XMM-Newton observations of SGRs

Sandro Mereghetti
INAF – IASF Milano

A.Tiengo, P. Esposito, D. Götz
A. Treves, R. Turolla, S. Zane
G.L. Israel, N. Rea, L. Stella
M. Feroci, K. Hurley

SGR 1806-20

On going monitoring program

7 observations done since April 2003

Pre- and Post- Giant Flare

SGR 1627-41

1 observation (+2 serendipitous) in 2004

SGR 1900+14

1 observation in September 2005
(impossible to observe it before due to satellite constraints)

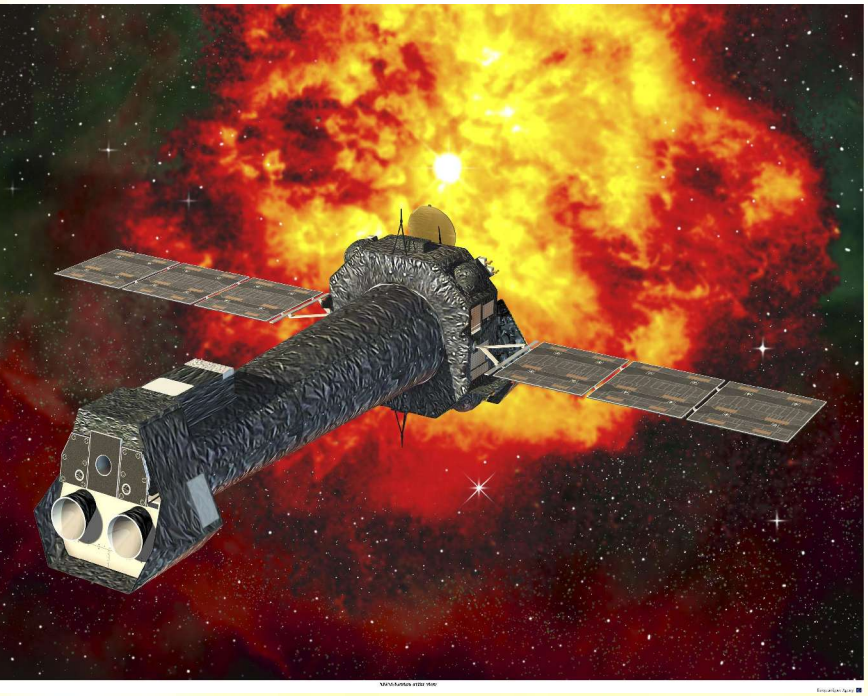
SGR 0526-66 in LMC

Several observations but

angular resolution inadequate to resolve from SNR N49

XMM-Newton

Imaging with high throughput and CCD energy resolution



EPIC instrument

3 CCD Cameras

0.2-12 keV energy range

Effective area ~2500 cm^2 @ 1.5 keV
1600 cm^2 @ 6 keV

THE BEST INSTRUMENT FOR X-RAY SPECTROSCOPY

Complementary to RossiXTE (timing) and Chandra (angular resolution)

SGR 1806-20

Mereghetti, et al. 2005, The Astroph. Journal 628, 938 XMM Before Giant Flare

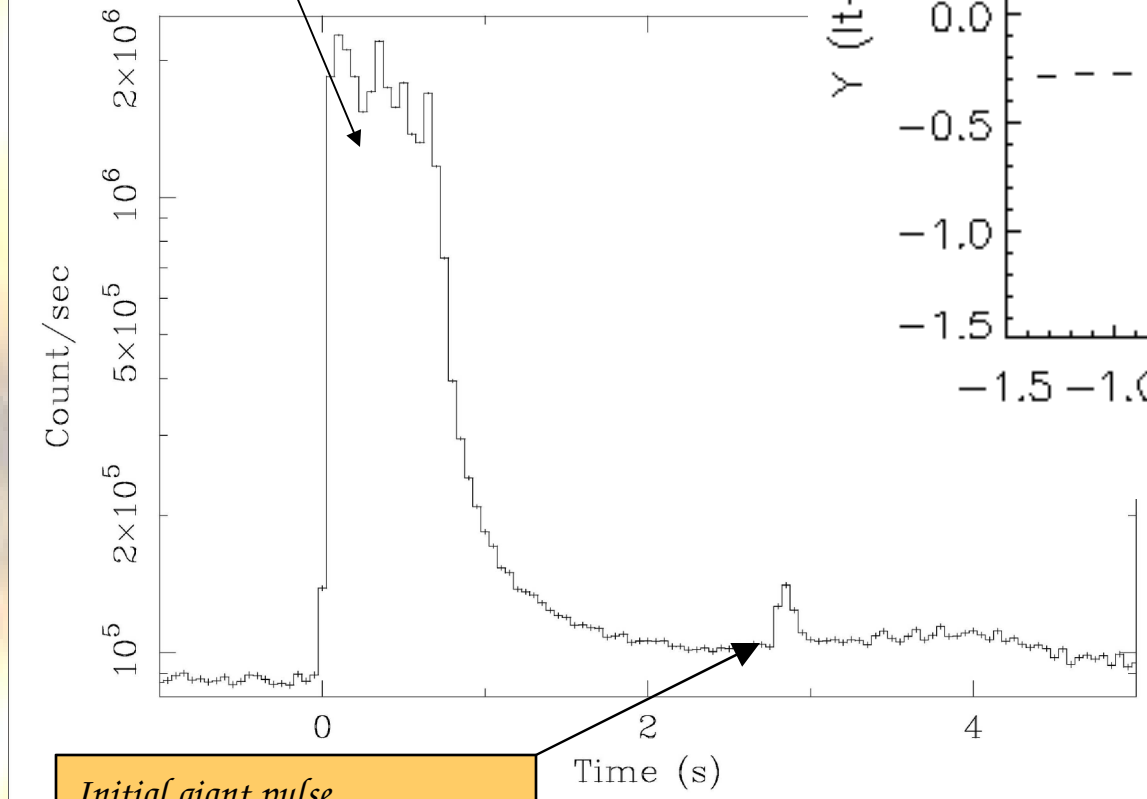
Tiengo et al. 2004, Astron. & Astrophysics, 440, L63 XMM After Giant Flare

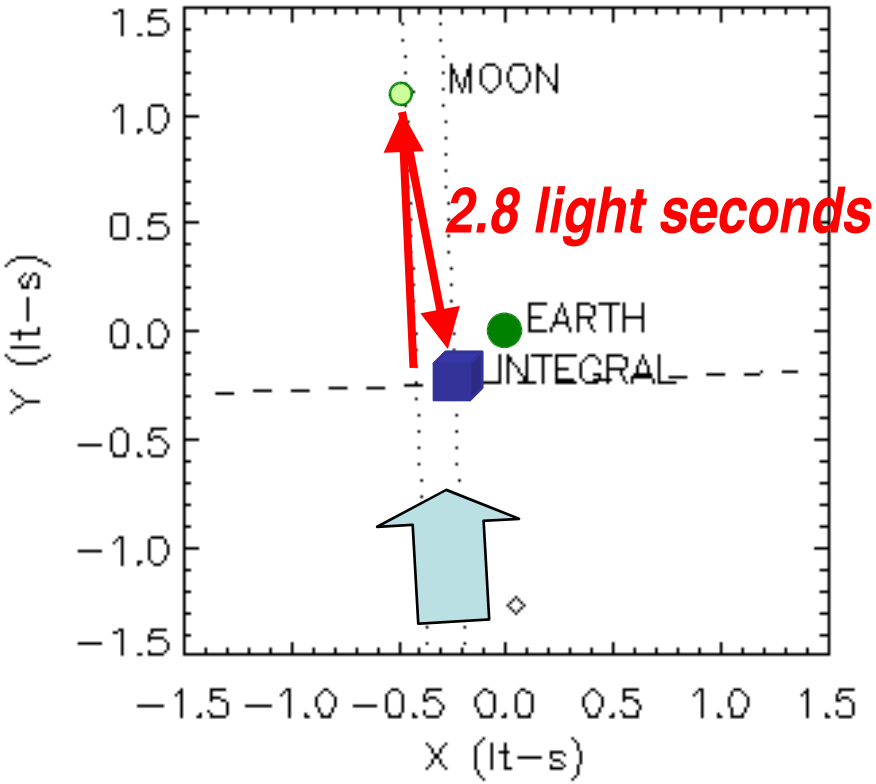
SGR 1806-20

- Discovered in 1979 (Laros et al. 1986) and very active since then
- P = 7.5 s Pdot = 8×10^{-11} s/s $\rightarrow$ B = 8×10^{14} G
  (Kouveliotou et al 1998)
- High absorption: $N_H \sim 6 \times 10^{22}$ cm^{-2} Av~30
- Giant Flare on 2004 December 27
  (Hurley et al. 2005, Palmer et al. 2005, Mereghetti et al. 2005a)

Peak affected by instrument saturation

Mereghetti et al. 2005, ApJ 624, L105



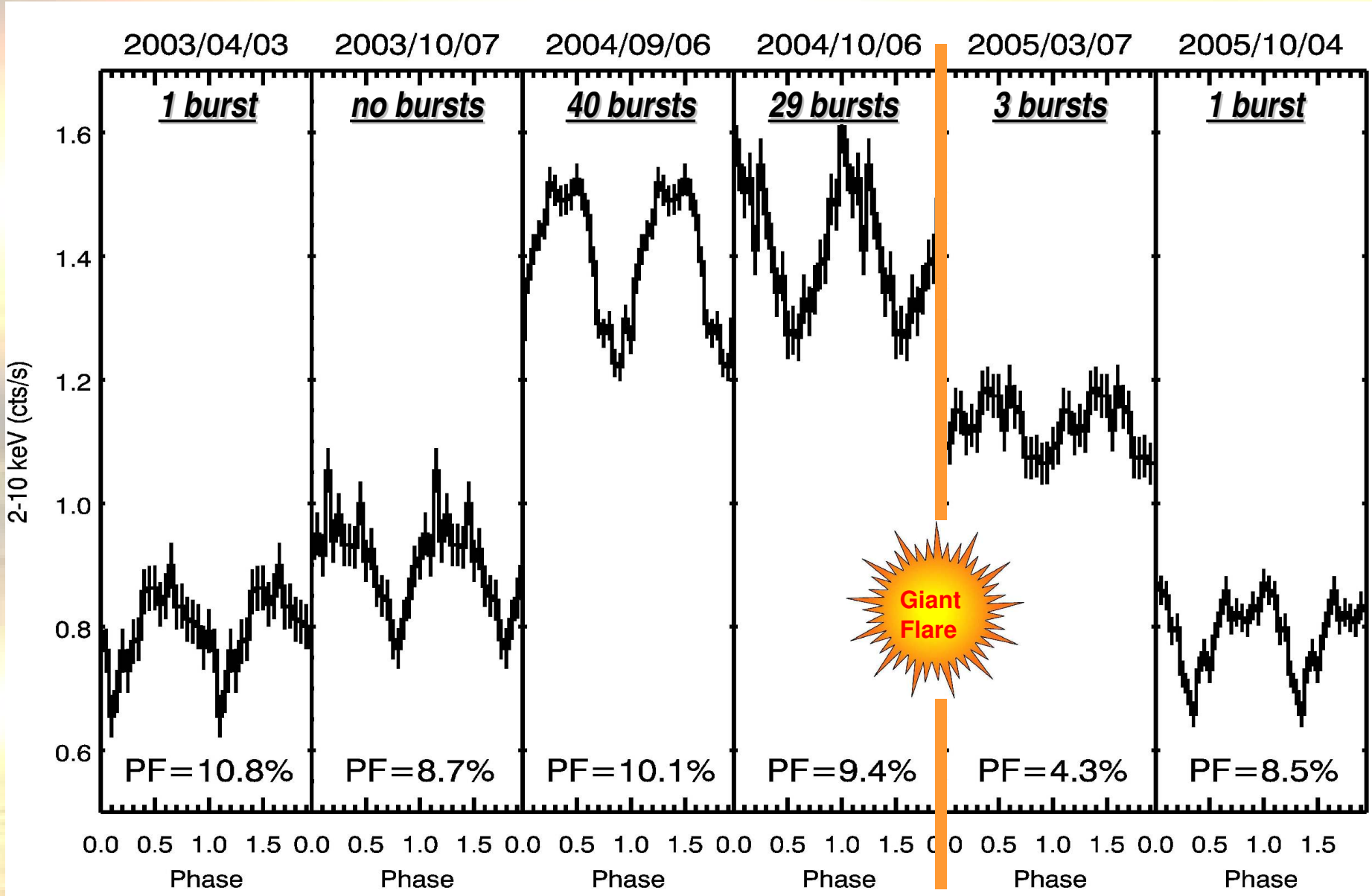


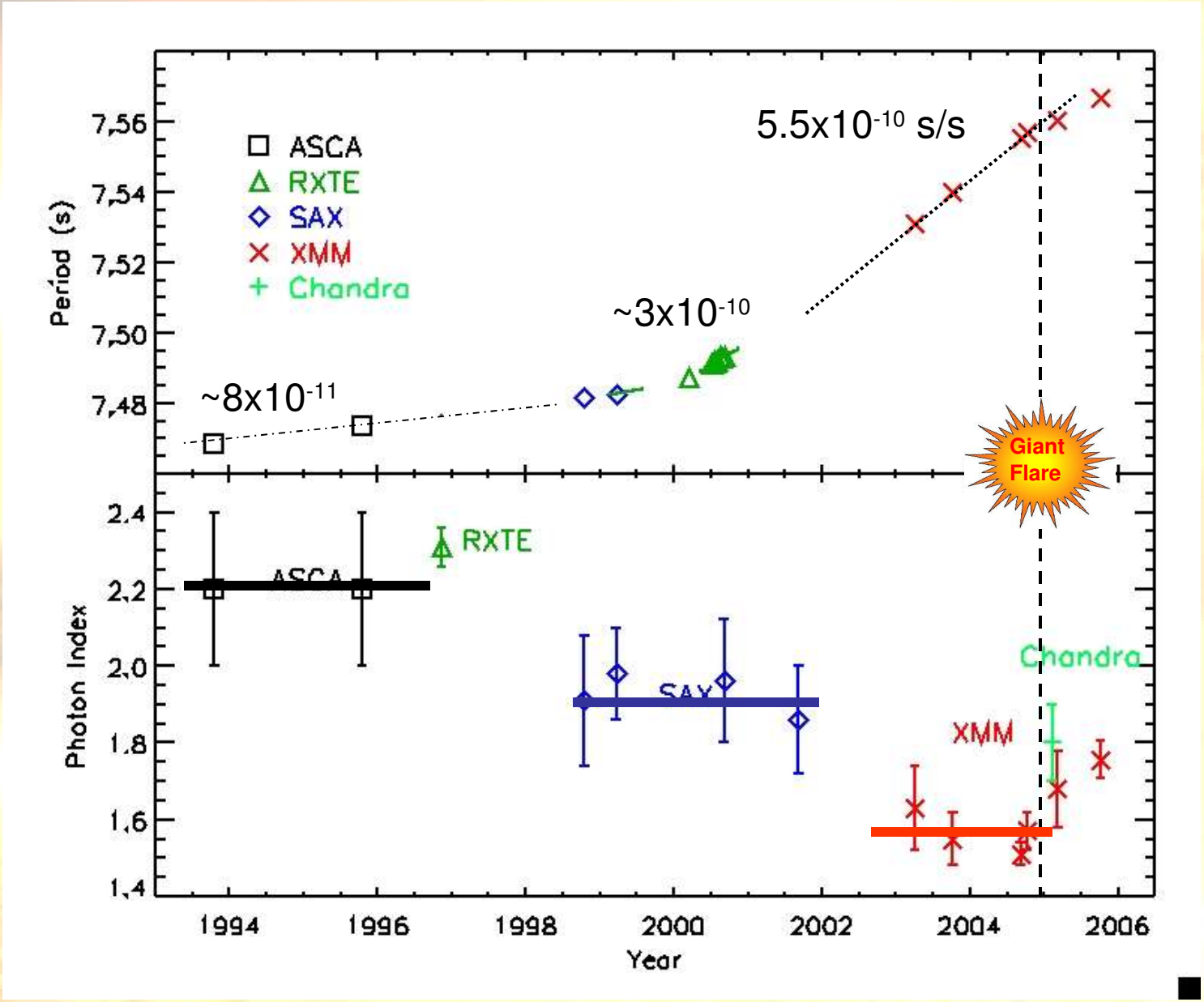
Initial giant pulse backscattered by the Moon

SGR 1806-20 Giant Flare 2004 Dec 2004

SGR 1806-20

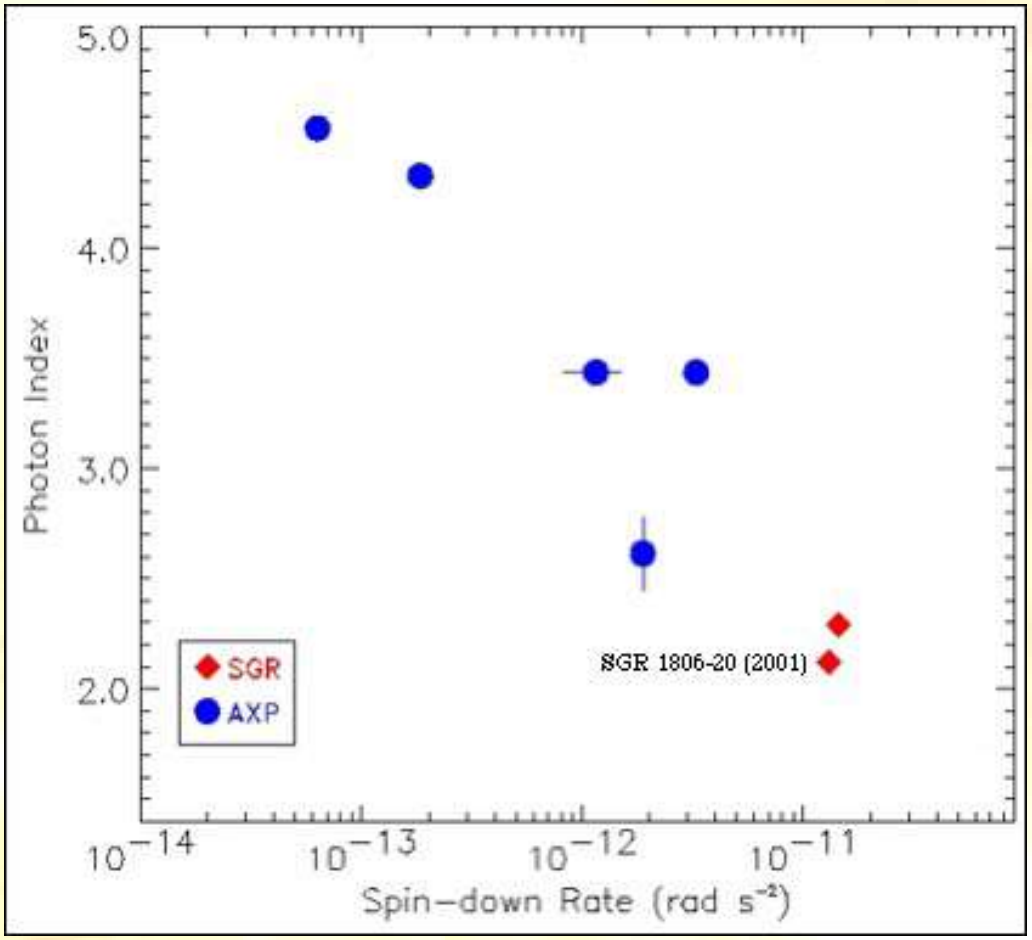
- Discovered in 1979 (Laros et al. 1986) and very active since then
- P = 7.5 s Pdot = 8×10^{-11} s/s → B = 8×10^{14} G
  (Kouveliotou et al 1998)
- High absorption: $N_H \sim 6 \times 10^{22}$ cm^{-2} Av~30
- Giant Flare on 2004 December 27
  (Hurley et al. 2005, Palmer et al. 2005, Mereghetti et al. 2005a)
- Variable NIR counterpart K~19-20
  (Israel et al. 2004, 2005; Kosugi et al 2005)
- Distance is debated: >6 kpc ; 8-15 kpc ??
  (Cameron et al. 2005, McClure-Griffiths & Gaensler 2005,)
  we assume 15 kpc (Corbel & Eikenberry 2004)
- Persistent 20-150 keV emission
  (Mereghetti et al. 2005b, Molkov et al. 2005)


2003/04/03
2003/10/07
2004/09/06
2004/10/06
2005/03/07
2005/10/04
1 burst
no bursts
40 bursts
29 bursts
3 bursts
1 burst
2-10 keV (cts/s)
1.6
1.4
1.2
1.0
0.8
0.6
PF=10.8%
PF=8.7%
PF=10.1%
PF=9.4%
PF=4.3%
PF=8.5%
Giant Flare
0.0 0.5 1.0 1.5
Phase


ASCA
RXTE
SAX
XMM
Chandra
5.5x10-10 s/s
~3x10-10
~8x10-11
Giant Flare
Period (s)
7,56
7,54
7,52
7,50
7,48
Photon Index
2,4
2,2
2,0
1,8
1,6
1,4
1994
1996
1998
2000
2002
2004
2006
Year

Correlation between spectral hardness and spin-down rate in SGRs and AXPs (Marsden & White 2001)

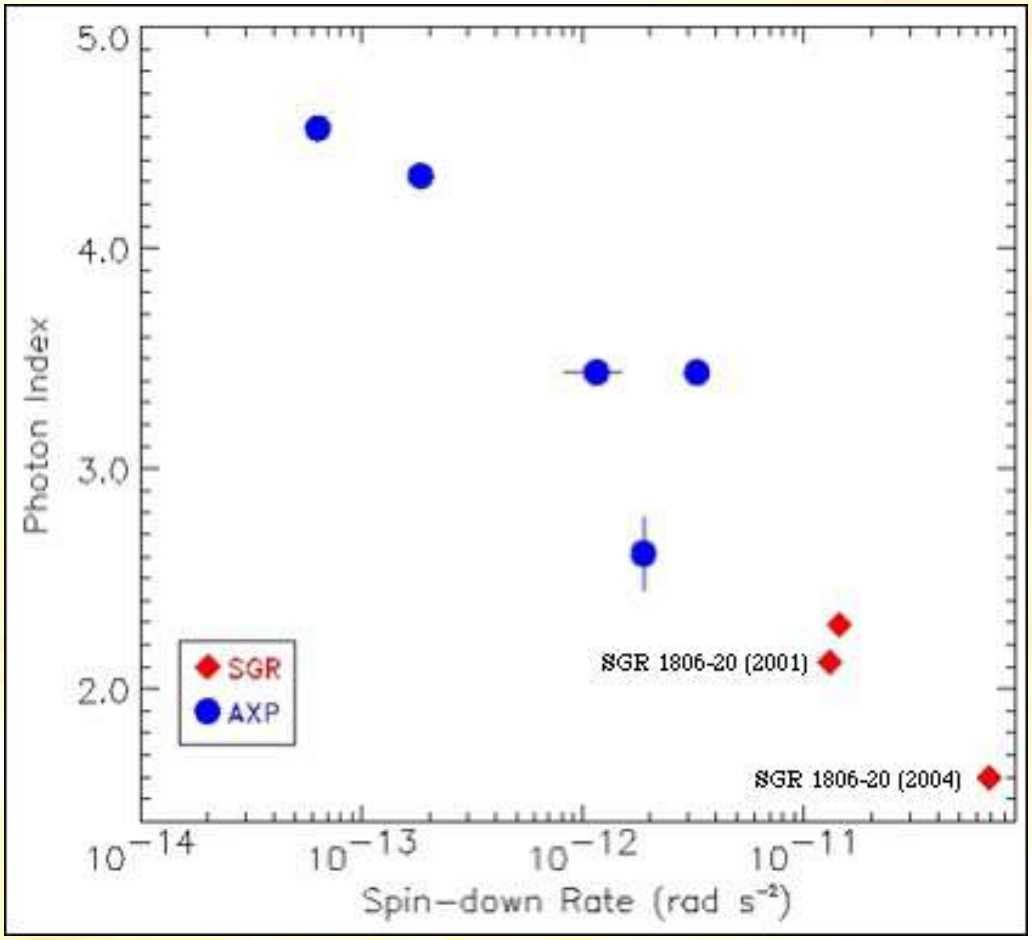
Harder X-ray spectrum



Larger Spin-down rate

Correlation between spectral hardness and spin-down rate in SGRs and AXPs (Marsden & White 2001)

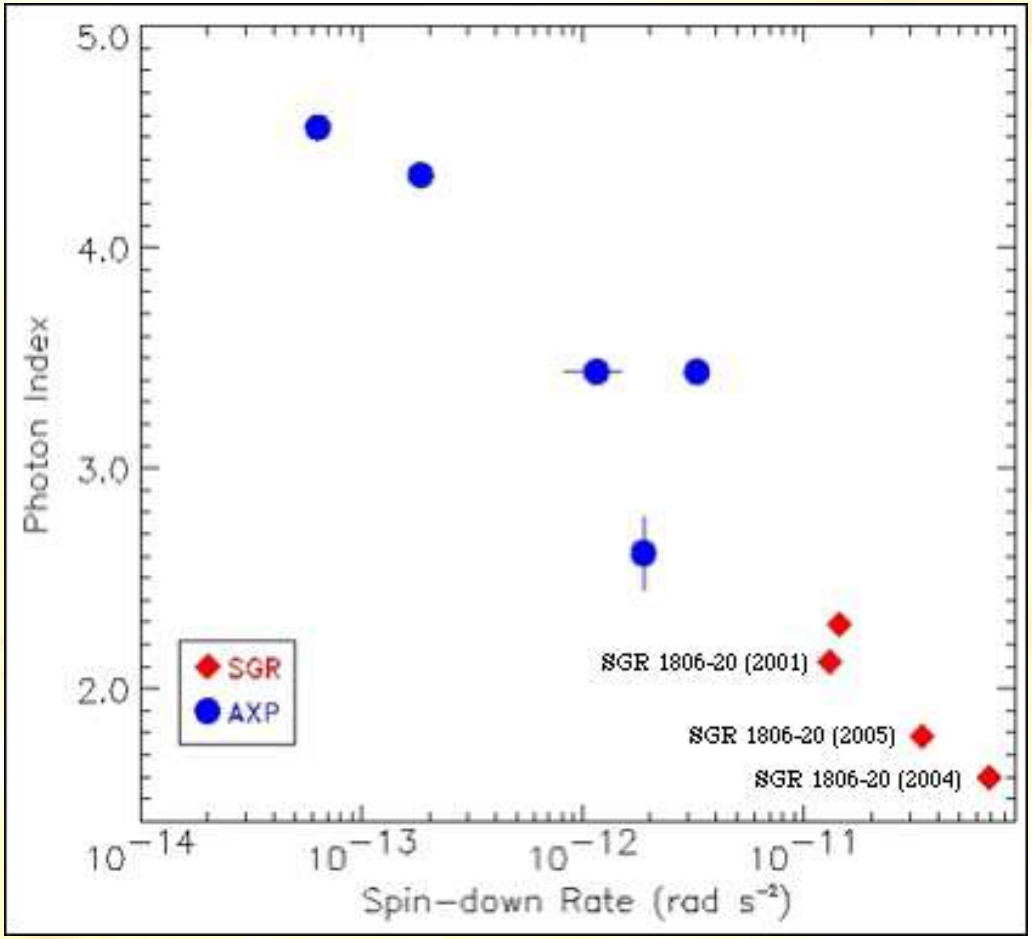
Harder X-ray spectrum



Larger Spin-down rate

Correlation between spectral hardness and spin-down rate in SGRs and AXPs (Marsden & White 2001)

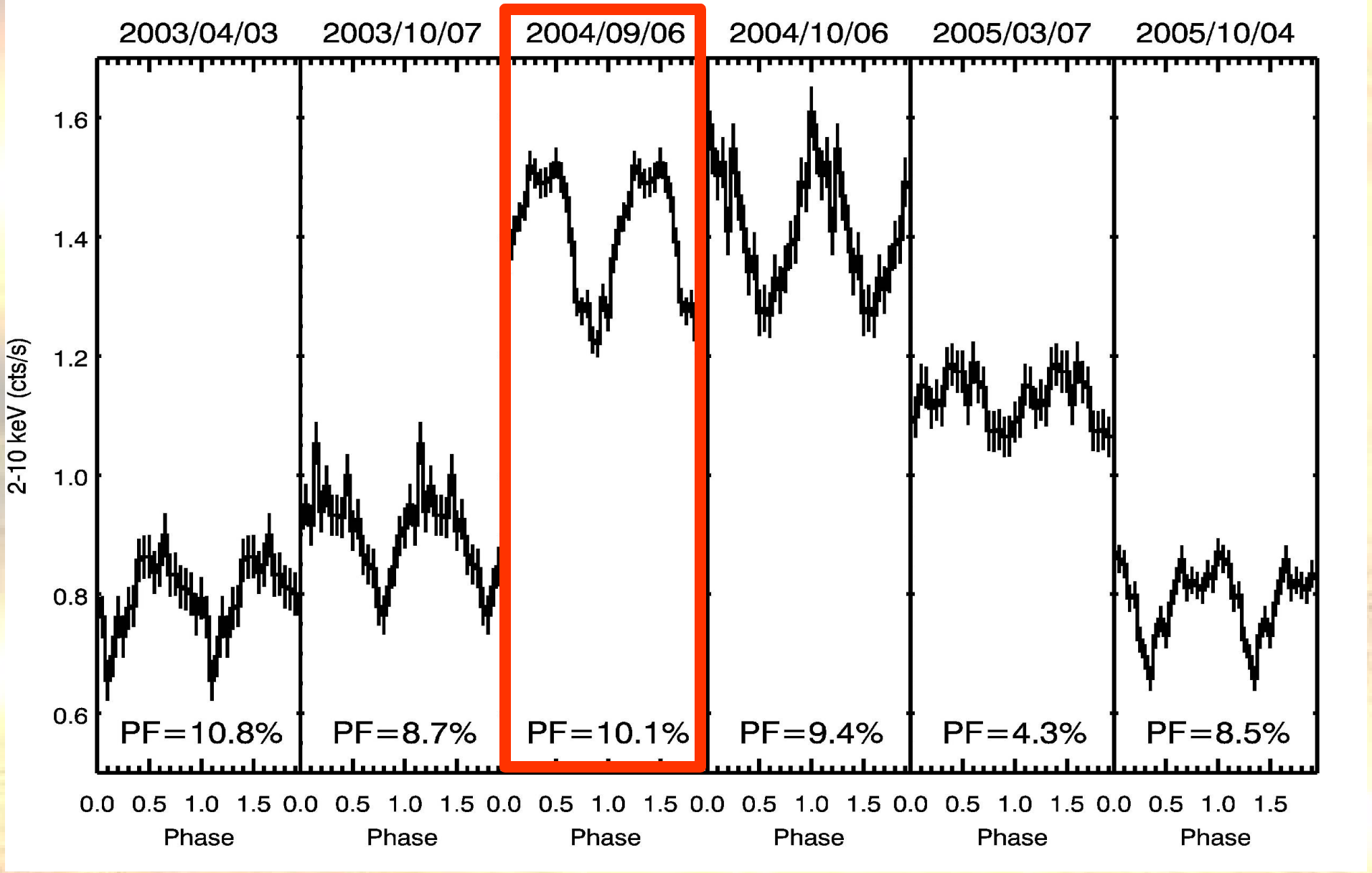
Harder X-ray spectrum

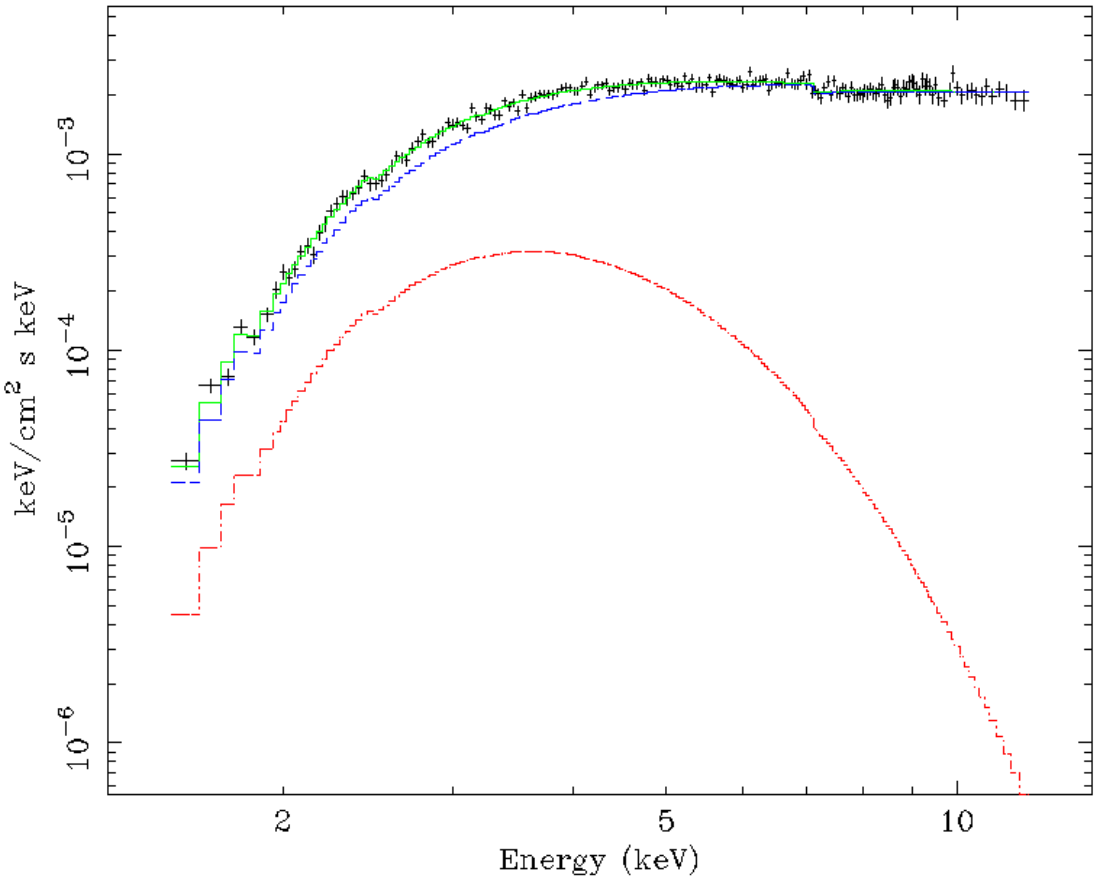


Larger Spin-down rate

September 2004 observation - long duration and high flux

→ Best quality XMM-Newton spectrum





- Single power law is not acceptable

- Two components required:

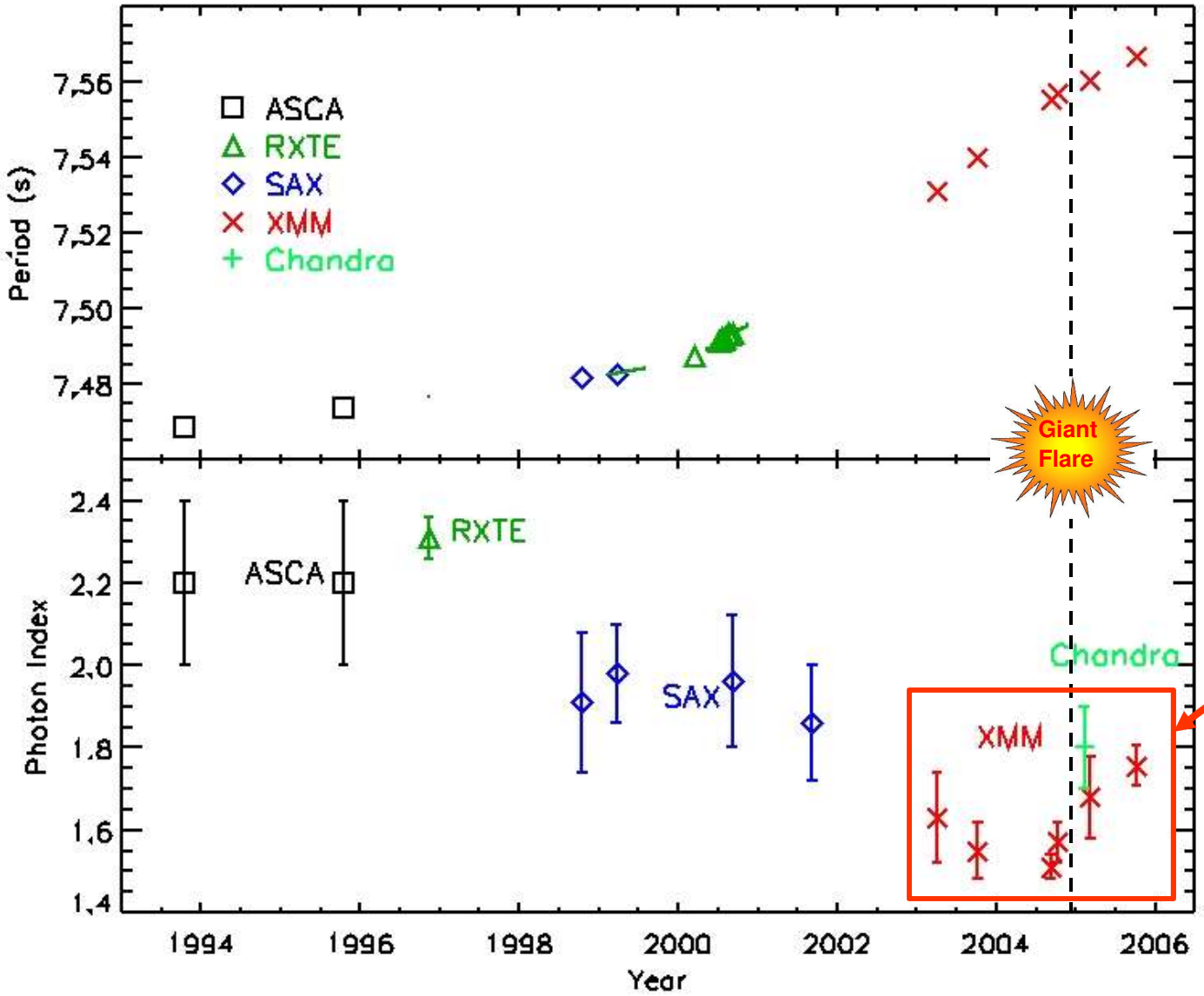
BB: kT~0.8 keV, R~2 km

+

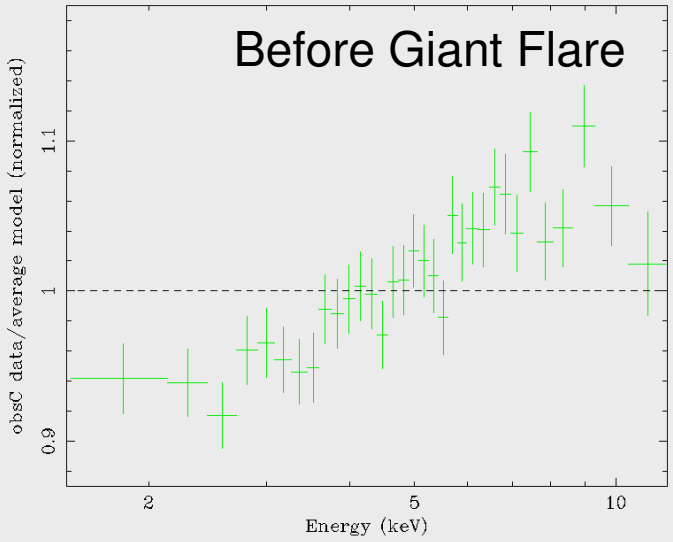
PL: photon index~1.2

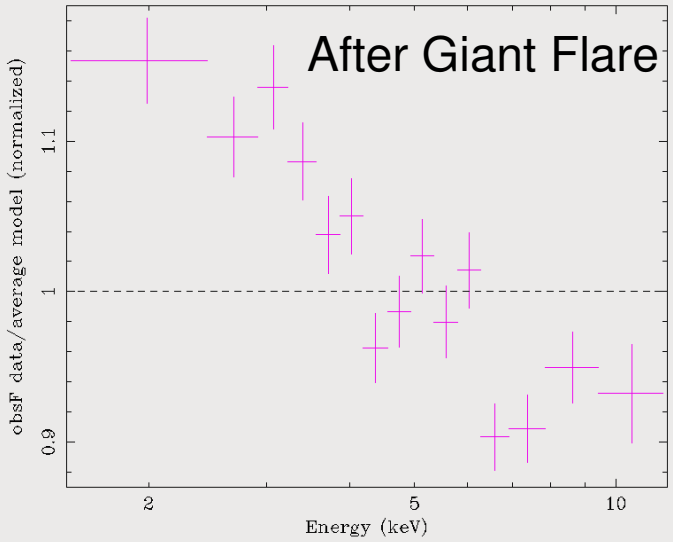
- No evidence for phase variations

- No evidence for lines



Spectral variations related to the g flare ?





- The four pre-GF observations (2003-2004) give marginal evidence for hardening but are statistically consistent with no spectral variation

- The two post-GF observations (2005) have a softer spectrum

- They require PL+BB
  March: Γ~0.8 kT~0.9 keV
  October: Γ~1.4 kT~0.7 keV

- It is possible to fit the 6 observations (pre- and post- GF) keeping a fixed BB component (~10% of the flux) and ascribing all other variations to the Power Law component

SGR 1806-20 – Summary of results:

- Overall spectral hardening on ~ ten years timescale
- Increase in spin-down rate
- Hardness vs. spin-down rate correlation
- In late 2004 also increase in bursting rate and in hardness and intensity of 20-100 keV emission (see talk by D.Gotz)
- After Giant Flare: spectral softening, decrease in pulsed fraction (lasted only a few months), reduction in spin-down rate

→ in agreement with twisted magnetosphere model

Twisted magnetars

(Thompson, Lyutikov & Kulkarni 2002)

- Twisted internal B field provide source for helicity of magnetosphere by shearing the NS crust
- Currents in twisted magnetosphere produce hard spectral tails by resonant scattering
- Twisted field produces stronger braking than dipole

✂ → both spin-down rate and spectral hardness increase with increasing twist of the magnetosphere

- At the same time stresses in the crust increase causing a higher rate of bursts
- Major B reconfiguration occurs with the Giant Flare → change in light curve and spectrum

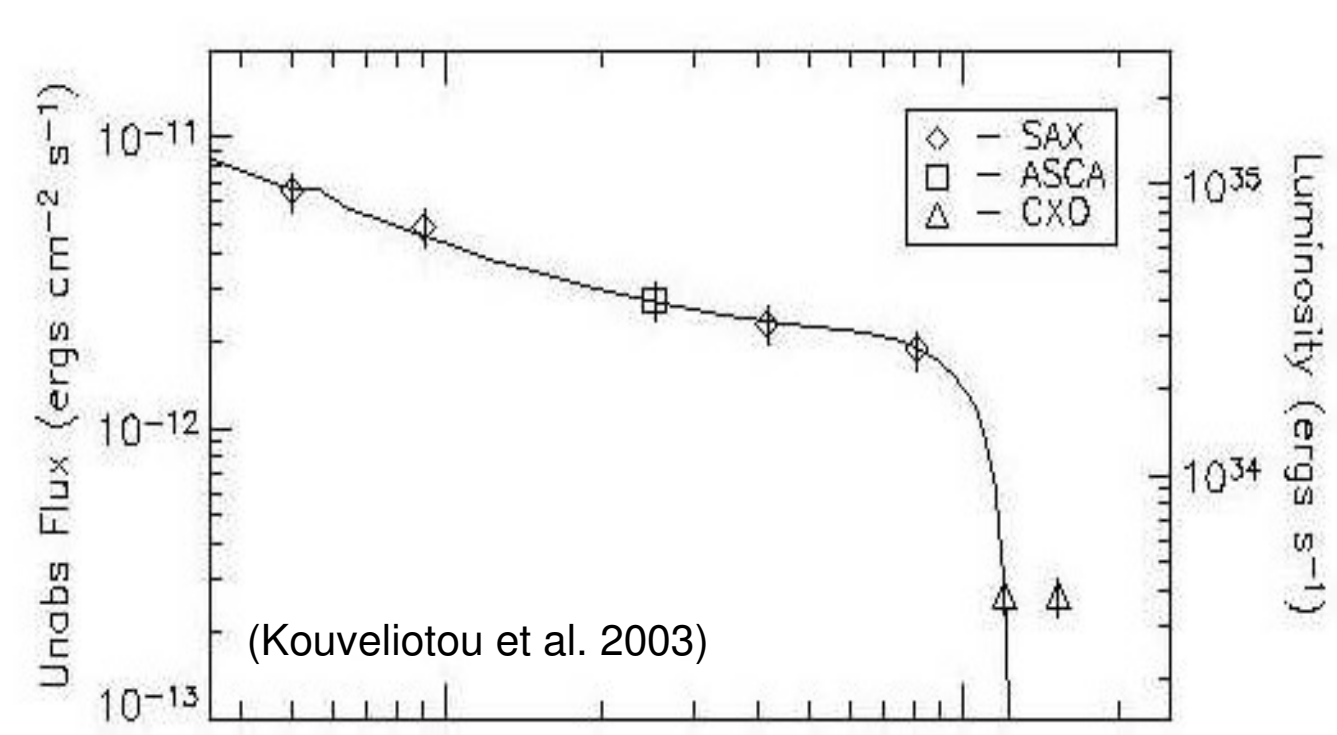
SGR 1627-41

Mereghetti, et al. 2006, Astron. & Astrophysics 450, 759

SGR 1627-41

- Discovered in 1998 (Woods et al. 1999);
  active only a few weeks and quiescent since then
- P: unknown (but upper limits not constraining)
- Very high absorption: $N_H \sim 10^{23}$ cm^{-2} Av ~ 40 – 50
- distance unknown - (we assume 11 kpc)
- No identified optical/NIR counterparts (Wachter et al 2004)
- No giant flares
- Long term decrease in X-ray luminosity (Kouveliotou et al. 2003)

SAX, ASCA and Chandra data spanning 4 years



Model of cooling after the deep crustal heating occurred during the active period (Lyubarsky, Eichler & Thompson 2002)

→ See talk by D. Eichler

XMM-Newton results

- 52 ks observation on 2004 September 22

- Faint source (~9 pn cts / ks)
- Soft spectrum:

  Power law photon index = 3.7 +/- 0.5

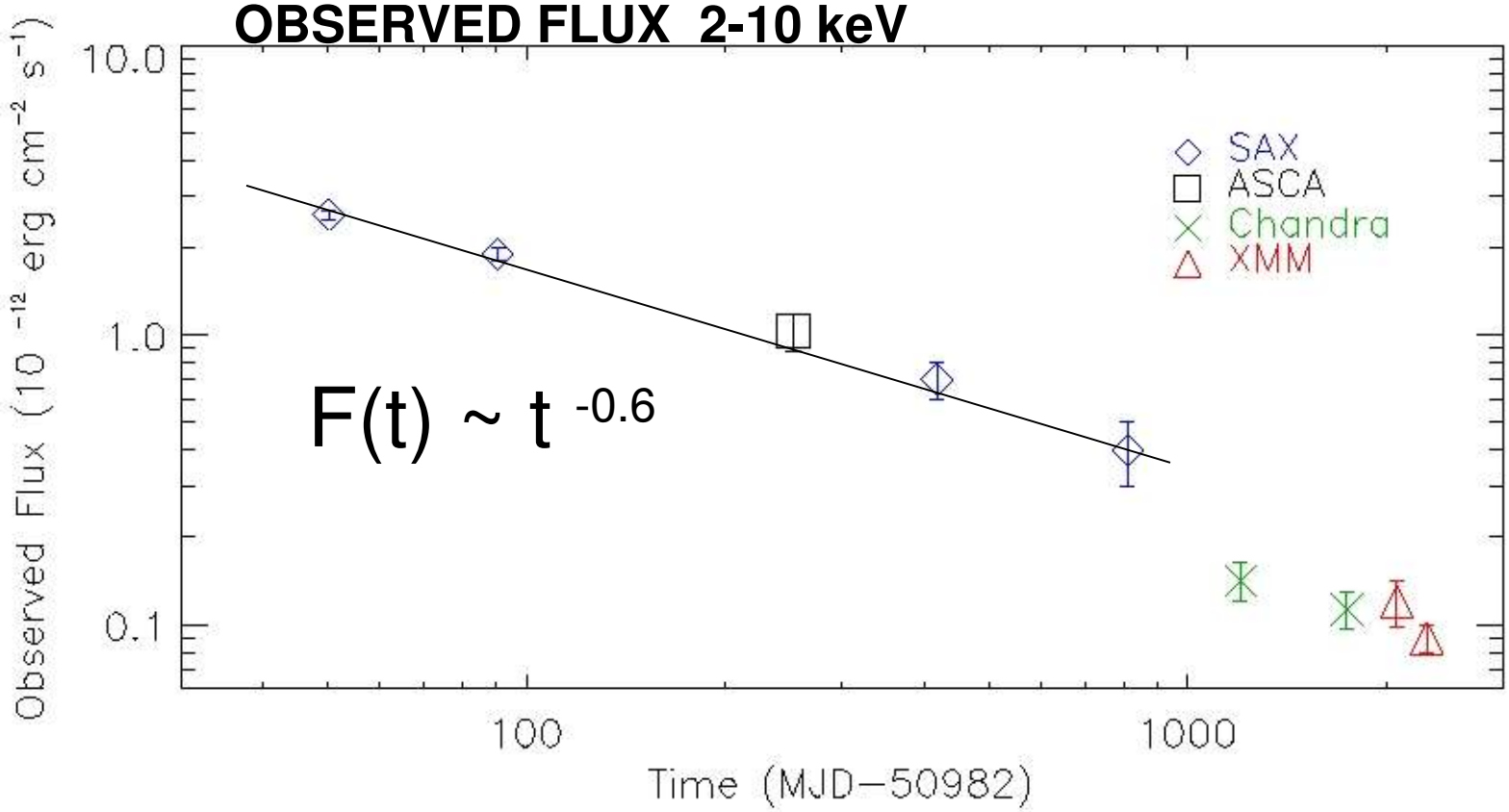
  or

  blackbody kT = 0.8 keV R~0.2 km

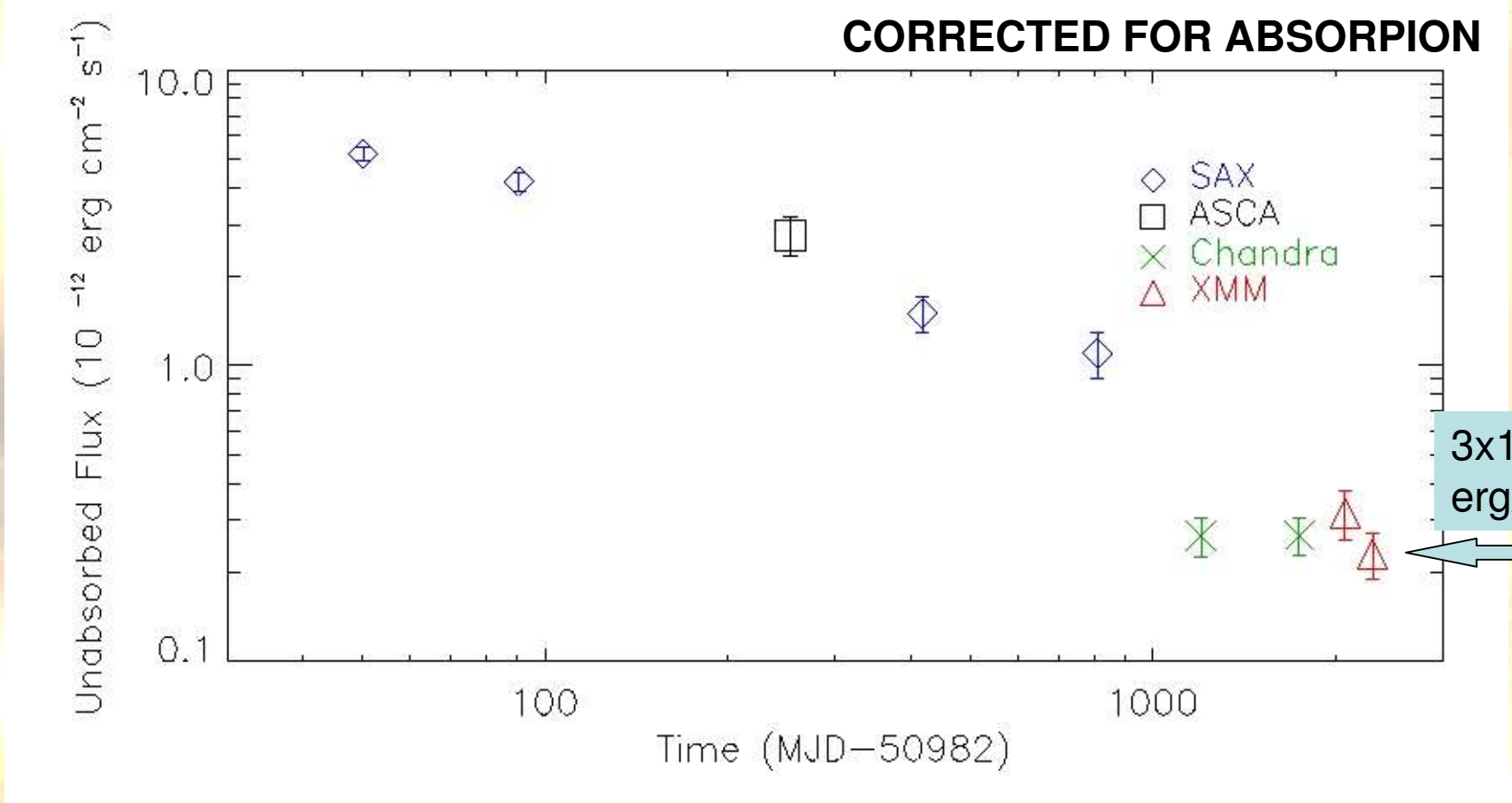
- Two serendipitous detections (off-axis) in February and September 2004 gave similar results

- Luminosity ~ 3.5 10^{33} erg/s

SGR 1627-41 long term flux decay



SGR 1627-41 long term flux decay



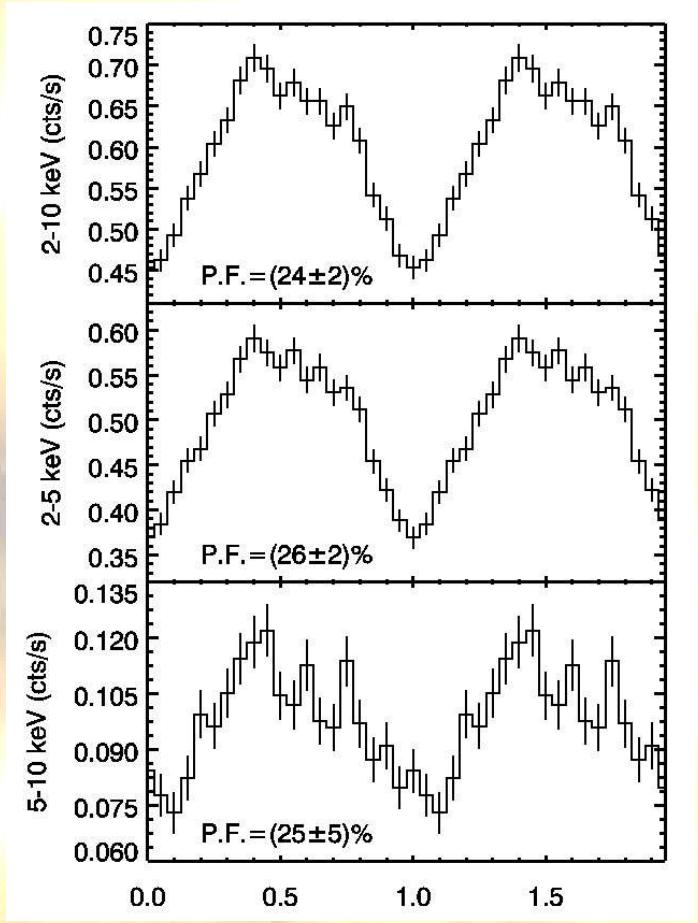
SGR 1900+14

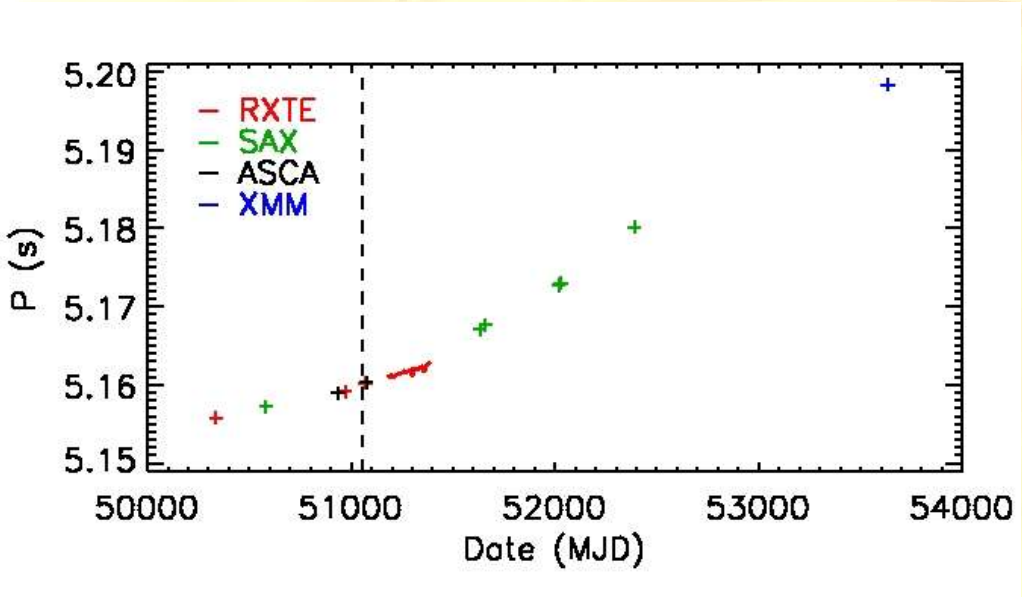
SGR 1900+14

- Discovered in 1979 (Mazets et al. 1979)
- P = 5.2 s Pdot = 6×10^{-11} s/s → B = 8×10^{14} G
  (Hurley et al. 1999, Kouveliotou et al 1999)
- $N_H \sim 2 \times 10^{22}$ cm^{-2} (the less absorbed Galactic SGR)
- No opt/IR counterpart - K>21 (Kaplan et al. 2002)
- Giant Flare on 1998 Aug 27 (and few "intermediate" flares)
- Distance ~15 kpc
- Persistent 20-150 keV emission with steep spectrum (Götz et al. 2006)

XMM-Newton results

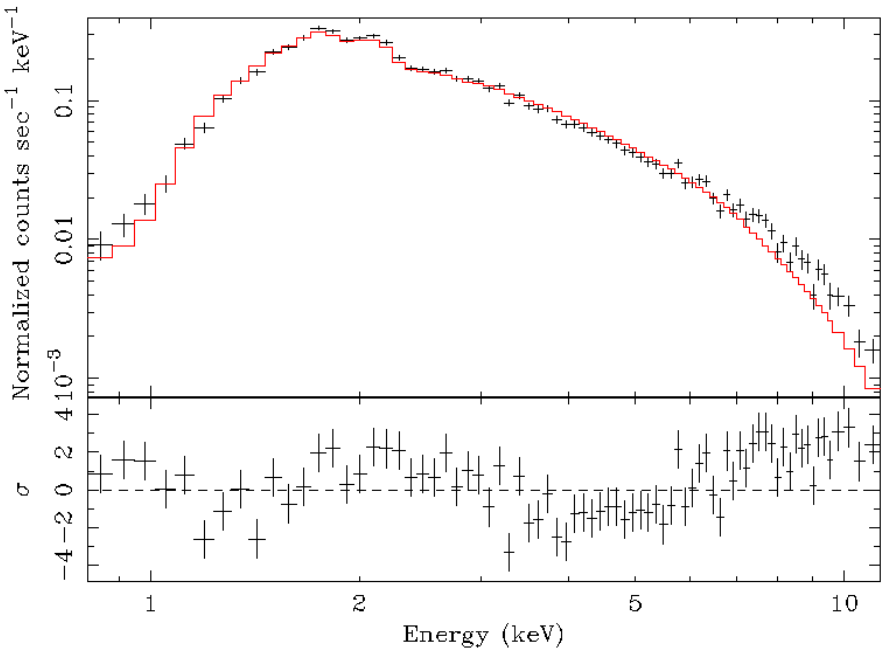
50 ks observation on 2005 September 20-22 - No bursts detected



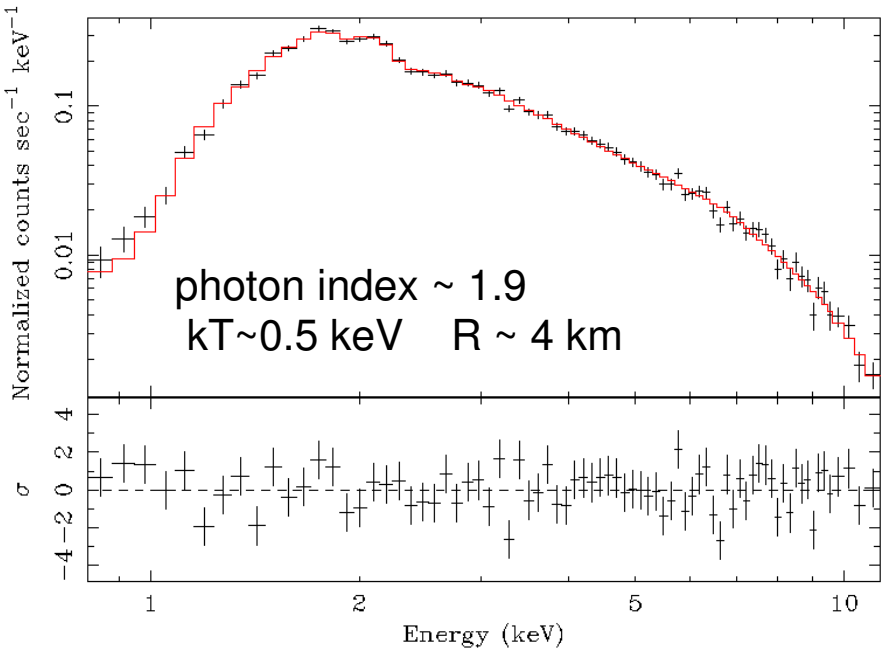


XMM-Newton EPIC spectrum

Power Law



Power Law + Blackbody

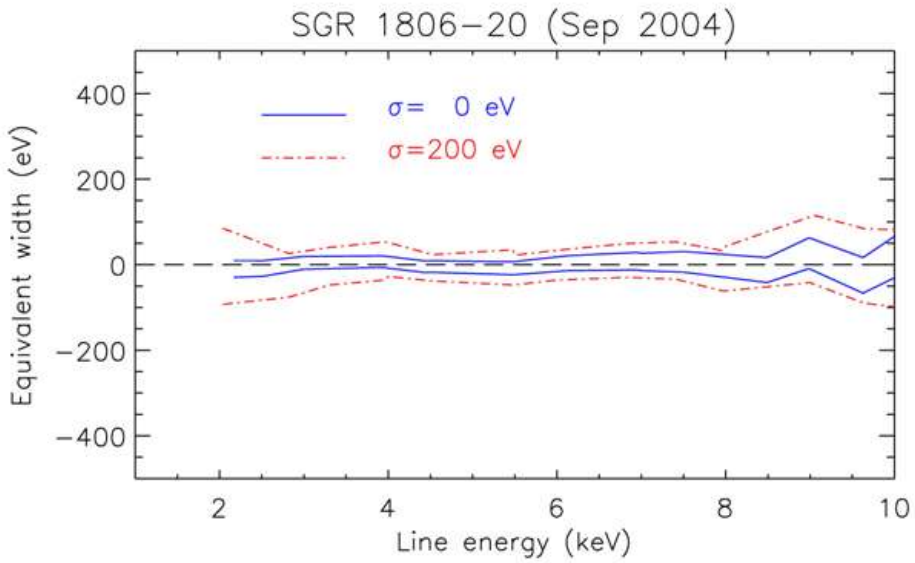


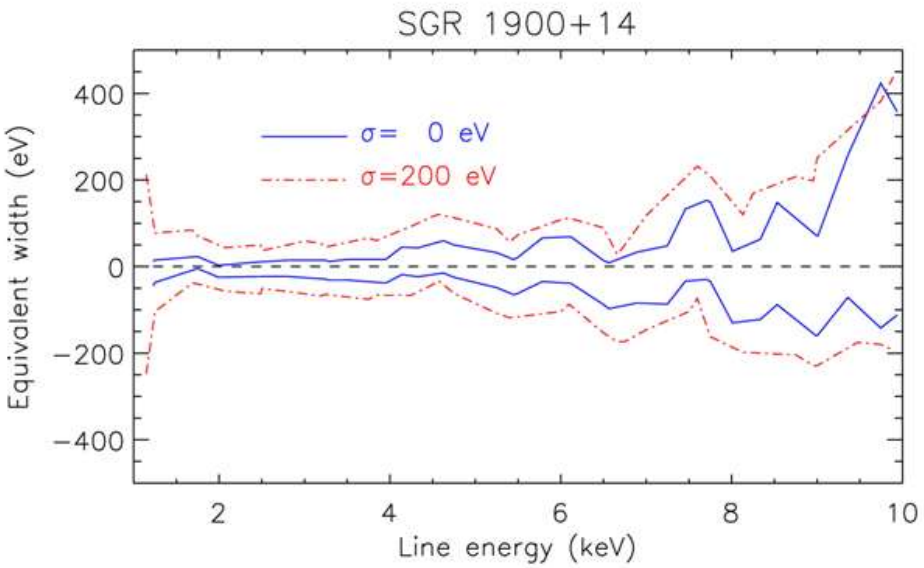
Flux ~5x10^{-12} erg cm^{-2} s^{-1} (2-10 keV, unabs.)

LOWER THAN "HISTORICAL" VALUE → see Tiengo's talk

Upper limit on lines in SGR 1806-20 and SGR 1900+14

3σ upper limits on emission and absorption lines in persistent emission





Lines reported in SGRs only during bursts with Rossi-XTE

- **SGR1806-20** (Ibrahim et al. 2002, 2003)

  Absorption feature at E ~ 5 keV EW~400-850 eV
  seen in a few bursts

  with less significant features at ~7.5, 11.2, 17.5 keV

  Width inconsistent with thermal broadening if electrons, but OK for protons
  in $B \sim 10^{15}$ G

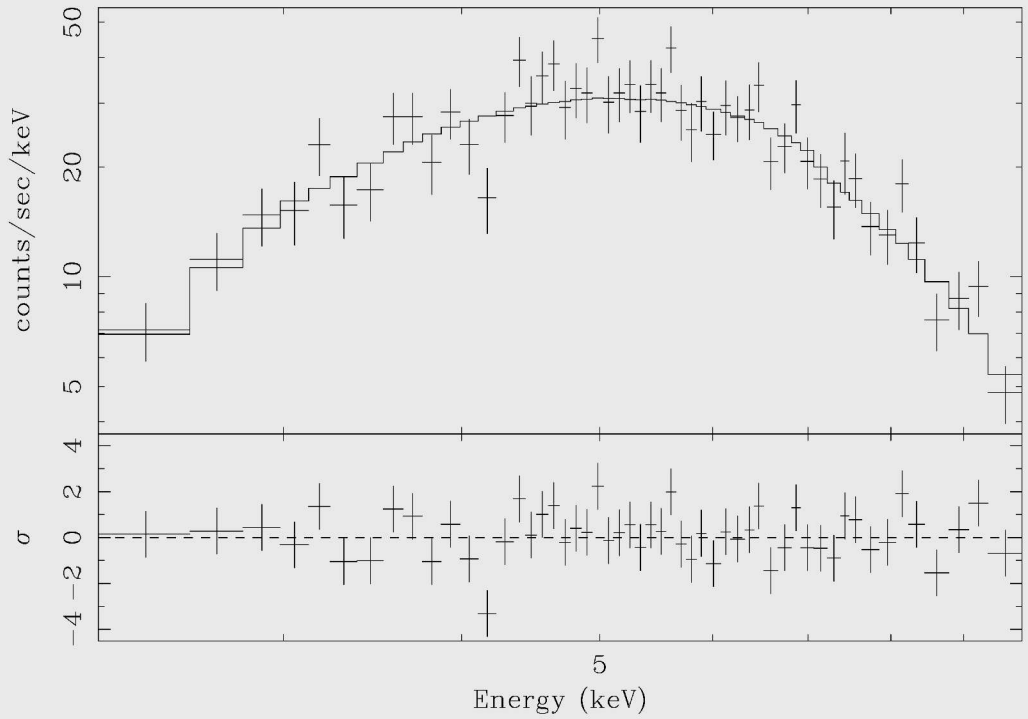
- **SGR 1900+14** (Strohmayer & Ibrahim 2000)

  Emission feature at 6.4 keV seen only once
  During precursor burst of 1998 August 29 "intermediate" Flare

See Ibrahim talk on new feature at 20 keV

SGR 1806-20

Cumulative XMM-Newton spectrum of ~70 bursts



Blackbody fit

kT = 2.3 keV

$N_H = 6x10^{22}$ cm^{-2}

CONCLUSIONS

- Overall results at first order consistent with twisted magnetosphere model

- Details indicate more complicated picture and unsolved issues, e.g.:
  - Is there a “quiescent” SGRs luminosity level ?
  - How and when is it reached ? → SGR 1627-41 AXP XTE J1810-197
  - Why SGR 0526-66 is so luminous despite being ‘’silent’’ since 1979 ?
  - Is 1900+14 behaving like 1806-20 ?
  - Can a coherent picture be found for the activity observed in SGRs and AXPs ?
  - what are the relations with other classes of isolated neutron stars ? (see De Luca talk)

CONCLUSIONS

- XMM-Newton monitoring is essential to study long term flux / spectral evolution
- Important to complement this with multiwavelength observations (INTEGRAL, Suzaku + NIR + AGILE, GLAST) and timing studies (RXTE)
- Observations above 10 keV are promising but suffered of limited sensitivity so far

  → new generation telescope with hard X-ray focusing greatly needed