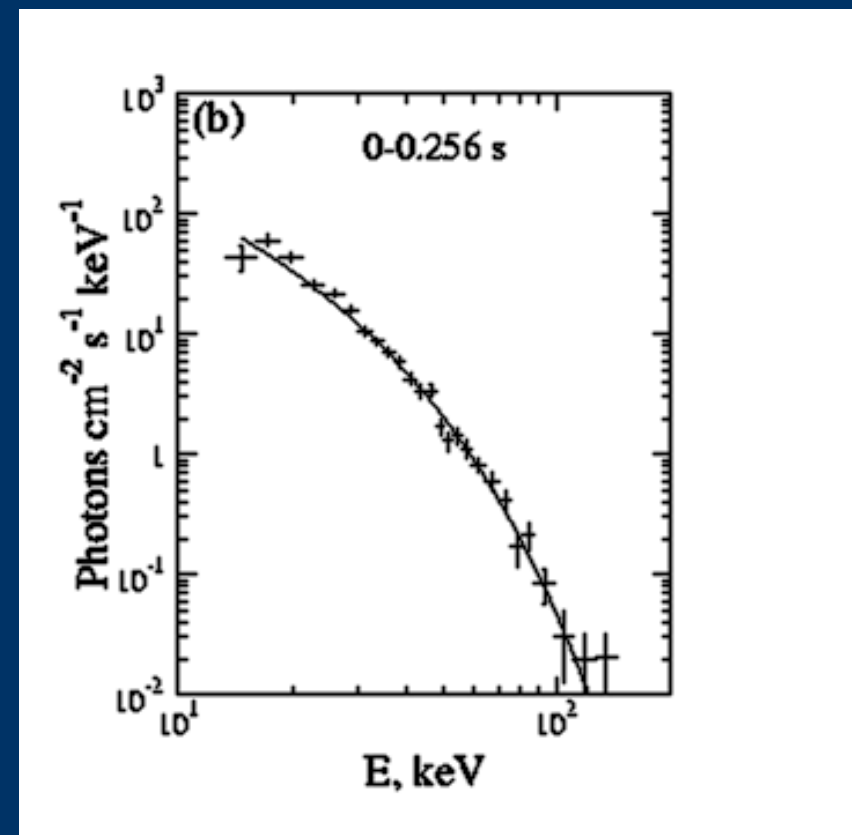
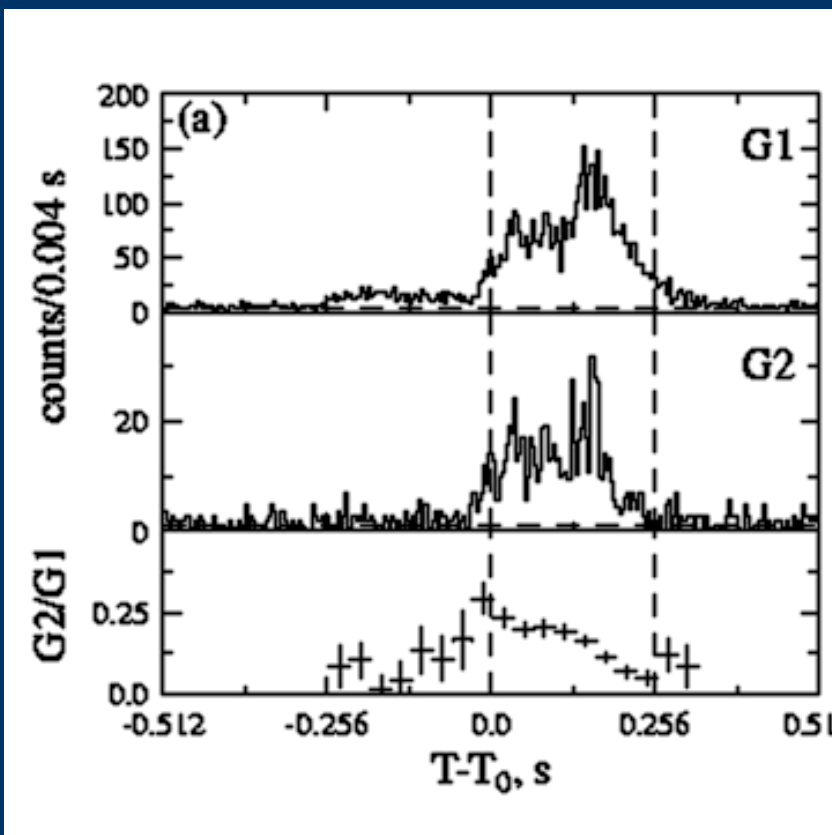
SGR 1627-41

- An intense burst 980625 from SGR 1627-41 which demonstrates strong spectral evolution typical for this SGR.



New SGR 1801-23

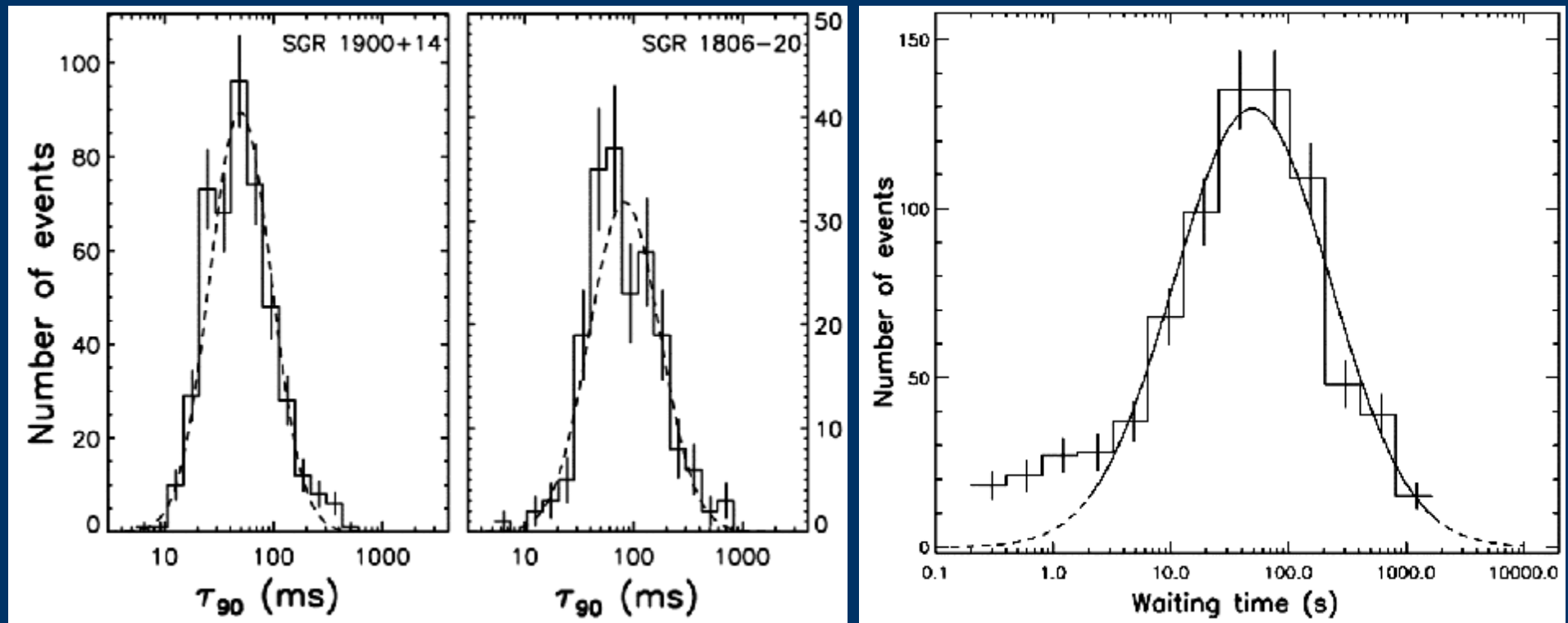
Burst 970629b detected by Konus-Wind at
 $T_0=23493.221$ s UT



Soft Gamma Repeaters (SGRs)

Recurrent bursts statistics (Gogus et al., 1999, 2001)

- RXTE, BATSE data





Soft Gamma Repeaters (SGRs)



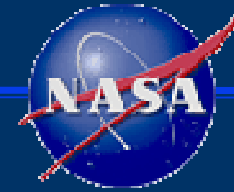
Goddard
Flight
Space
Center

SGR observational summary (ii)

- Persistent X-ray emission (0.5-10 keV)
 - Flux $\sim 10^{-11}$ erg cm $^{-2}$ s $^{-1}$ ($L_X \sim 10^{35}$ erg s $^{-1}$)
 - power law spectra with $\gamma \sim 2.2$
 - Pulsation $\sim 10\%$, $P \sim 5-8$ s, $dP/dt \sim 10^{-11}$ s/s



Soft Gamma Repeaters (SGRs)



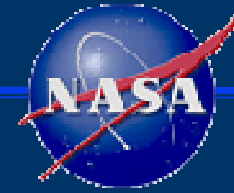
Goddard
Flight
Space
Center

Persistent emission

	SGR 0526-66	SGR 1627-41	SGR 1806-20	SGR 1900+14
Distance, kpc	~55	11±0.3	6-15	10-14
L_X (erg s ⁻¹)	1 × 10 ³⁶	<3 × 10 ³⁴	4 × 10 ³⁵	2 × 10 ³⁵
PL photon index	3.1	2.5	2.0 - 2.2	1.0 - 2.2
kT _{BB} , keV	-	-	0.5-0.7	0.5
Period (s)	8.0	6.4(?)	7.5	5.2
dP/dt (10 ⁻¹¹ s s ⁻¹)	6.5	...	8 – 30 (55 in 2004 –XMM data)	6 - 35



Soft Gamma Repeaters (SGRs)



Goddard
Flight
Space
Center

Recent progress

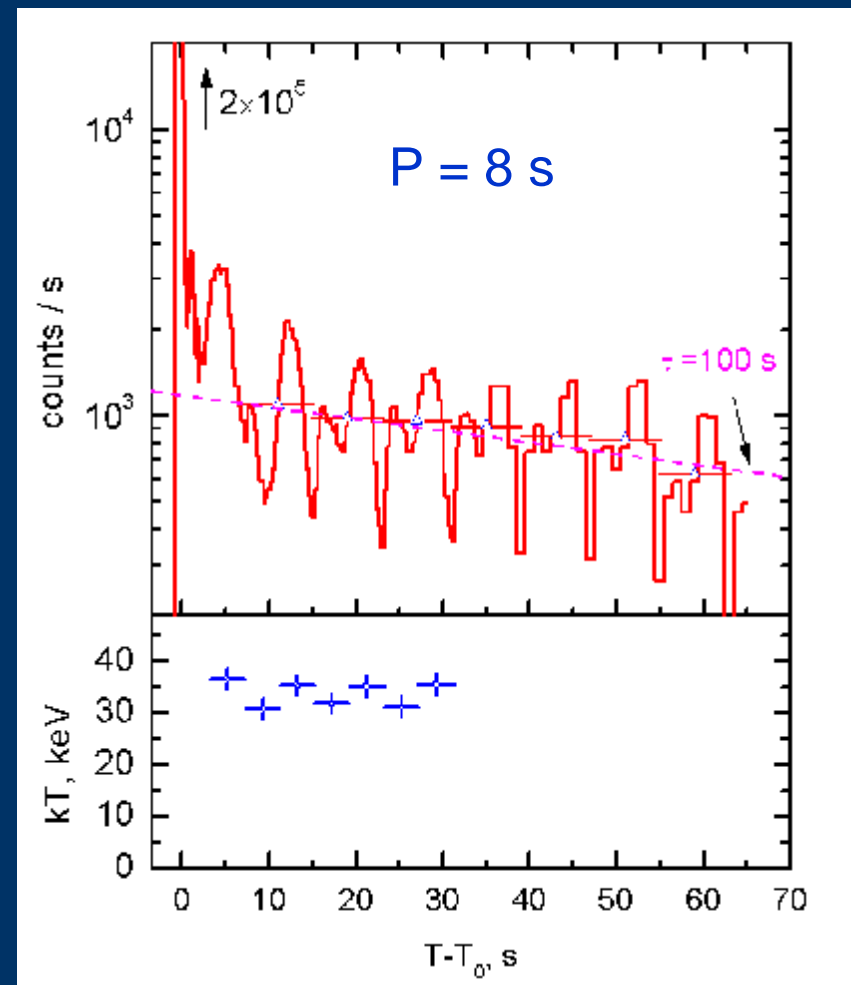
- Discovery of hard component (up to ~ 150 keV) in persistent emission of SGR 1806-20 by Integral/IBIS (Molkov et al. 2005; Mereghetti et al. 2005)
- Discovery of likely IR-counterpart of SGR 1806-20 by Subaru and VLT (Kosugi et al. 2005; Israel et al. 2005)

Giant flare on 1979 March 5 (SGR 0526-66)

Time and energy characteristics of the March 5 event.

Top: Background subtracted light curve of the outburst. Horizontal sections with triangles specify count rates averaged over the period. The sloped dashed line is a plot of $\exp(-t/\tau)$ relation for $\tau=100$ s.

Bottom: Horizontal sections with squares specify kT averaged over the period.

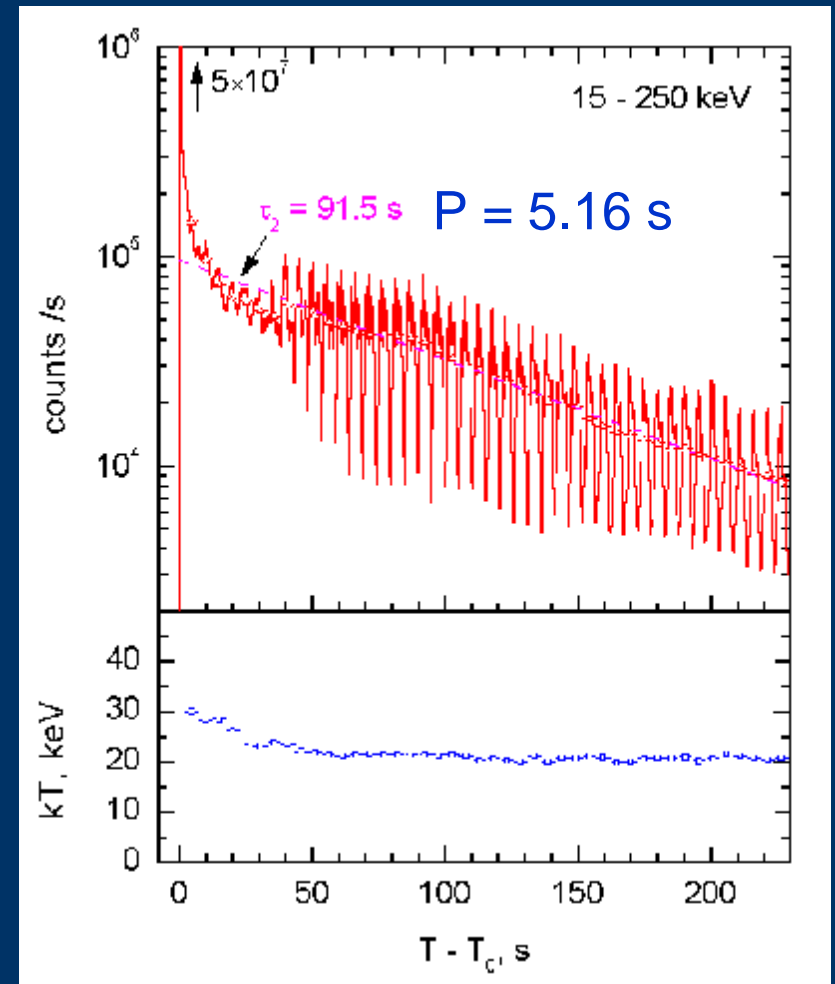


Giant flare on 1998 August 27 (SGR 1900+14)

**Time and energy characteristics
of the August 27 event.**

Top: Background subtracted light curve of the outburst. Horizontal sections with triangles specify count rates averaged over the period. The sloped dashed line is a plot of $\exp(-t/\tau)$ for $\tau = 91.5$ s.

Bottom: Horizontal sections with squares specify kT averaged over the period.





Soft Gamma Repeaters (SGRs)



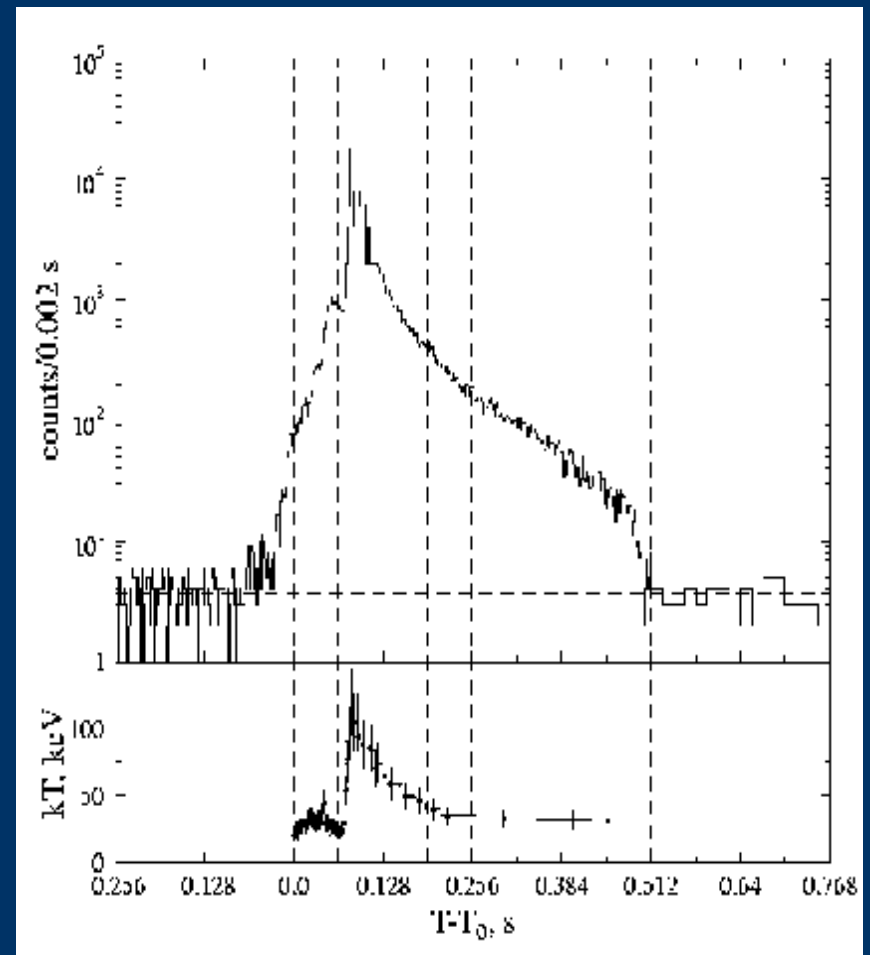
Goddard
Flight
Space
Center

Not-so-giant flare on June 18, 1998
(SGR 1627-41)

Time and energy
characteristics of the June
18 event.

Top: Background subtracted
light curve of the outburst.

Bottom: Spectral evolution
during the burst.





Soft Gamma Repeaters (SGRs)



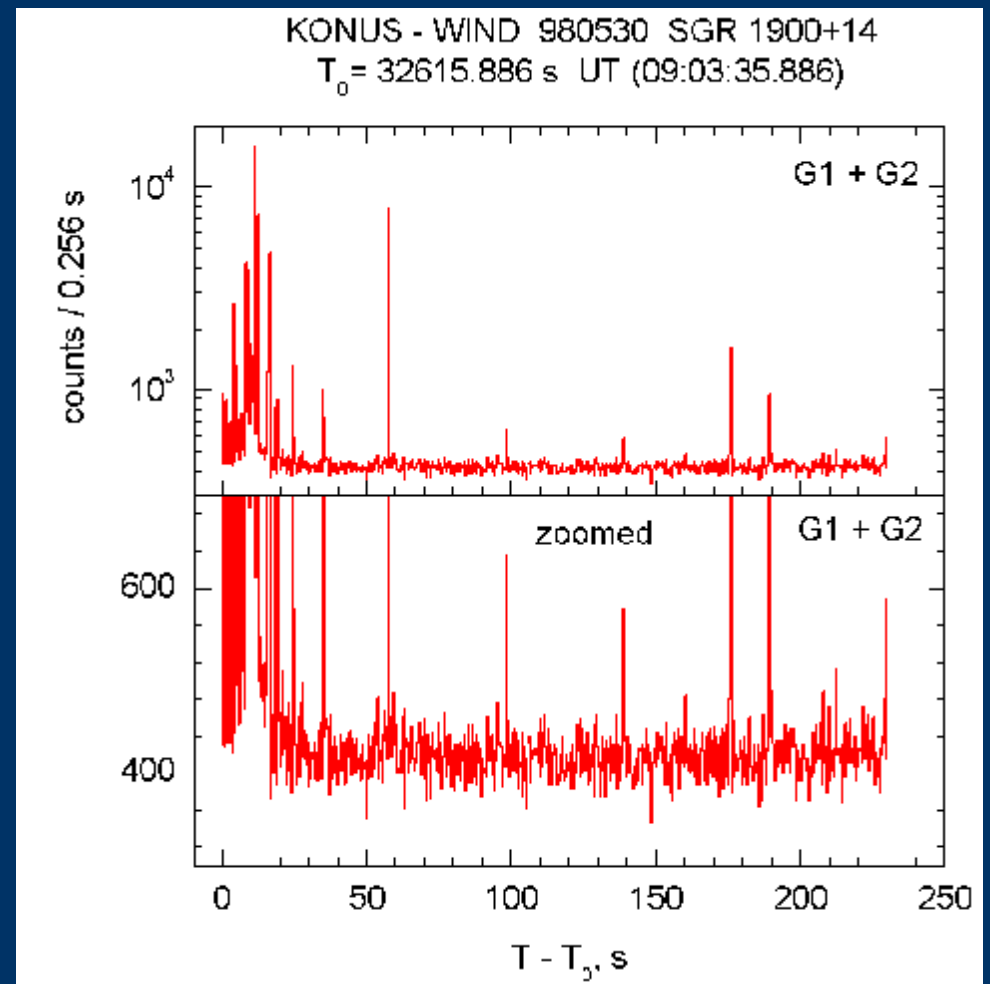
Goddard
Flight
Space
Center

SGR 1806-20 activity before giant flare on 27 December 2004

- In 2004 2-10 keV luminosity nearly doubled (XMM data; Mereghetti et al. 2004)
- Steep rise of activity in May 2004 (since January till May, only 2 trigger bursts from SGR 1806-20 had been detected by Konus-Wind)
- Since May, 74 triggers on K-W and Helicon were due to SGR 1806-20. Their total fluence 7.4×10^{-4} erg cm⁻² (energy release 2×10^{43} erg)

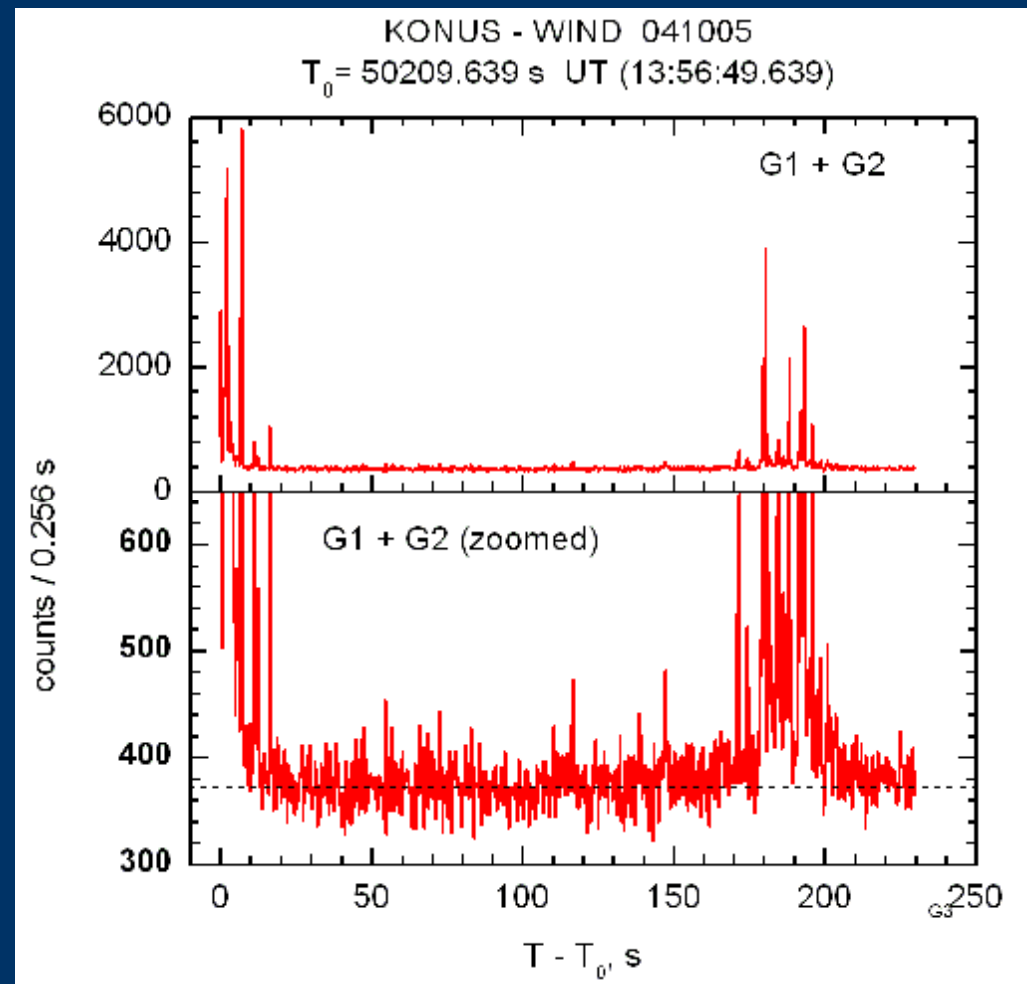
Burst series on 1998 May 30 (SGR 1900+14)

- 89 days before the giant fare on August 27
- Total fluence ($>20\text{keV}$)
 $S=5.6 \times 10^{-5} \text{ erg cm}^{-2}$
 [Energy release
 $Q=1.1 \times 10^{42} \text{ erg}$]



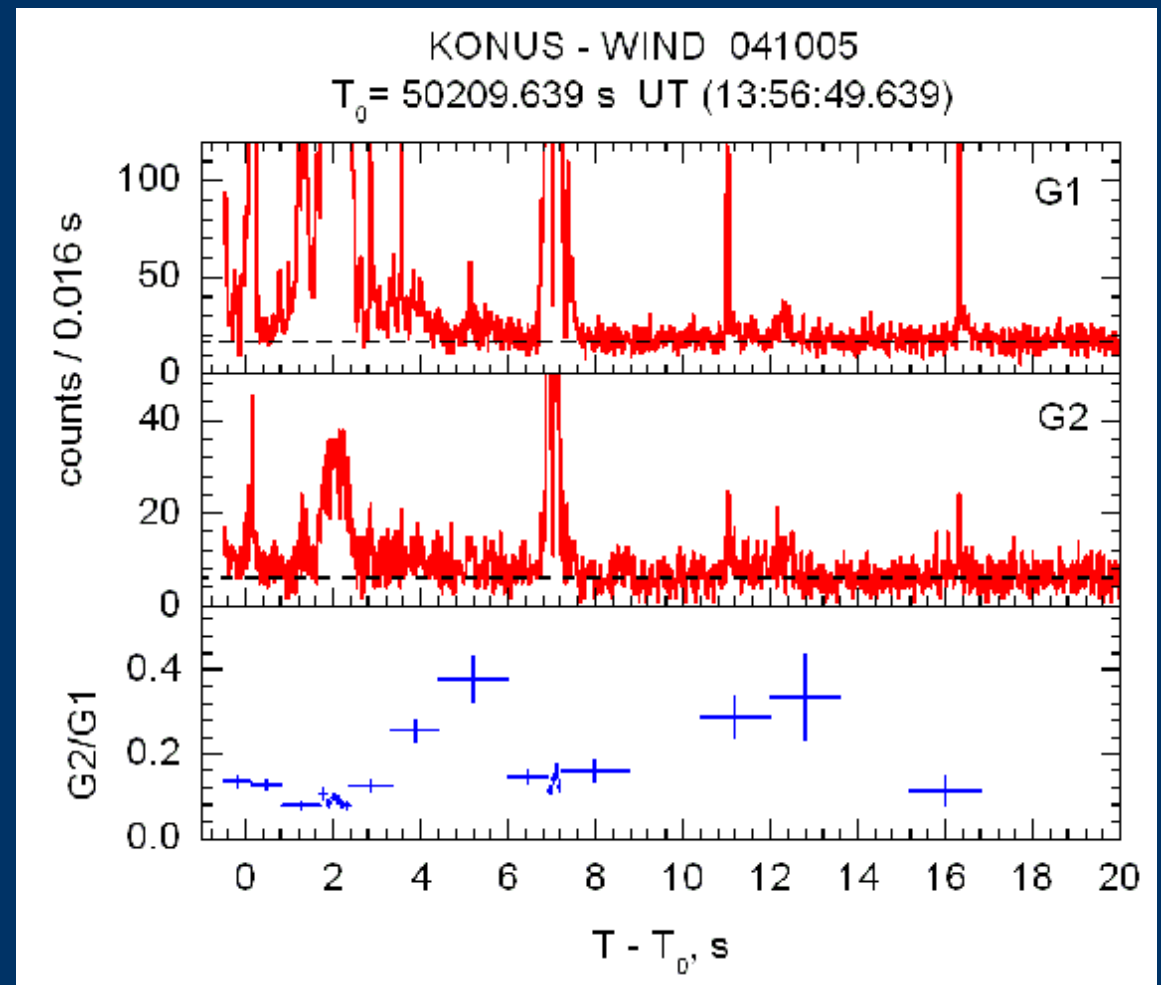
Burst series on 5 October 2004 from SGR 1806-20

- 83 days before the giant flare
- The series was also detected by INTEGRAL (IBIS/ISGRI)



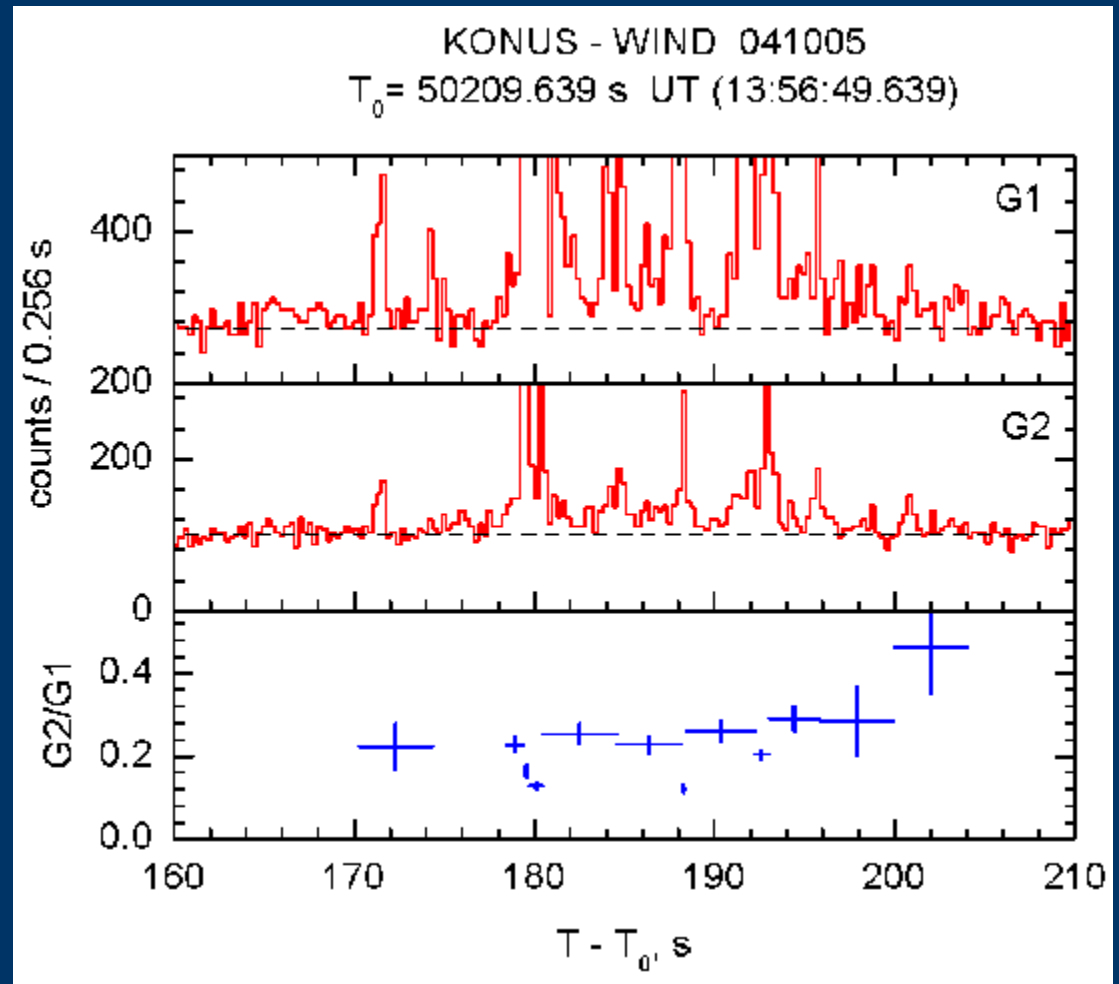
Burst series 040510 (i)

- Total Fluence ($>20\text{keV}$)
 $S=7.6\times 10^{-5}\text{ erg cm}^{-2}$
 [Energy release
 $Q=2\times 10^{42}\text{ erg}$]
- Peak Flux ($>20\text{keV}$)
 $P_{\text{max}}=5.6\times 10^{-5}\text{ erg cm}^{-2}\text{s}^{-1}$
 [$L_{\text{max}}=1.5\times 10^{42}\text{ erg s}^{-1}$]
 for $d=15\text{ kpc}$



Burst series 040510 (ii)

- The most intense peaks have lower rigidity (G2/G1) than remaining parts of the series.





Soft Gamma Repeaters (SGRs)



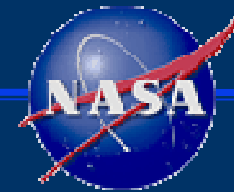
Goddard
Flight
Space
Center

Activity of SGR 1806-20 after the burst series of October 5, 2004

- Long burst series (~600 s) on December 21,
More than 30 bursts.
- Another, weaker series on December 25
- Three bursts on December 27 just before giant
flare

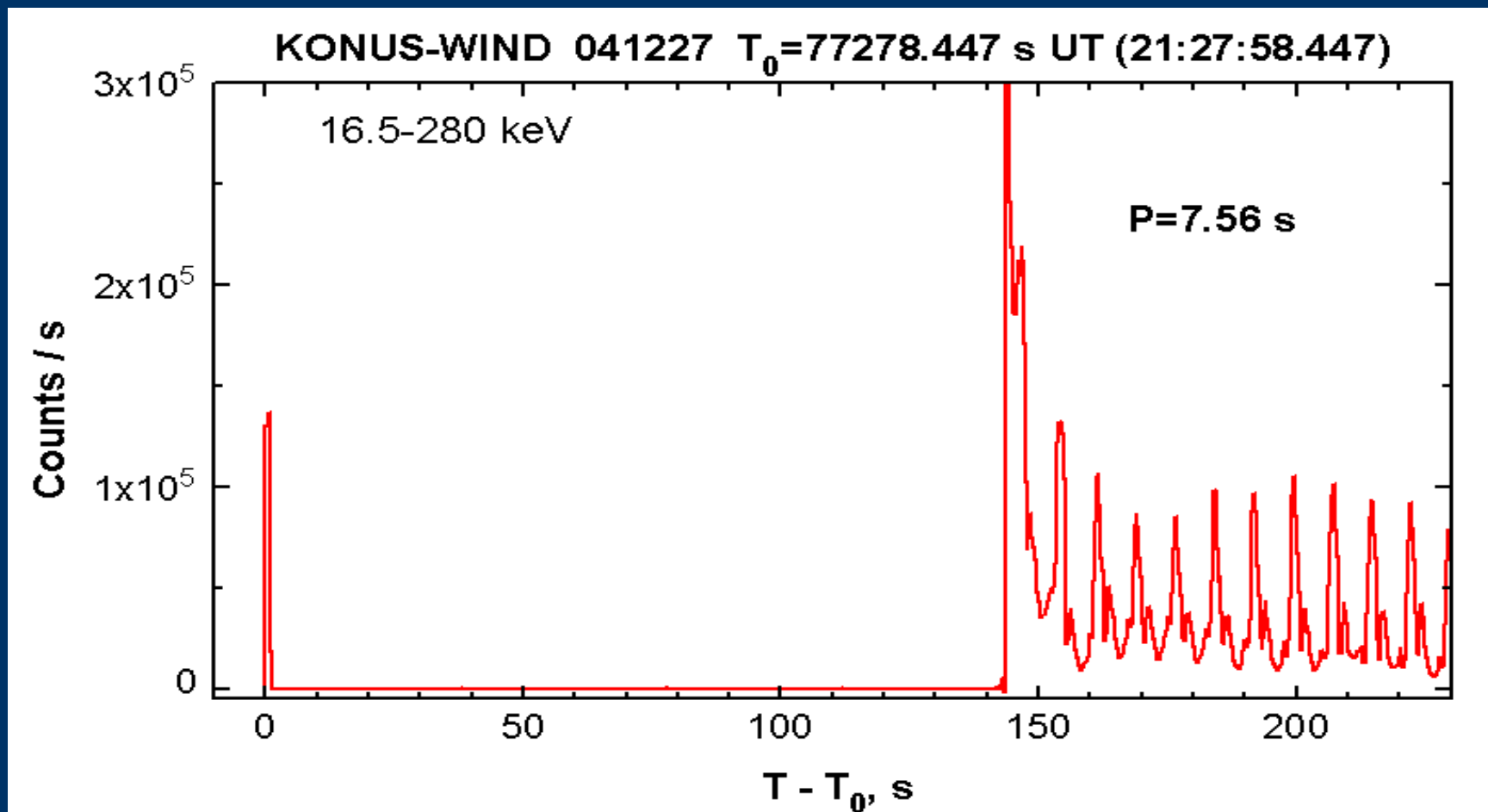


Soft Gamma Repeaters (SGRs)



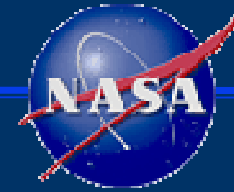
Goddard
Flight
Space
Center

041227





Soft Gamma Repeaters (SGRs)



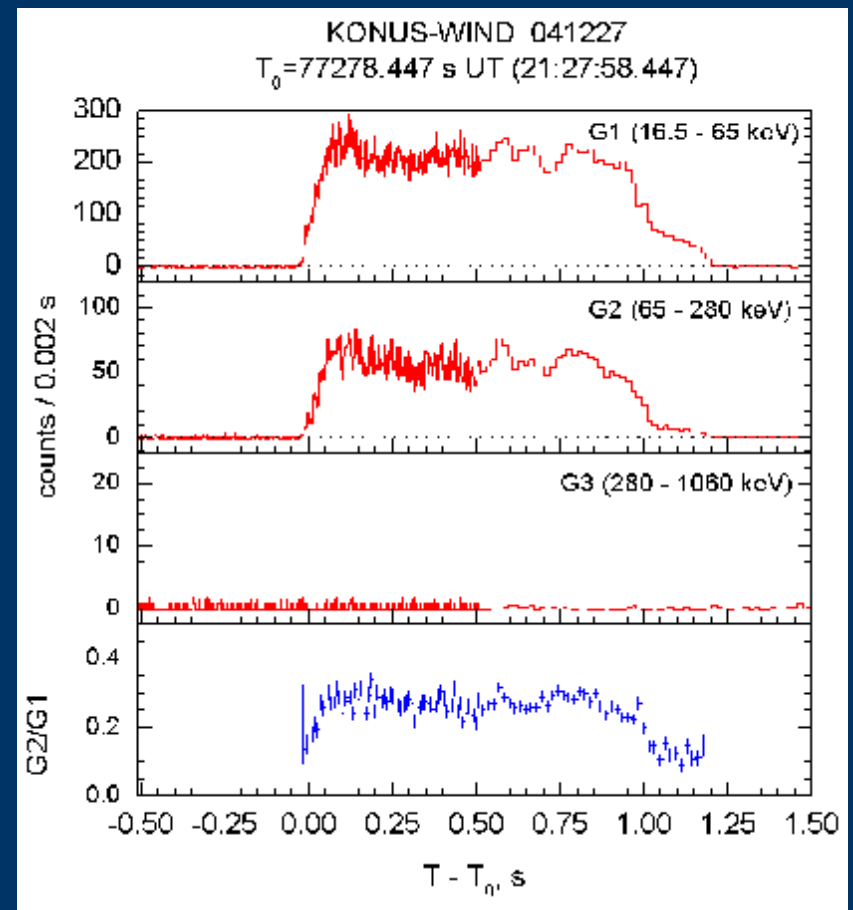
Goddard
Flight
Space
Center

Giant flare on 27 December 2004 from SGR 1806-20

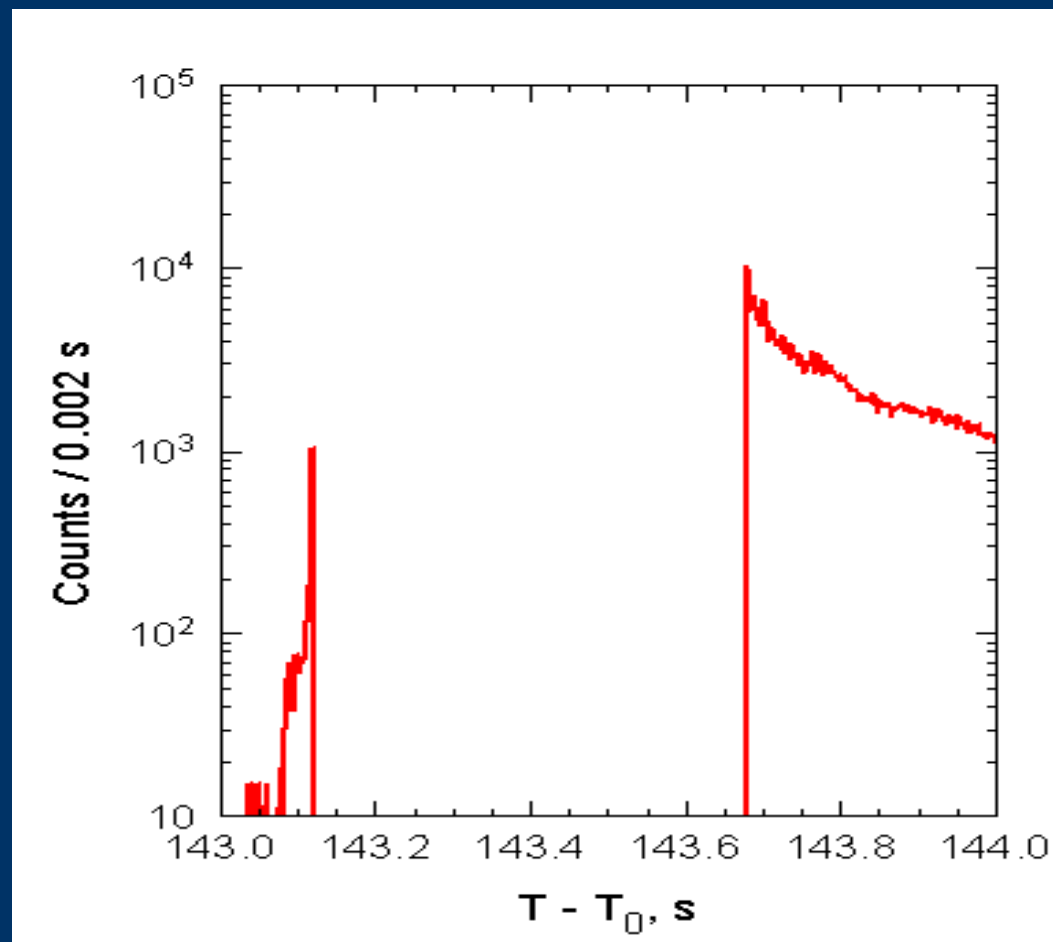
- Detected by many s/c (INTEGRAL, RHESSI, HEND, Wind, Swift, Geotail)
- First GCN Circular – INTEGRAL
(Borkowski et al., 2004)

Konus-Wind and Helicon-Coronas-F observations of giant flare on 27 Dec. 2004

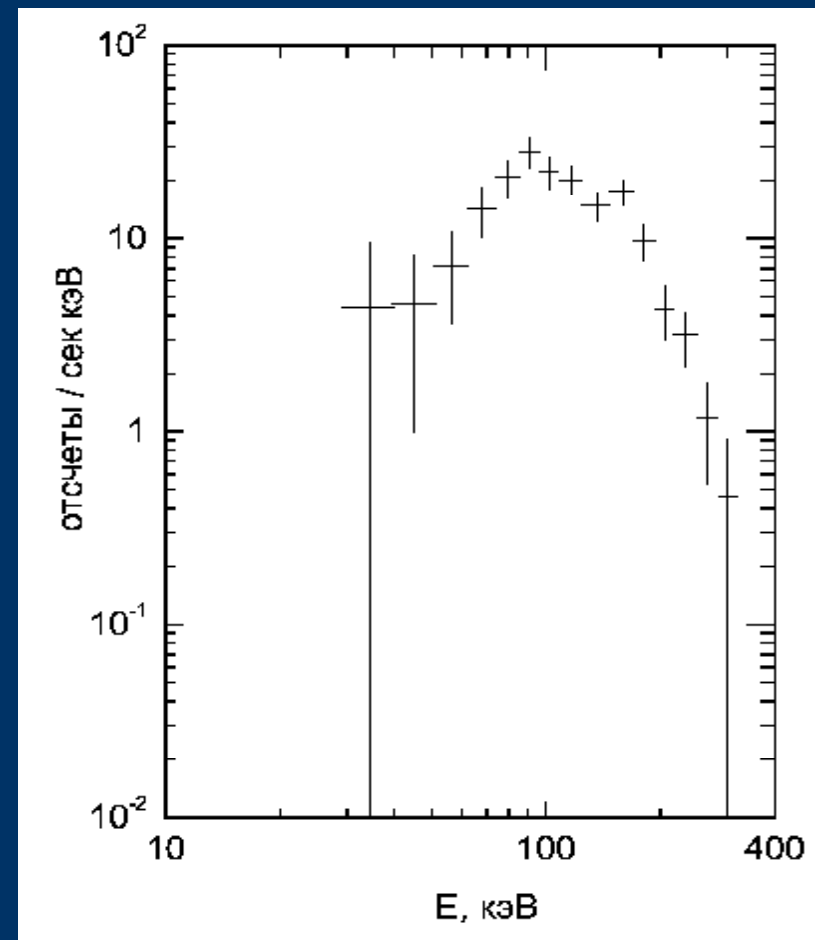
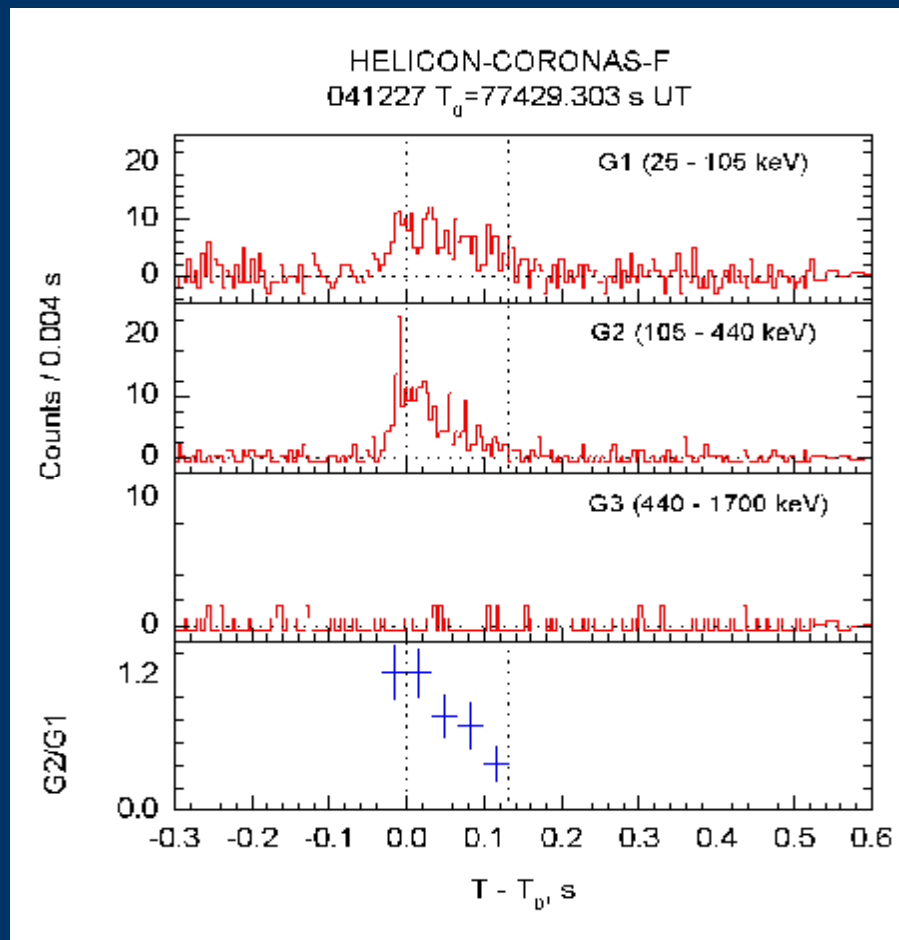
- Precursor – the most intense recurrent burst ever detected: fluence 1.25×10^{-4} erg cm² (energy release $Q = 3.4 \times 10^{42}$ erg for $d = 15$ kpc)



Initial pulse (saturation)



Helicon-Coronas-F event





Soft Gamma Repeaters (SGRs)



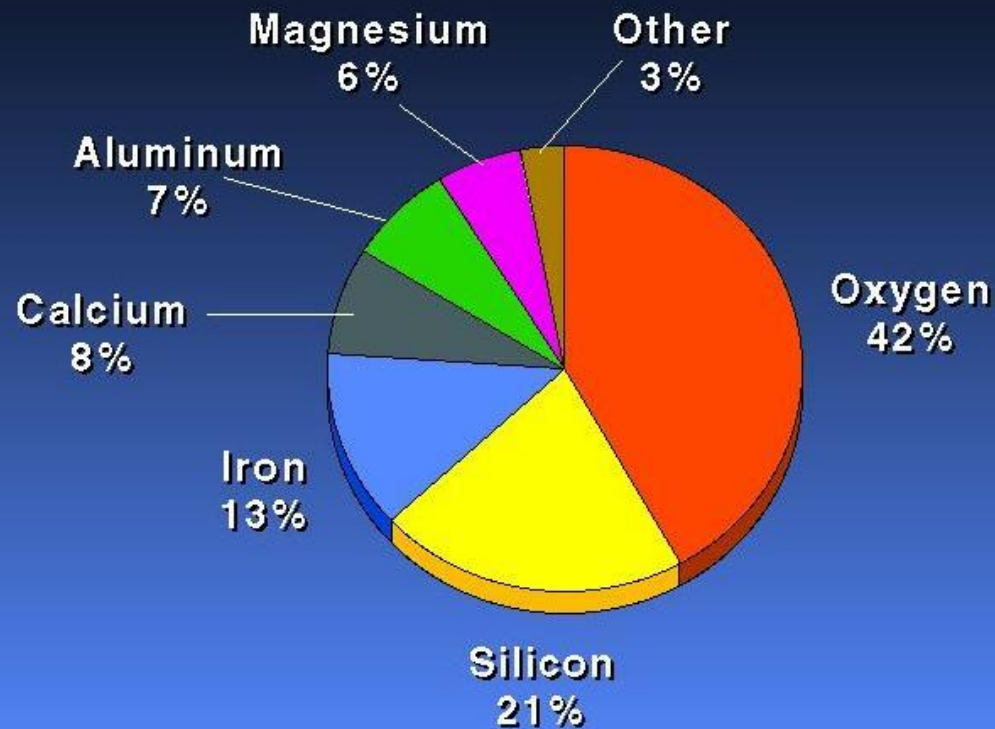
Goddard
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Space
Center

Reconstruction of initial pulse

- Calculation of lunar response matrix with GEANT4
- Folding lunar matrix with Helicon detector response matrix
- Standard spectral fitting procedures with XSPEC
- Light curve reconstruction

Moon response

Lunar Soil Composition

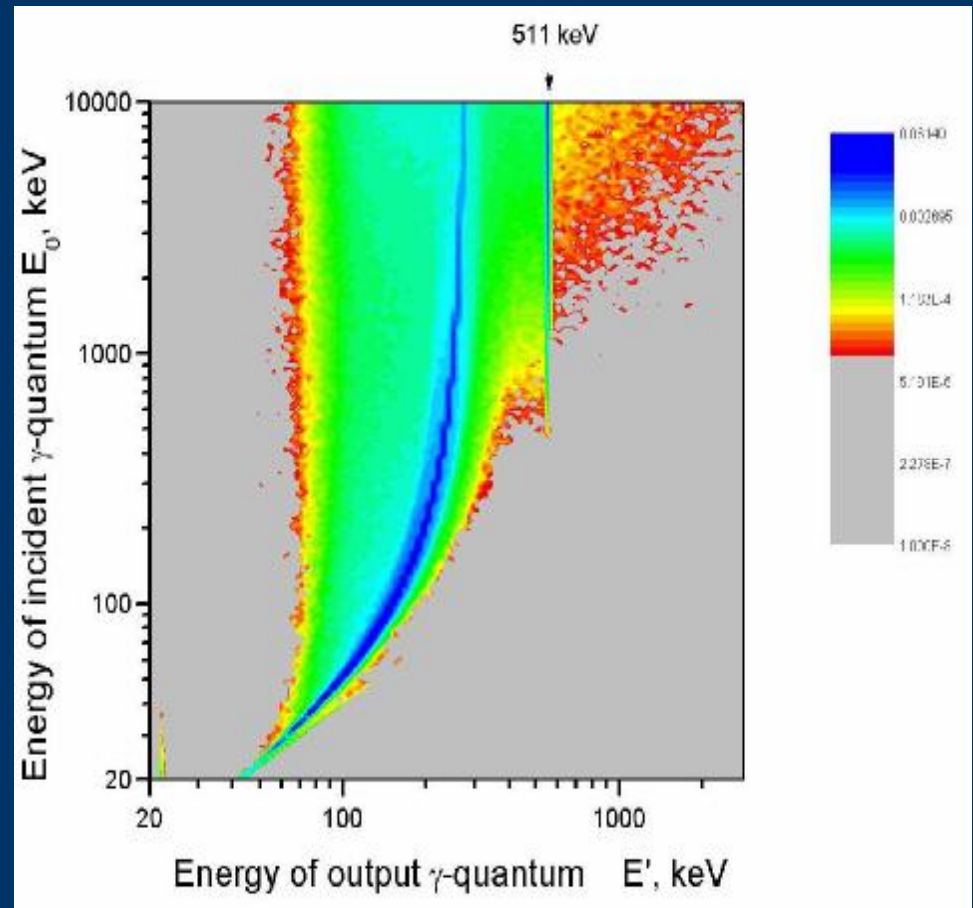


Moon response

- Scatter angle $\theta=159^\circ\pm 2^\circ$
- Energy of incident γ -quanta $E_0=20\text{ keV}\div 12\text{ MeV}$
- Compton scattering:

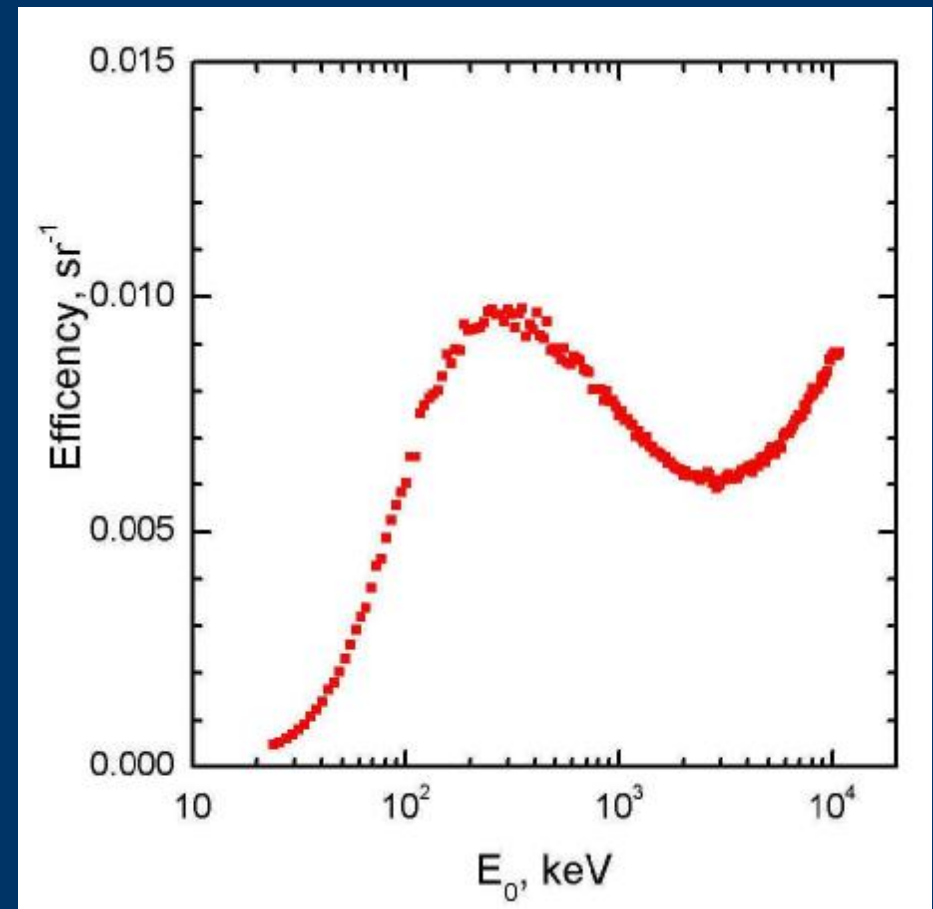
$$E' = \frac{E_0}{1 + \frac{E_0}{mc^2}(1 - \cos q)}$$

$$E' \rightarrow \frac{mc^2}{(1 - \cos q)} \cong 264\text{ keV} \quad E_0 \gg mc^2$$



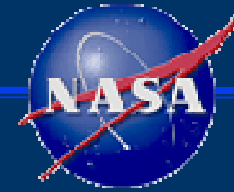
Moon reflectance efficiency

- Albedo (photons) as function of energy of an incident photon





Soft Gamma Repeaters (SGRs)

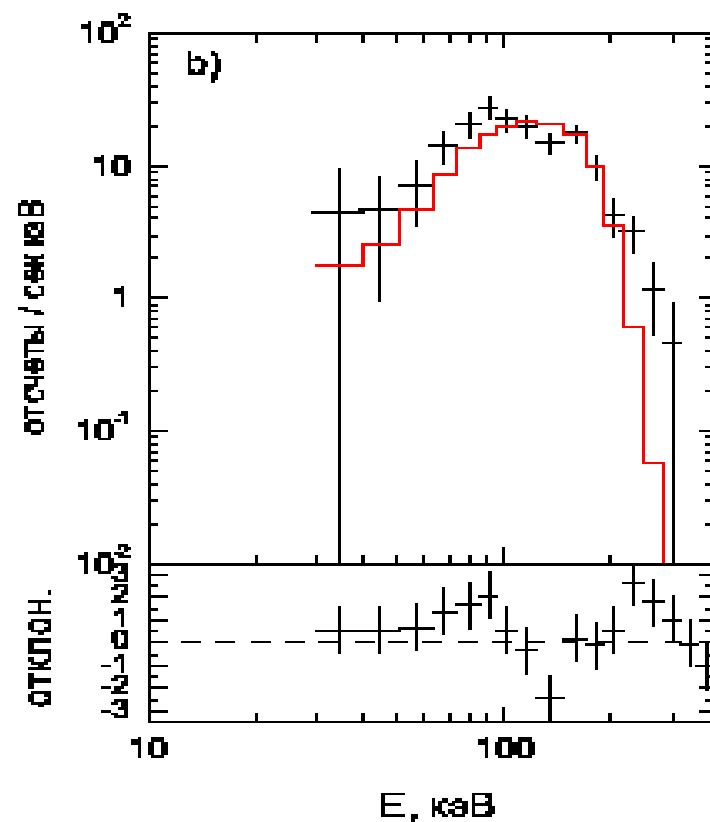
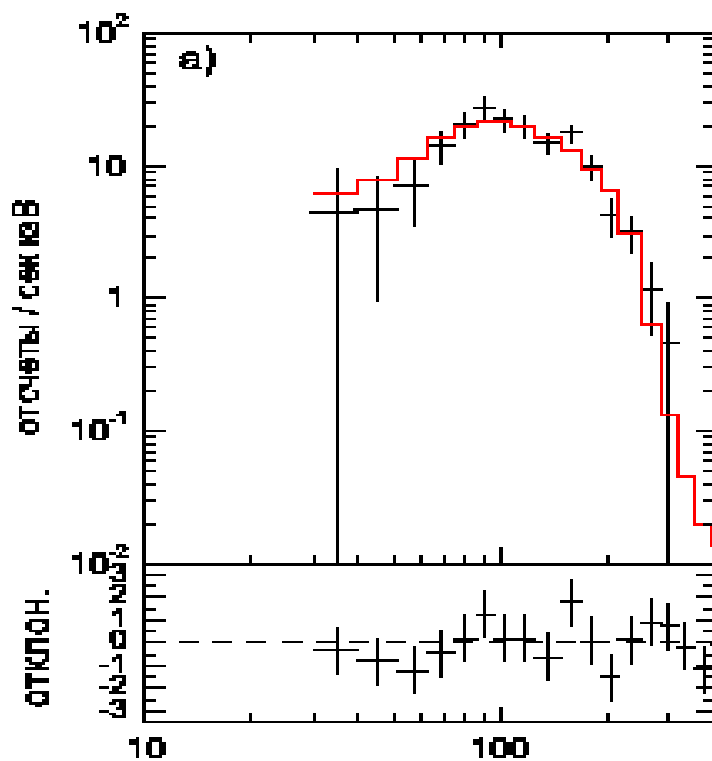


Goddard
Flight
Space
Center

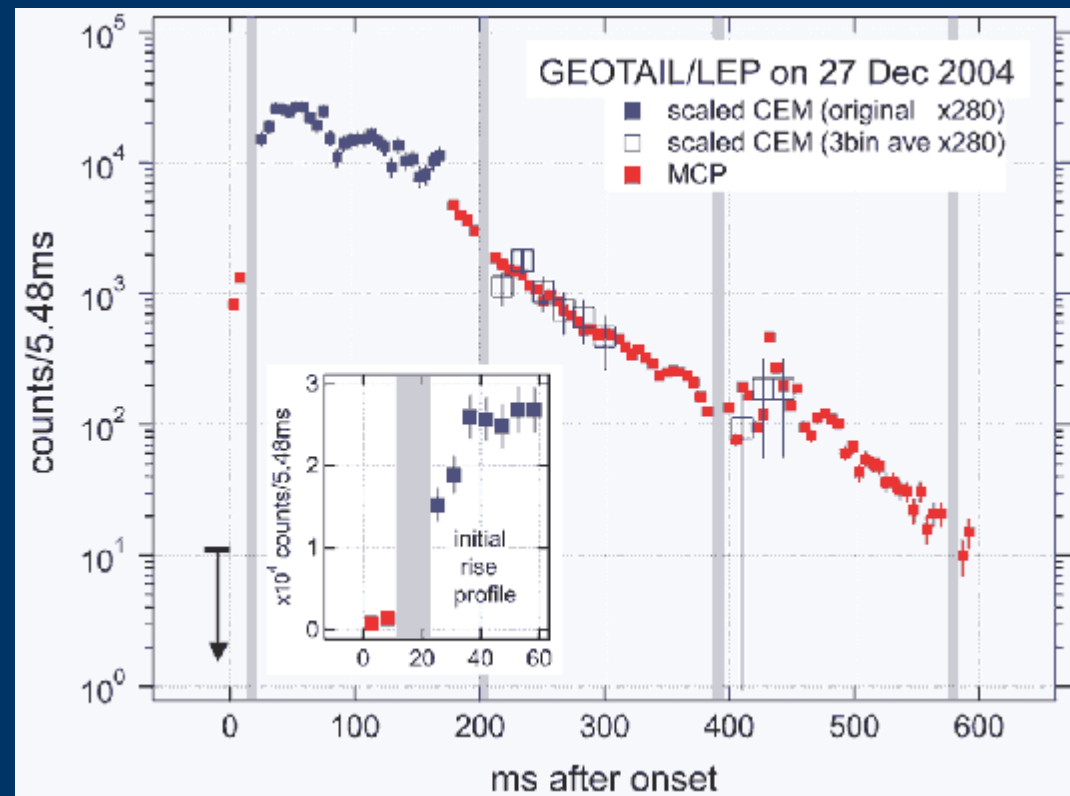
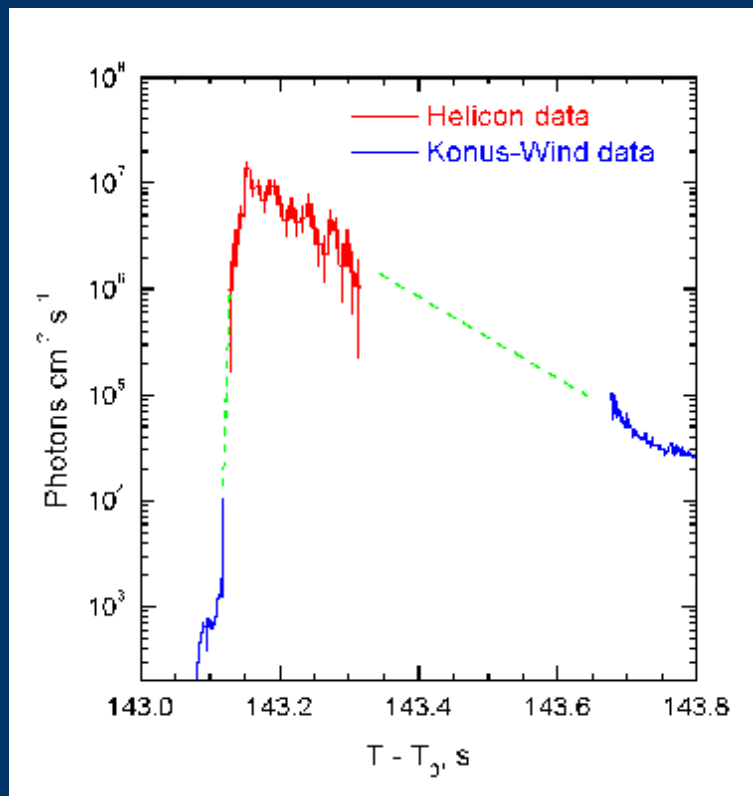
Fitting models (i)

- **Power law with exp cutoff:** $\alpha = 0.995 \pm 0.025$,
 $E_0 = 1150 \pm 330$ keV, $\chi^2 = 11.4/12$
- **GRB (Band) model:** the same, $\beta \leq 1.6$
- **Power law:** $\gamma = 1.41 \pm 0.07$, $\chi^2 = 18.4/13$
- **Blackbody:** $kT = 116$ keV, $\chi^2 = 27.5/13$

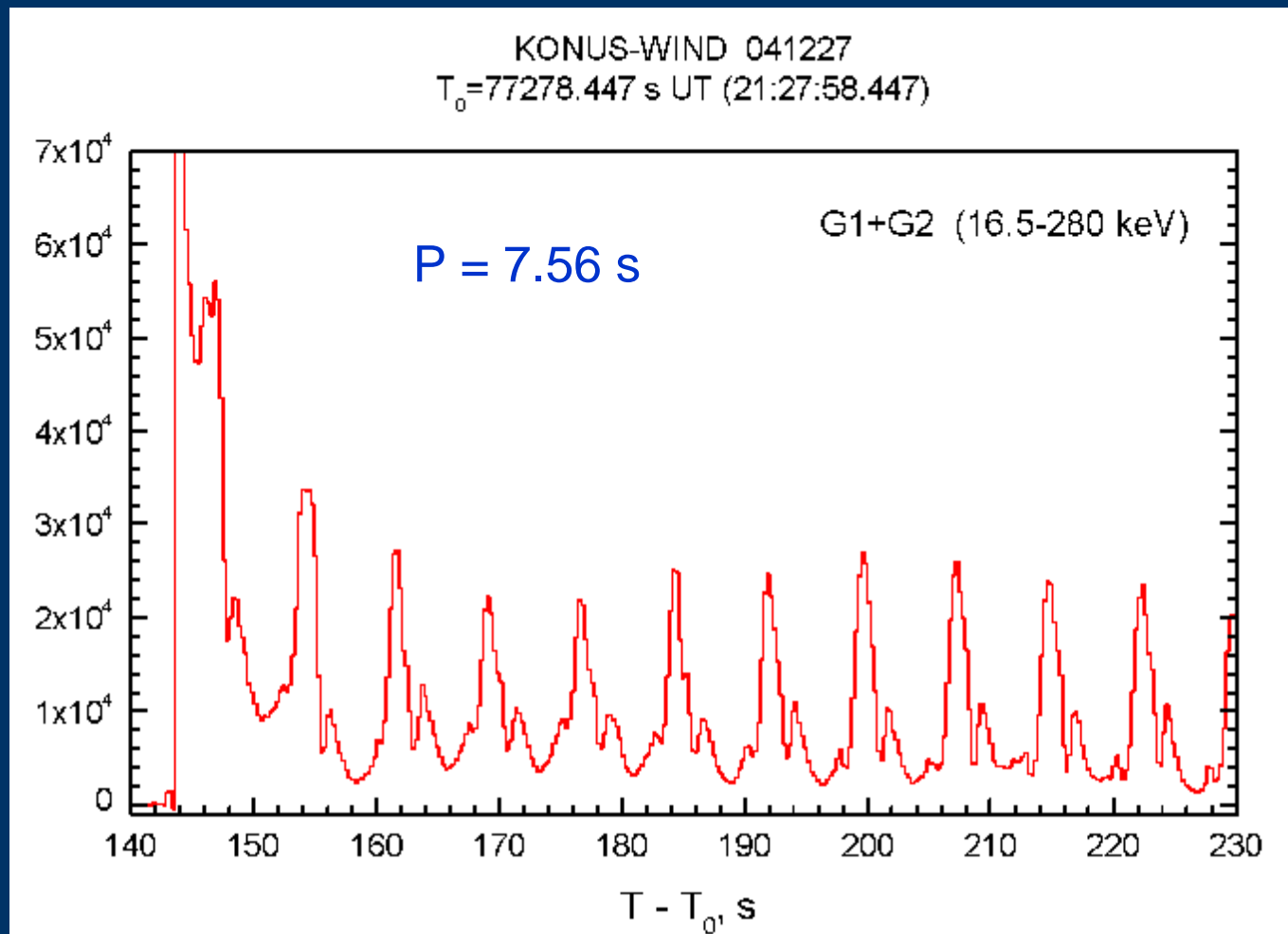
Fitting models (ii)



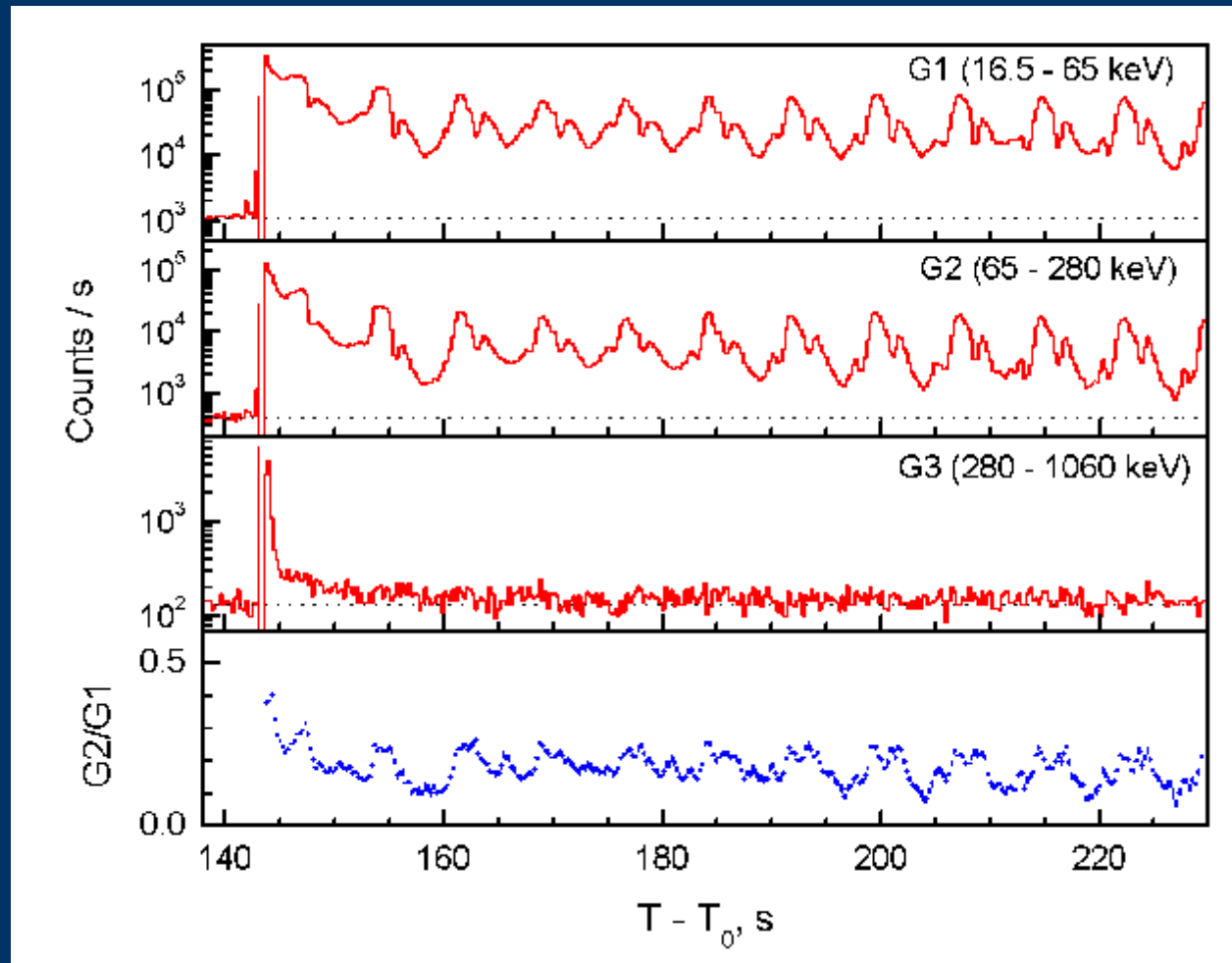
Reconstructed time history of the initial pulse



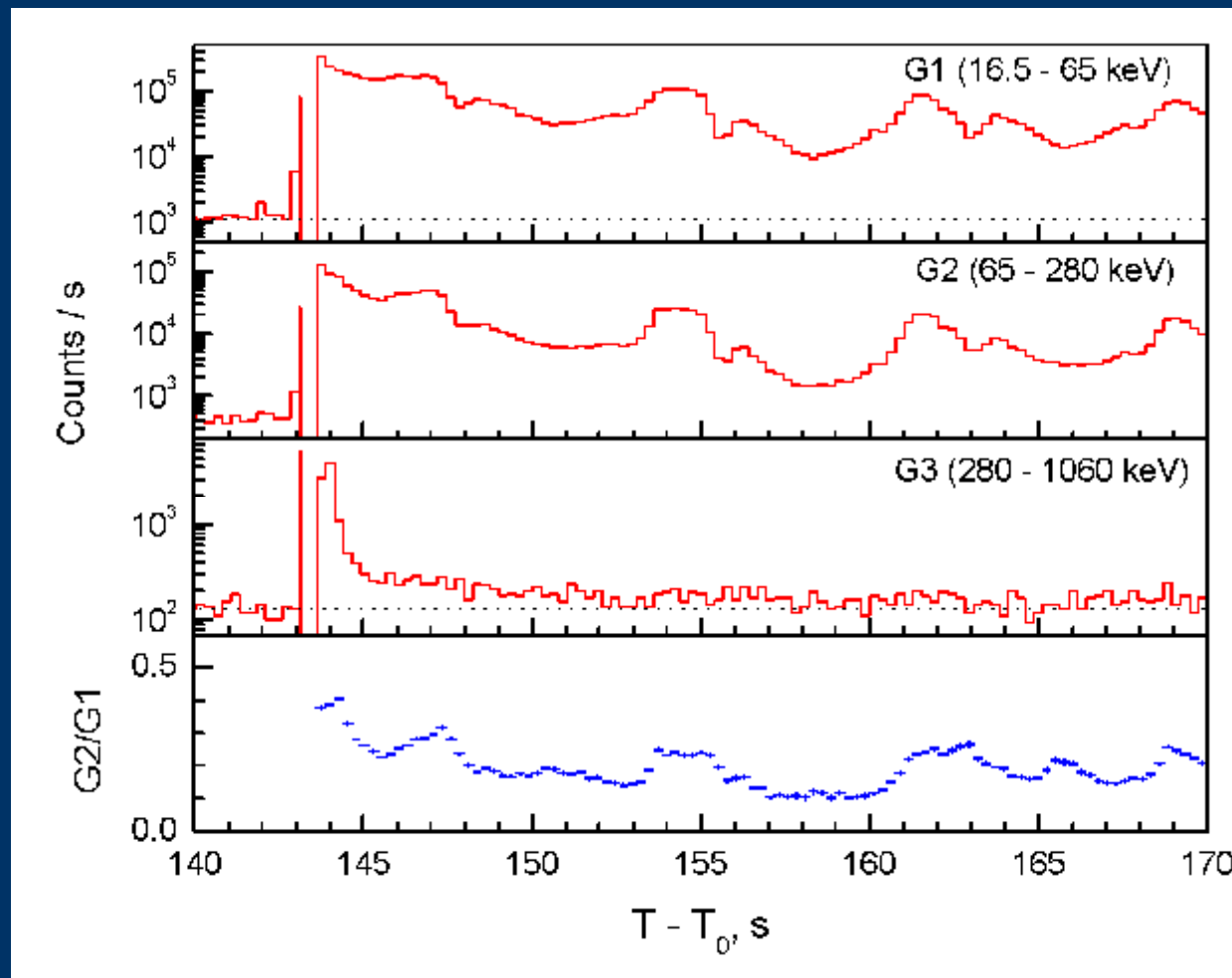
The giant flare on 2004 December 27 General view



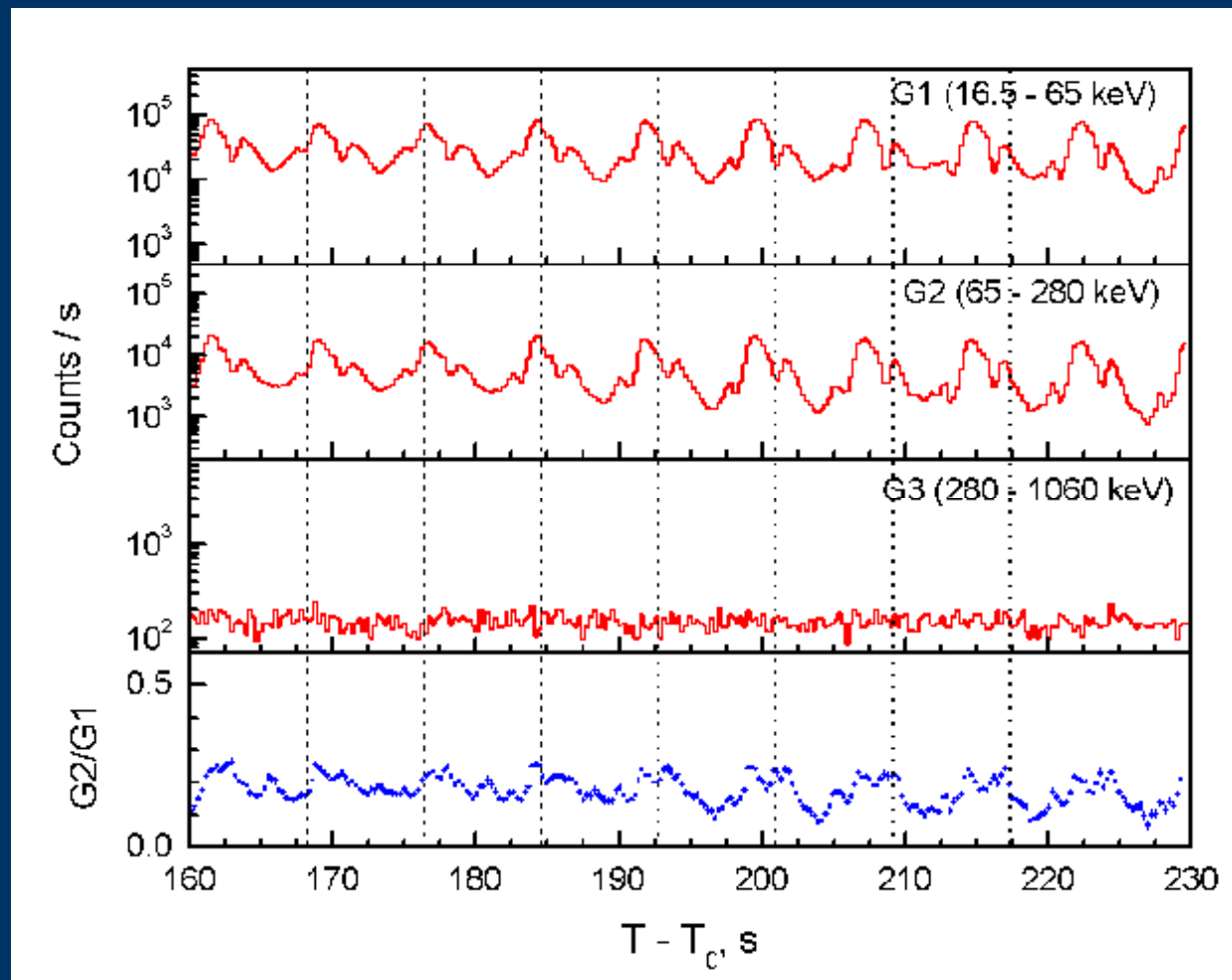
Giant flare – general view (Konus-Wind)



Giant flare on 27 Dec. - beginning

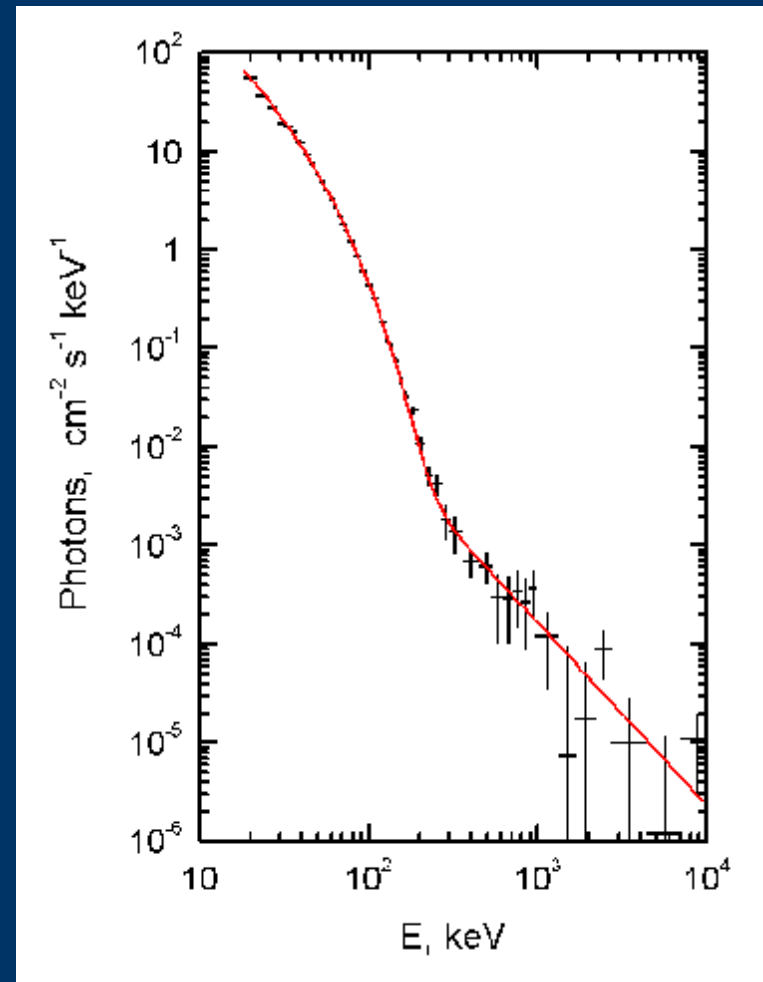


Giant flare on 27 Dec. – pulsating tail

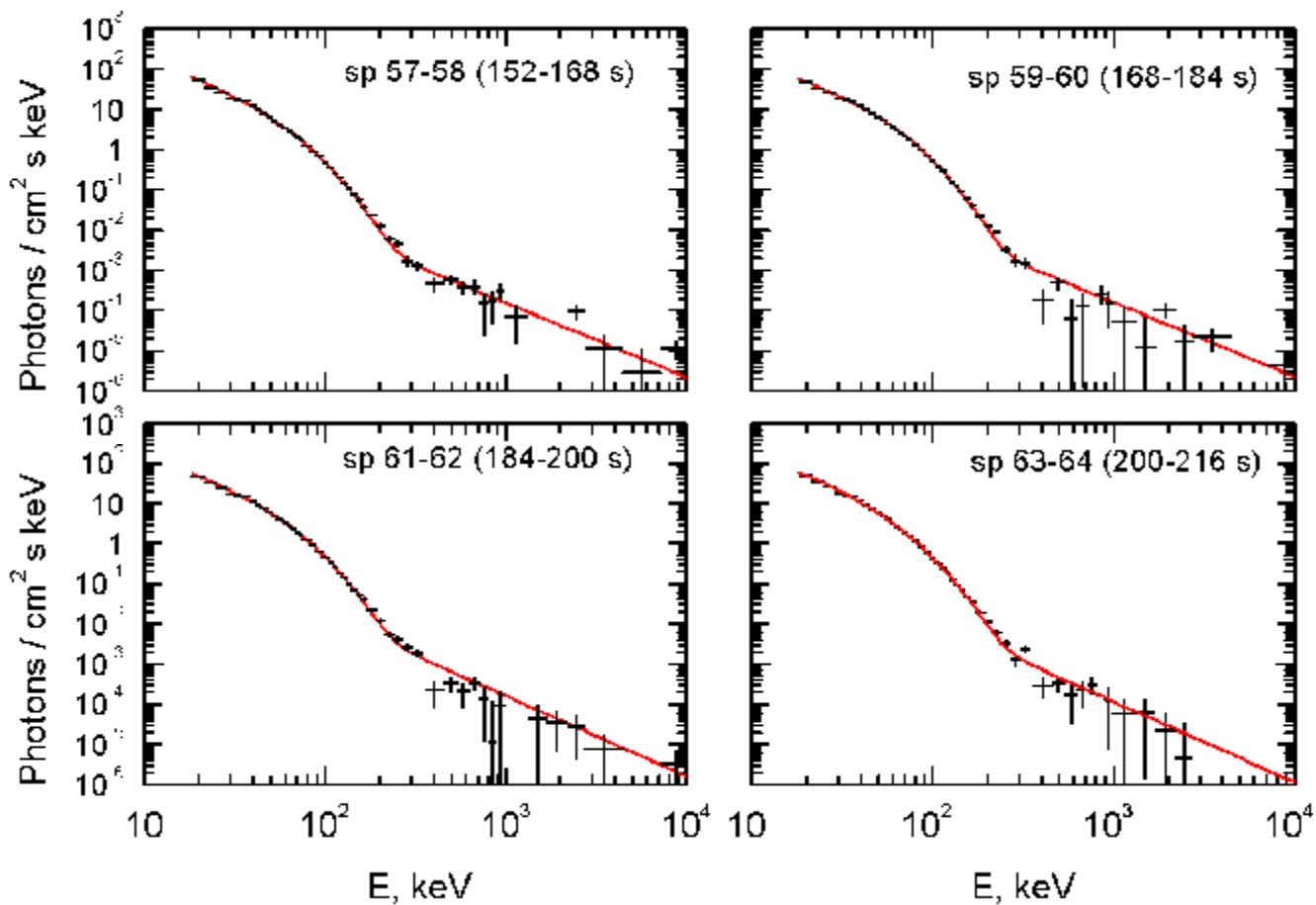


Tail spectra (i)

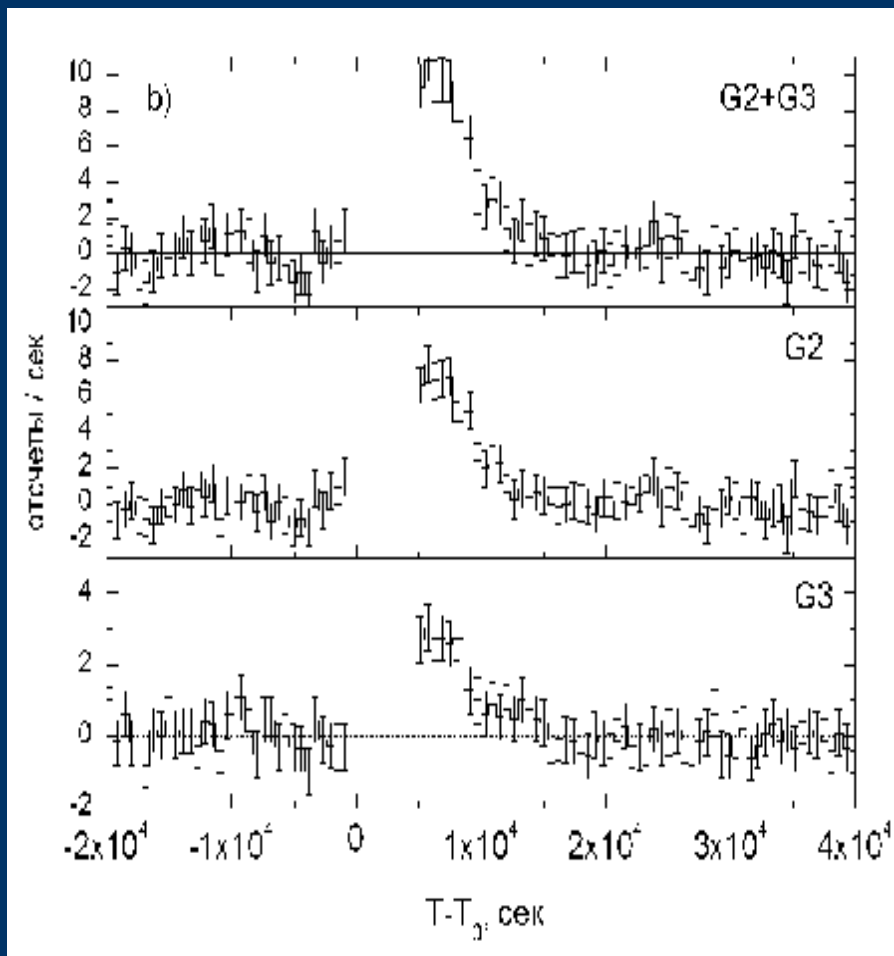
- Average spectrum:
two components
- OTTB ($kT \approx 30$ keV)
- + Power Law
 $\gamma = -1.8 \pm 0.2$



Tail spectra (ii)



80 keV – 1 MeV afterglow (Konus-Wind)



- Reported by INTEGRAL SPI-ACS (Mereghetti et al. 2005)
- Detectable during ~ 7000 s
- Fluence $\sim 2 \times 10^{-4}$ erg cm⁻²
- Power law index ~ 1.6



Soft Gamma Repeaters (SGRs)



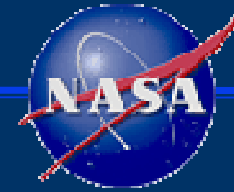
Goddard
Flight
Space
Center

SGR 1806-20 after the giant flare

- Since Dec 27, 2004 Konus and Helicon detected ~20 bursts from SGR 1806-20
- Bursts are generally weaker (than the bursts detected before the giant flare)
- As with post-flare SGR 1900+14, some bursts are unusually long

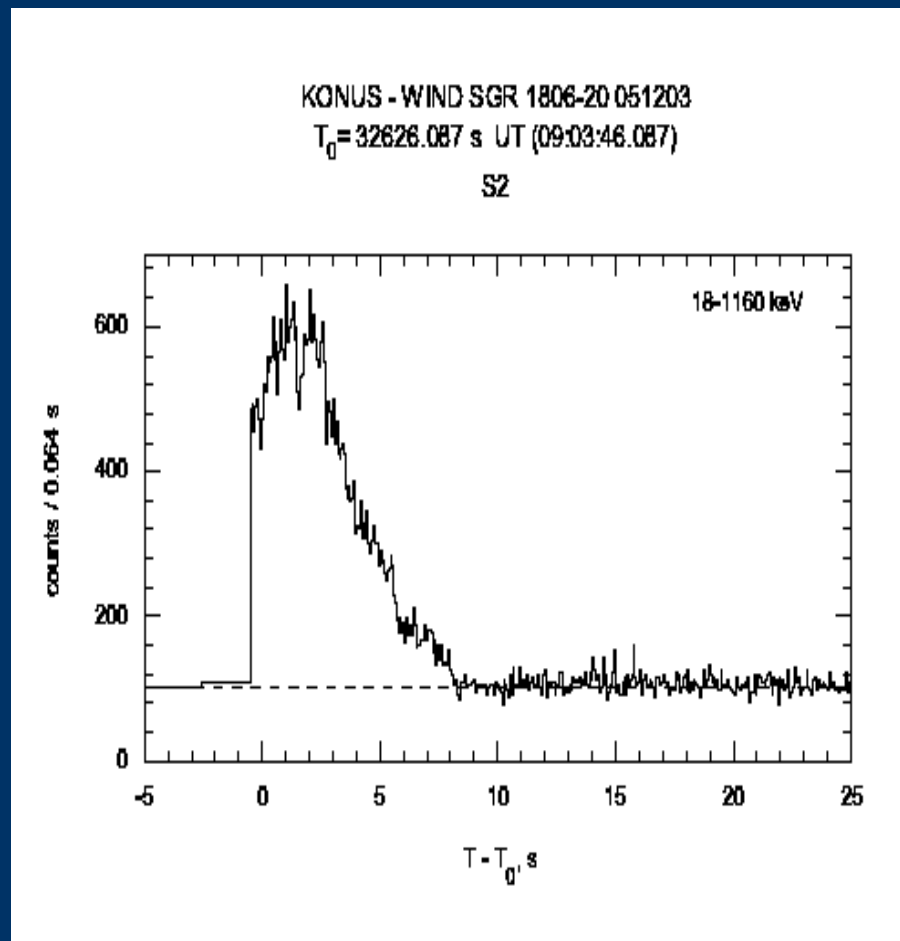


Soft Gamma Repeaters (SGRs)



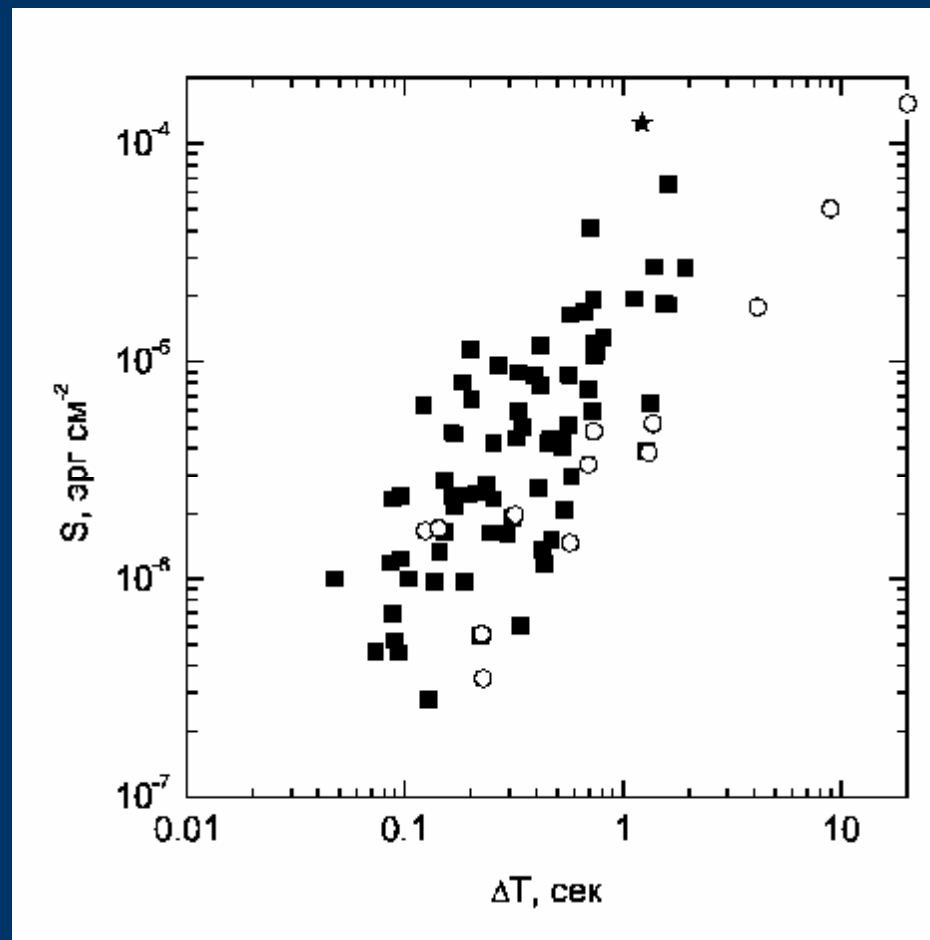
Goddard
Flight
Space
Center

SGR 1806-20 051203a event

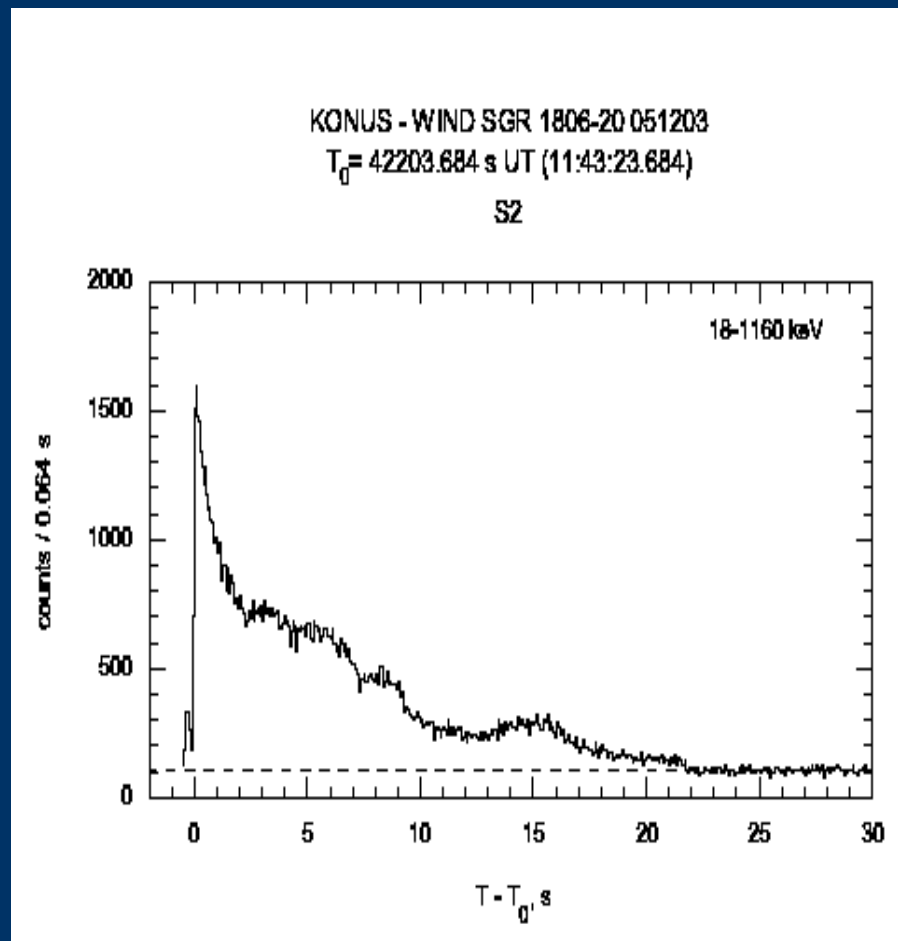


- Duration ~ 8.7 s
- $E_0 = 20.6 \pm 0.4$ keV
- $(5.17 \pm 0.03) 10^{-5}$ erg cm^{-2}
- $(1.19 \pm 0.06) 10^{-5}$ erg $\text{cm}^{-2} \text{sec}^{-1}$

Duration – Fluence



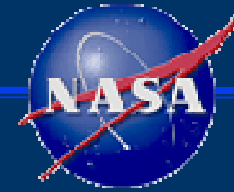
SGR 1806-20 051203b event



- Duration ~ 22.5 s (!)
- $E_0 = 19.9 \pm 0.5$ keV
- $(1.53 \pm 0.03) 10^{-4}$ erg cm^{-2}
- $(3.5 \pm 0.2) 10^{-5}$ erg $\text{cm}^{-2} \text{s}^{-1}$



Soft Gamma Repeaters (SGRs)



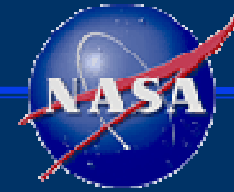
Goddard
Flight
Space
Center

Giant flares summary (initial pulse)

	SGR 0526-66	SGR 1627-41	SGR 1900+14	SGR 1806-20
	5 March 1979	18 June 1998	27 August 1998	27 December 2004
Distance, kpc	55	10	12	15
<u>Initial pulse</u>				
Duration, s	~0.25	~0.5	~0.35	~1
Rise time, ms	<2	~8	~4	~6
Fluence, erg cm ⁻²	~4.5 × 10 ⁻⁴	~7 × 10 ⁻⁴	>5.5 × 10 ⁻³	~0.6
Q, erg	~2 × 10 ⁴⁴	~1 × 10 ⁴³	>1.1 × 10 ⁴⁴	~1.8 × 10 ⁴⁶
Peak Flux, erg cm ² s ⁻¹	~1 × 10 ⁻³	~2 × 10 ⁻²	>3 × 10 ⁻²	~9
L _{max} , erg s ⁻¹	~4 × 10 ⁴⁴	~3 × 10 ⁴⁴	>6 × 10 ⁴⁴	~2.3 × 10 ⁴⁷



Soft Gamma Repeaters (SGRs)



Goddard
Flight
Space
Center

Giant flares summary (tail)

	SGR 0526-66	SGR 1627-41	SGR 1900+14	SGR 1806-20
	5 March 1979	18 June 1998	27 August 1998	27 December 2004
Distance, kpc	55	10	12	15
<u>Tail</u>		N/A		
Period, s	8.0		5.16	7.56
Duration, s	>70		~300	~380
Fluence, erg cm ⁻²	$1.0 \cdot 10^{-3}$		$4.2 \cdot 10^{-3}$	$1.2 \cdot 10^{-2}$
Q, erg	$1.6 \cdot 10^{44}$		$7.5 \cdot 10^{43}$	$3.2 \cdot 10^{44}$



Soft Gamma Repeaters (SGRs)



Goddard
Flight
Space
Center

Conclusion

- Three Giant Flares from four SGR in 25 year observation history
- SGR 1627-41 – a peculiar SGR?
- Recurrence period?



Soft Gamma Repeaters (SGRs)

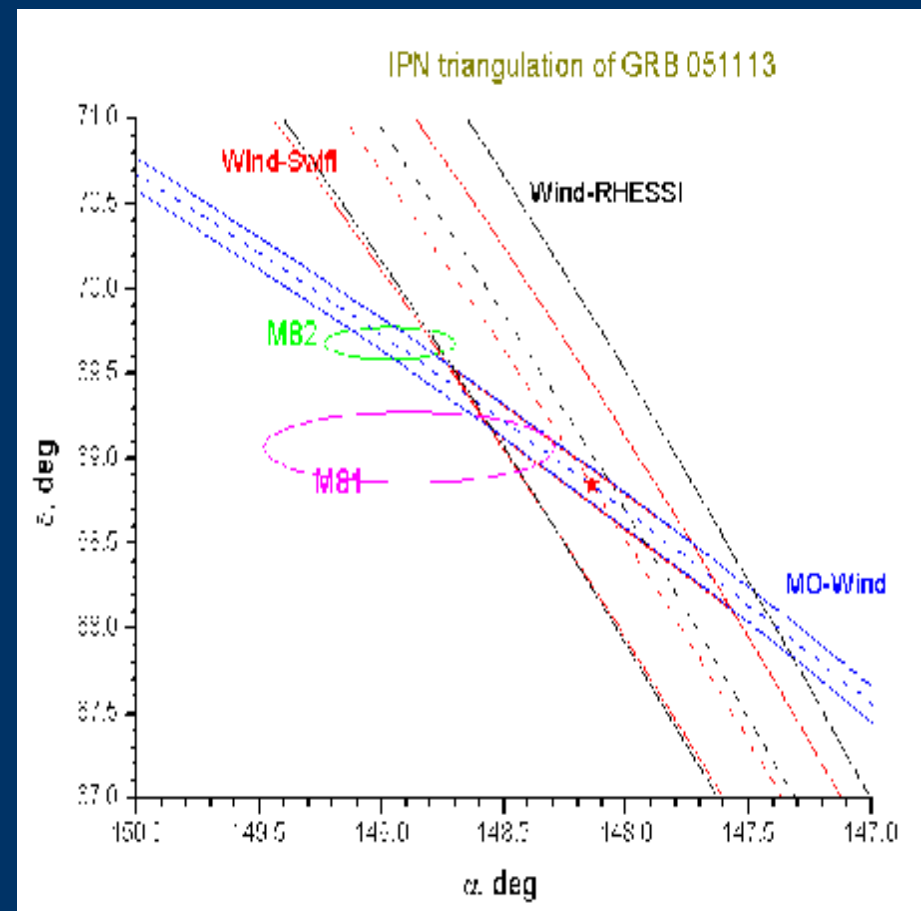
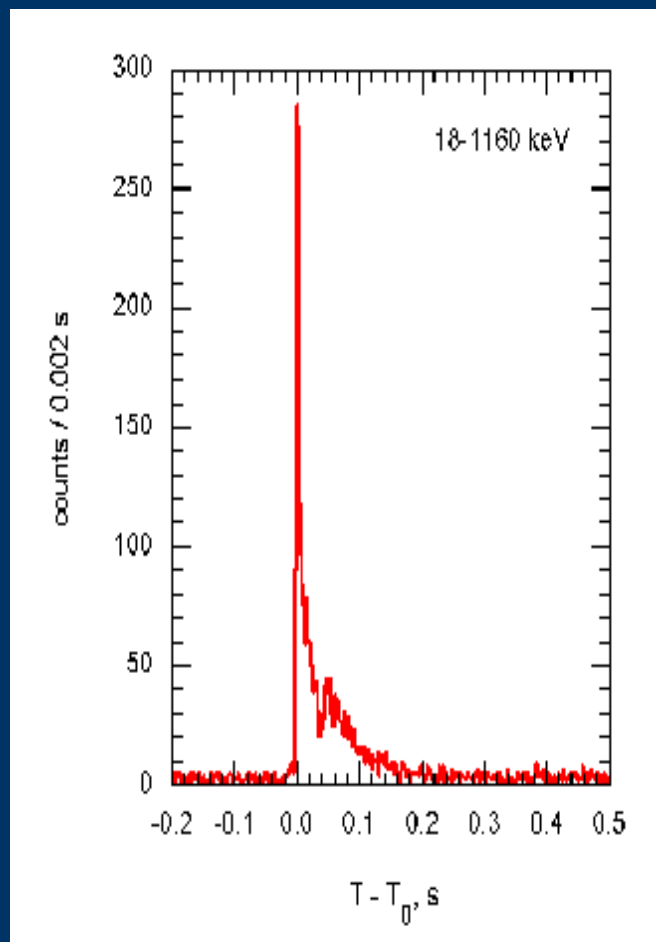


Goddard
Flight
Space
Center

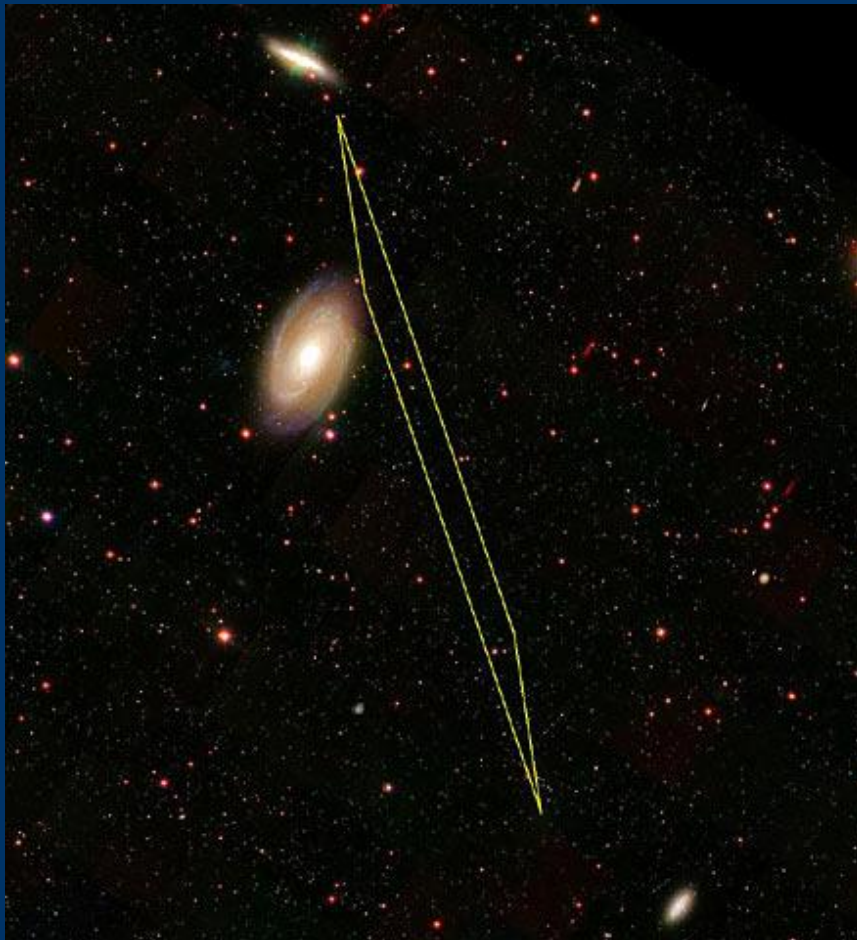
Short Hard GRB – SGR GF connection

- Short
- Hard
- Rare identifications
- Cataloged events search
- Statistical studies (rapid afterglows?)

GRB 051103



GRB 051103 (contd)



- Observed by **Konus-Wind**, **Swift-BAT**, **HETE-Fregate**, **Mars-Odyssey (GRS and HEND)**, and **RHESSI**
- Duration ~ 0.17 sec
- $E_{\text{peak}} = 1940 \pm 400$ keV
- Fluence (20keV–10 MeV): $(2.34 \pm 0.3) \times 10^{-5}$ erg cm^{-2}
- Peak flux (2ms scale): $(1.89 \pm 0.3) \times 10^{-3}$ erg $\text{cm}^{-2} \text{s}^{-1}$
- $Q_{\text{iso}} \sim 4.5 \times 10^{46}$ erg, assuming M81 distance (~ 4 Mpc)