INTEGRAL Monitoring of Magnetars' High Energy Tails & 071017 : the INTEGRAL Anniversary Burst

Diego Götz

CEA Saclay

S. Mereghetti, P. Esposito, A. Tiengo (INAF-IASF Milano), K. Hurley(UCB), G.L. Israel (INAF-OAR Roma), N. Rea (UvA), S. Zane (UCL), R. Turolla (Padua Univ.), E.V. Gotthelf (Columbia Univ.)

Introduction

dapnia SAp

cea saclay

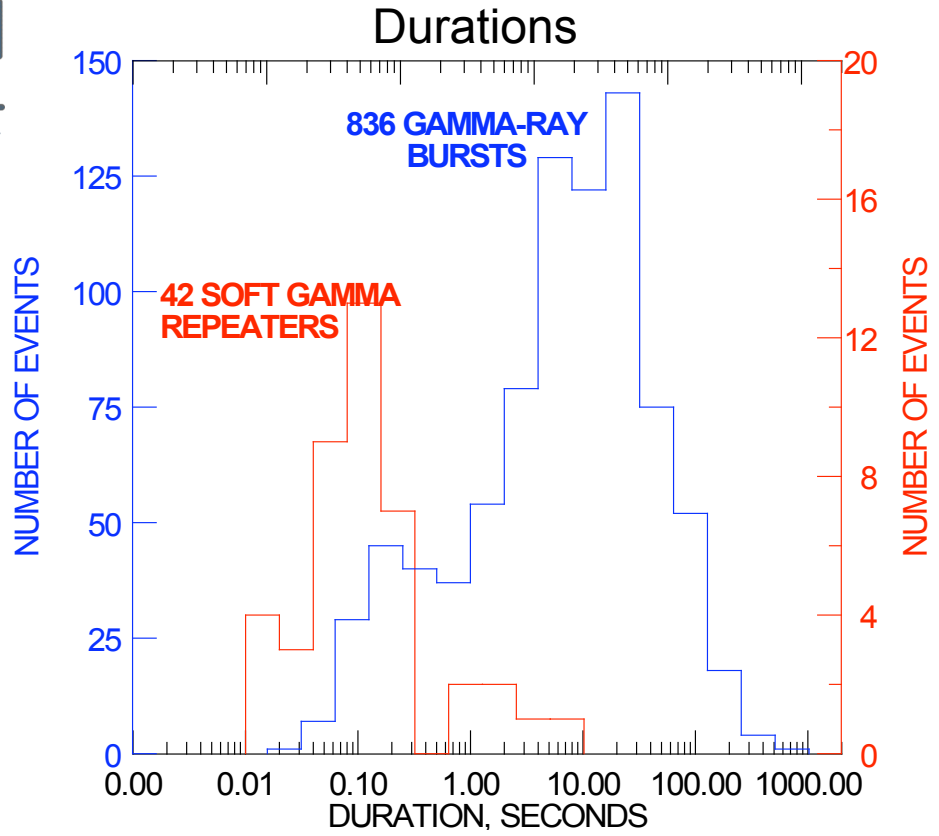
- There are 13 members and 3 candidates
- They are didvided in 2 classes: the Anomalous X-ray Pulsars (AXPs) and the Soft Gamma-Ray Repeaters (SGRs)
- Magnetars are neutron stars whose main energy source is neither rotation nor accretion, but the ***magnetic energy***
- Their inferred surface dipolar magnetic field is larger than the quantum critical value

$$B_{QED} = \frac{m_e^2 c^3}{e\hbar} \cong 4.4 \times 10^{13} G$$

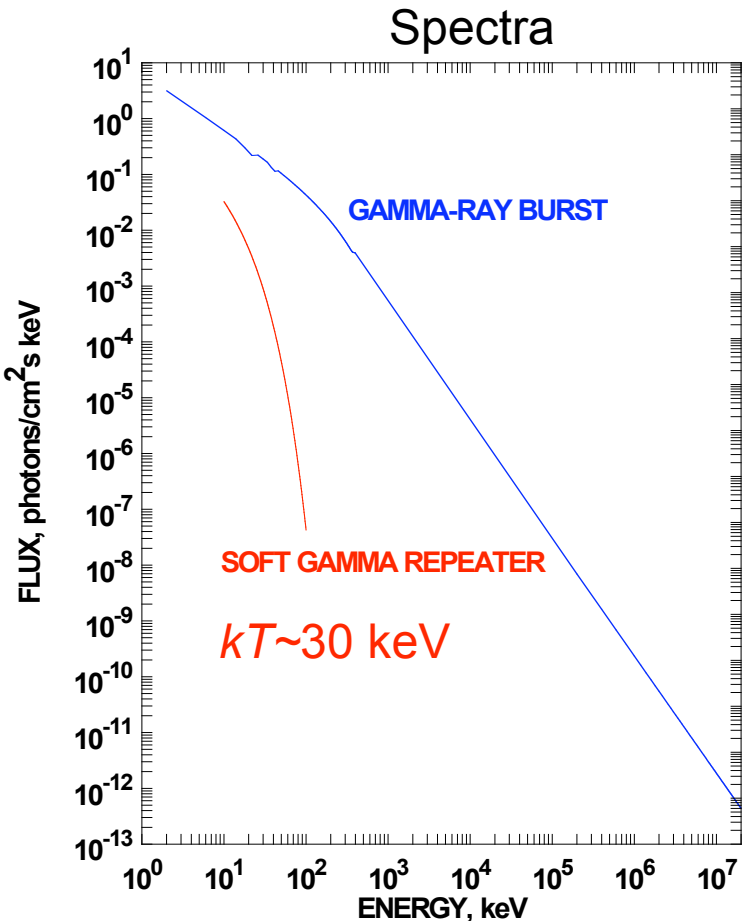
Introduction - SGRs

SGRs: Initially considered a peculiar class of Gamma-Ray Bursts

short, **“soft”, “repeating” , L_{peak}>>> $L_{Eddington}$**



Courtesy K. Hurley



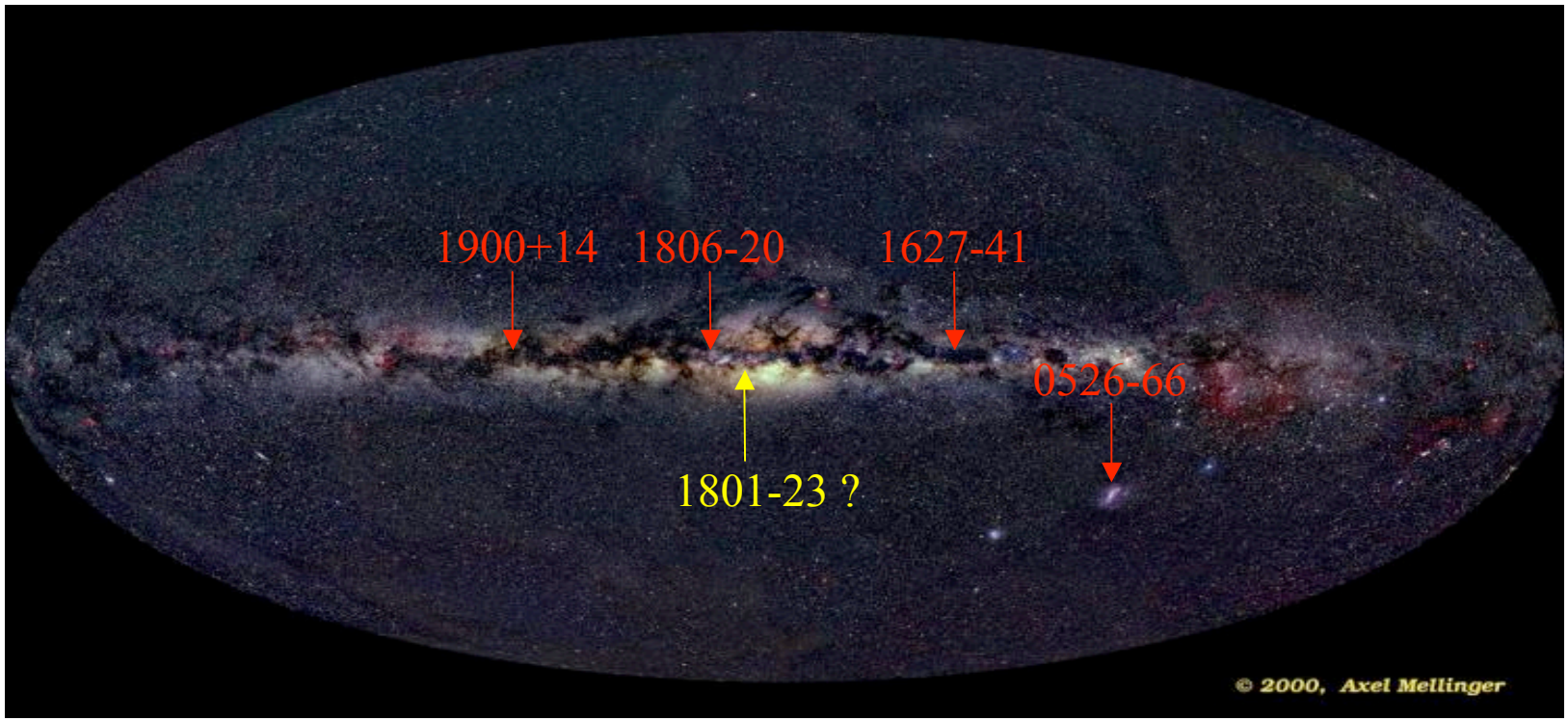
Introduction - SGRs

4 confirmed SGRs (+2 candidates: 1808-20 and 1801-23)

3 are in the Galactic plane → typical distance ~several kpc

One is in the N49 supernova remnant in the Large Magellanic Cloud (d=55 kpc)

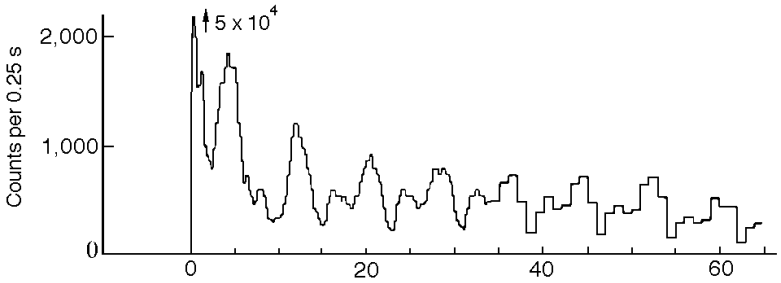
Soft X-ray spectra and timing properties similar to AXPs



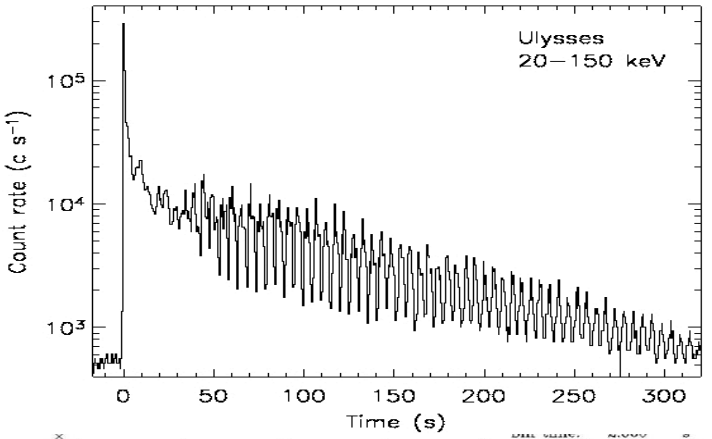
Introduction - SGRs

3 Giant Flares from 3 SGRs

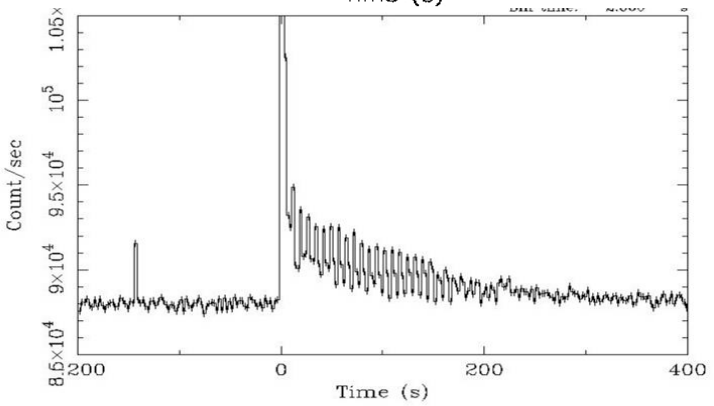
1979 March 5 - SGR 0526-66



1998 August 27 - SGR 1900+14



2004 December 27 – SGR 1806-20



Introduction - AXPs

dapnia SAp
cea
saclay

•The AXPs have been originally identified as a « class » due to their narrow period distribution and due to other X-ray properties

•No evidence for companion stars; 2 (or 3 ?) are in Supernova Remnants
(very faint IR counterparts, no Doppler delays in pulses)

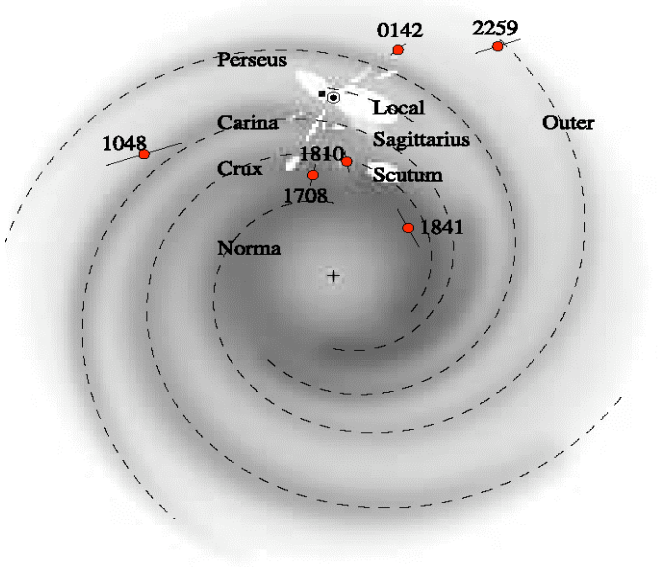
• Rotational period of a few seconds (2-12 s)

• Secular spin-down (0.05-4)x10^{-11} s/s

• L_x ~ 10^{34} - 10^{36} erg s^{-1} >> Rotational Energy Loss

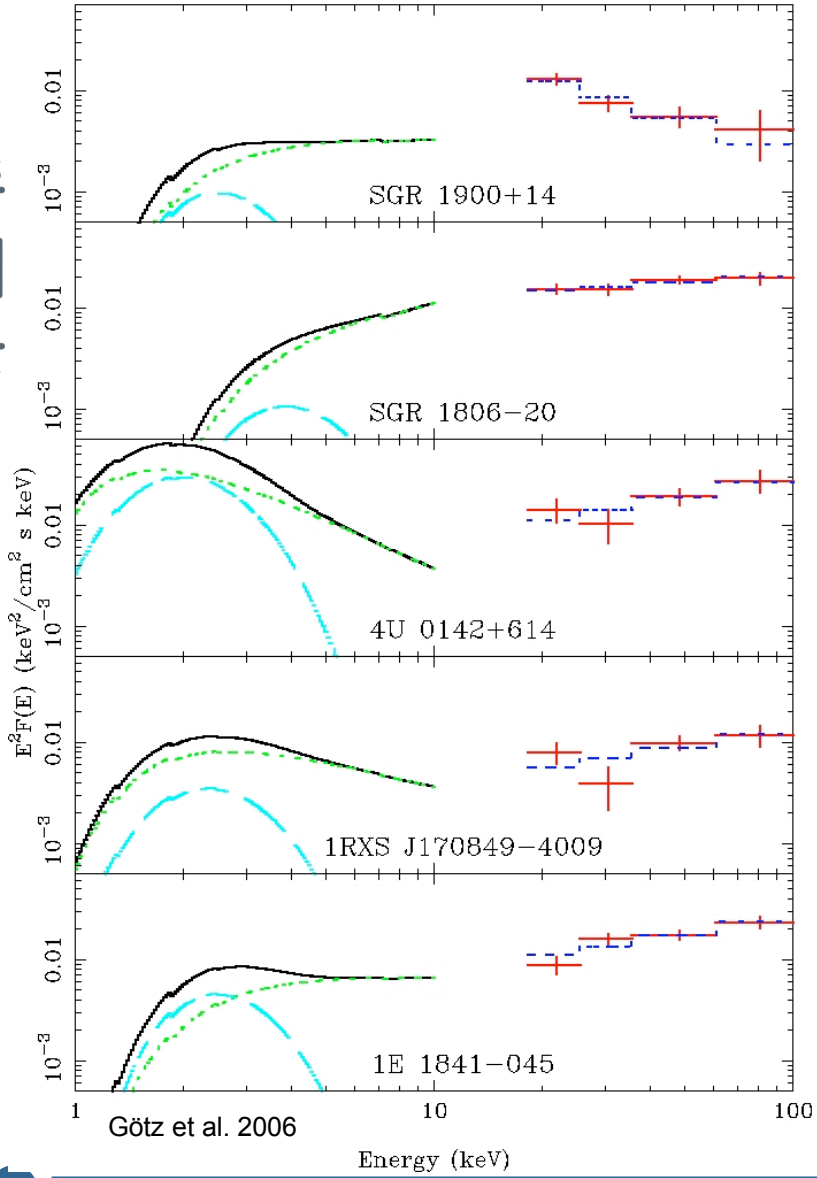
• Very soft X-ray spectrum (kT~0.5 keV)

"SGR-like" short bursts detected from five AXPs



	P (s)	dP/dt (10^{-11} s/s)	
4U 0142+61	8.7	0.2	
1E 2259+586	7	0.05	
1E 1048-5937	6.4	2-3	
1E 1841-045	11.8	4	
AX J1845-03	7	-	
RXS 1708-40	11	2	
CXO J0110-72	8	2	
XTE J1810-197	5.5	1.8	Tr./R
CXO J1647-45 (Wes1)	10.6	0.1	Tr.
1E 1547.0-5408	2.069	2.3	R

INTEGRAL/IBIS Discovery of Hard Tails



AXPs

Kuiper et al. 2004
den Hartog et al. 2005
Kuiper et al. 2006

SGRs

Mereghetti et al. 2005
Molkov et al. 2005
Götz et al. 2006

Clear evidence for non-thermal <u>persistent</u> emission.
Energetically important contribution:
L(>10 keV) ~10^{36} erg/s

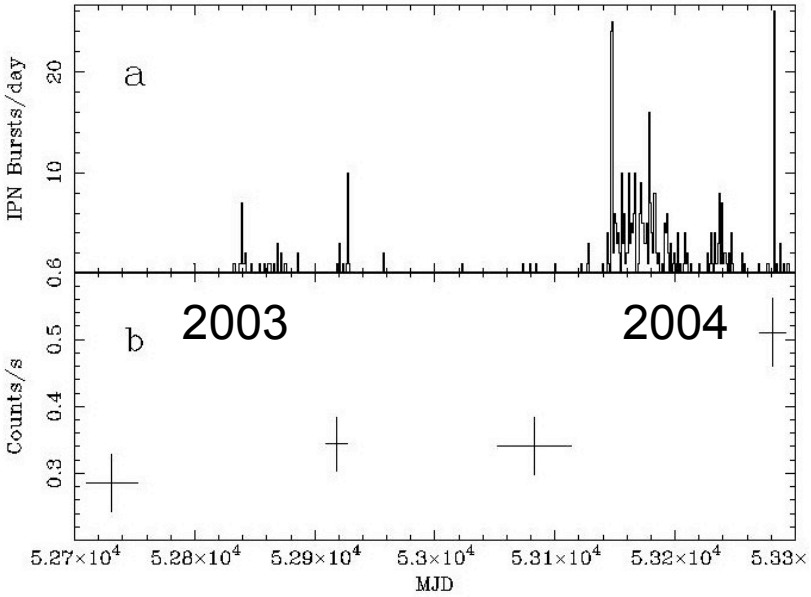
Spectrum above 10 keV *hardens* for AXPs, while for SGRs it *softens*

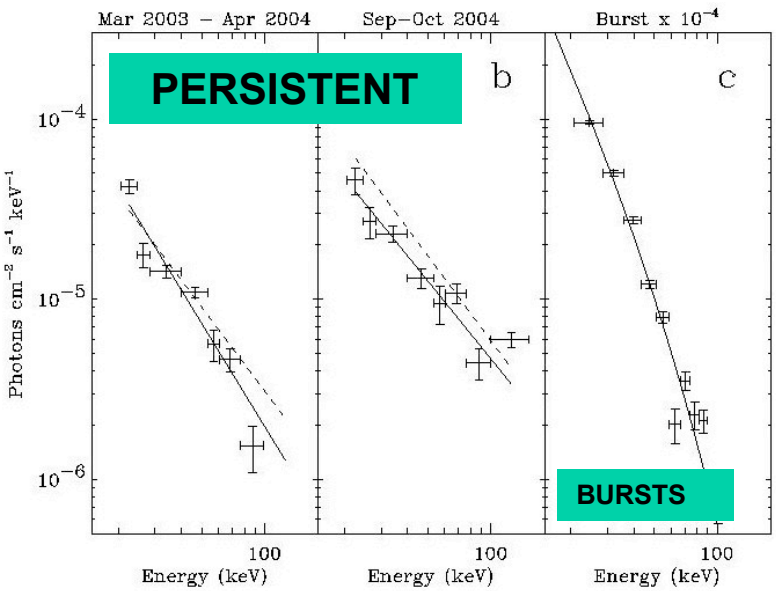
<u>No clear physical model has yet been devloped for the broad-band spectra of Magnetars.</u>

Persistent hard X-ray emission can be due to:

- Bremsstrahlung photons produced in a thin layer close to the neutron star (Thompson & Belobodorov 2005). Cutoff at ~100 keV.
- at 100 km altitude in the magnetosphere through multiple resonant cyclotron scattering (Thompson et al. 2002). Cutoff at ~1 MeV
- A third scenario involving resonant magnetic Compton up-scattering of soft X-ray photons by a non-thermal population of highly relativistic electrons has been proposed by Baring et al. (2007)

SGR 1806-20: variability





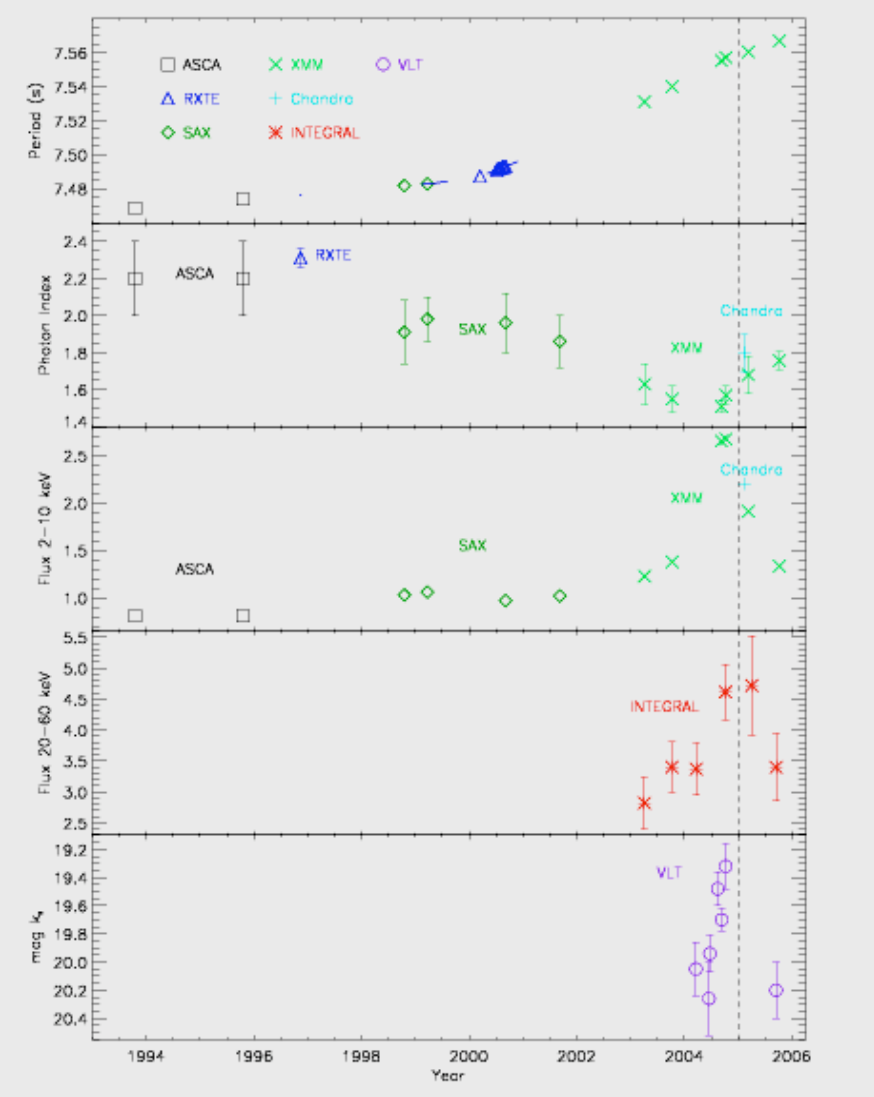
Mereghetti et al. 2005

- 20-100 keV power law spectrum

- both spectral hardness and intensity correlate with burst rate

- source “activity level” increased in 2003-2004…
  … leading to the Dec 27 Giant Flare

Multi λ source monitoring programme



PULSE PERIOD

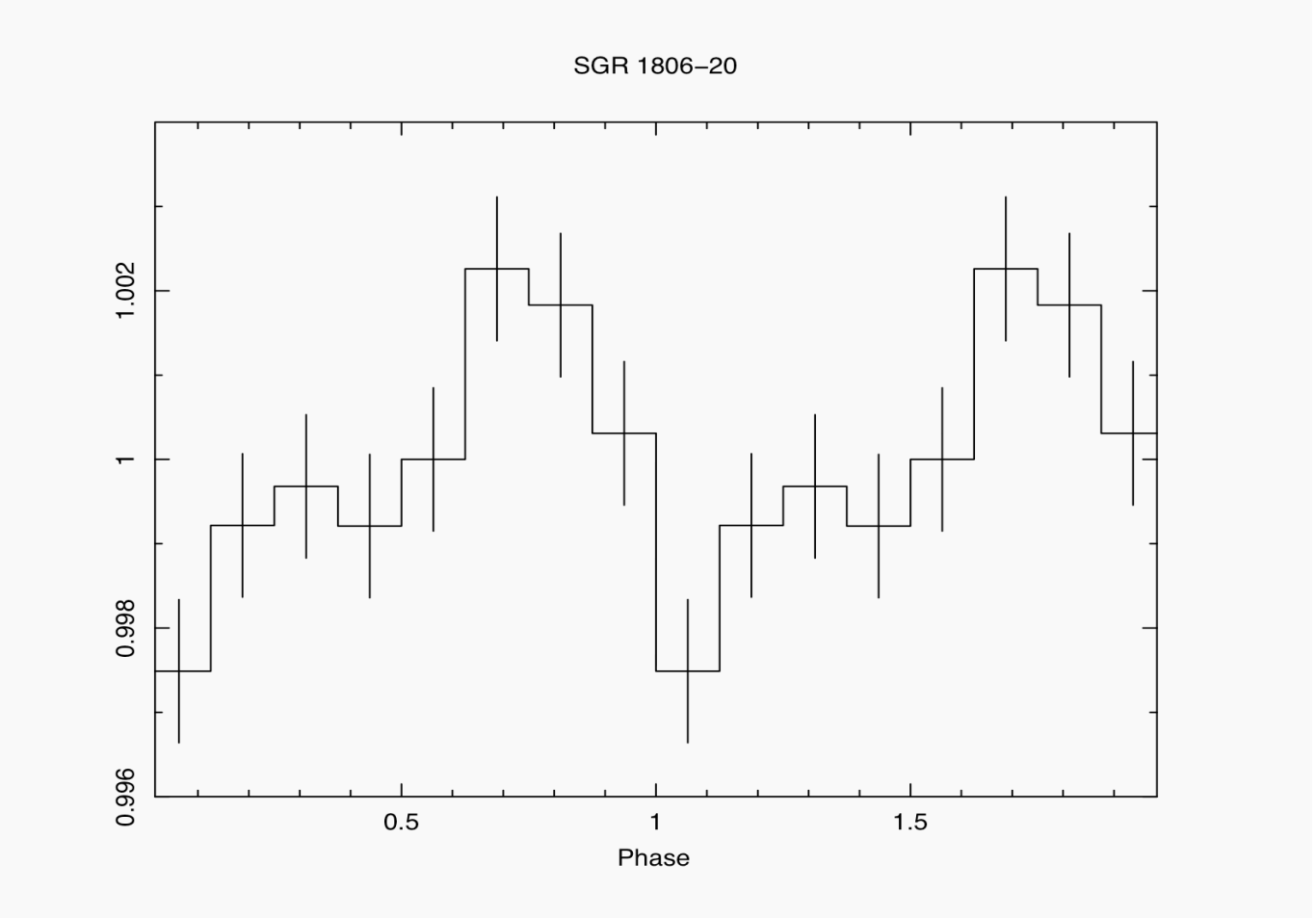
POWER LAW INDEX
(2-10 keV)

2-10 keV FLUX *XMM*

20-40 keV FLUX
INTEGRAL/IBIS

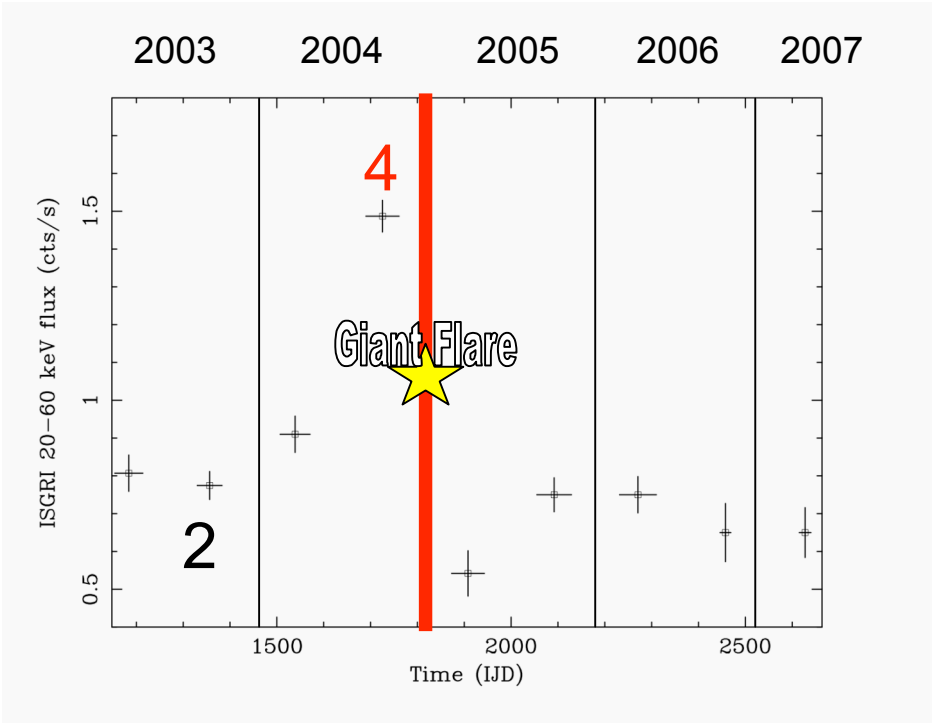
INFRARED FLUX
Israel et al. (2005)

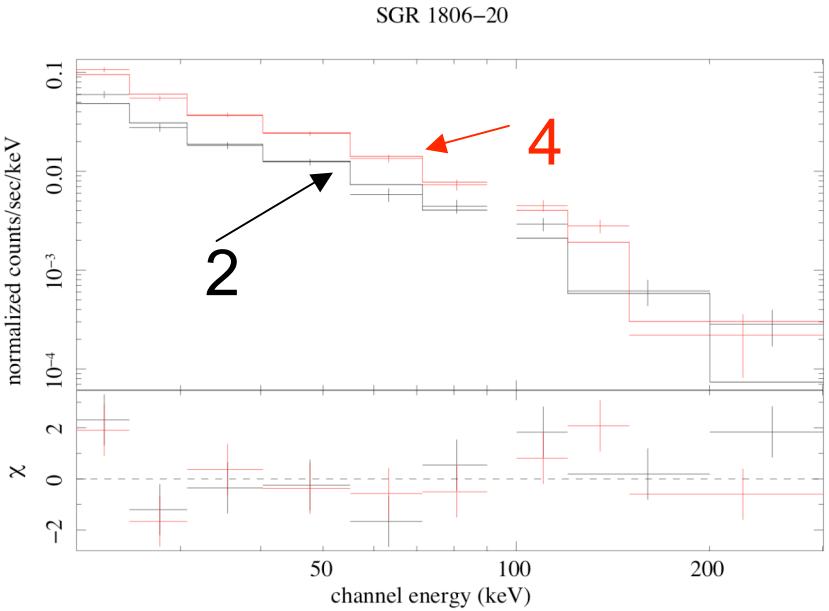
SGR 1806-20 pulsations



2.8 sigma level detection in the 20-60 keV band with ISGRI
Smaller PF than AXPs (like in X-rays)

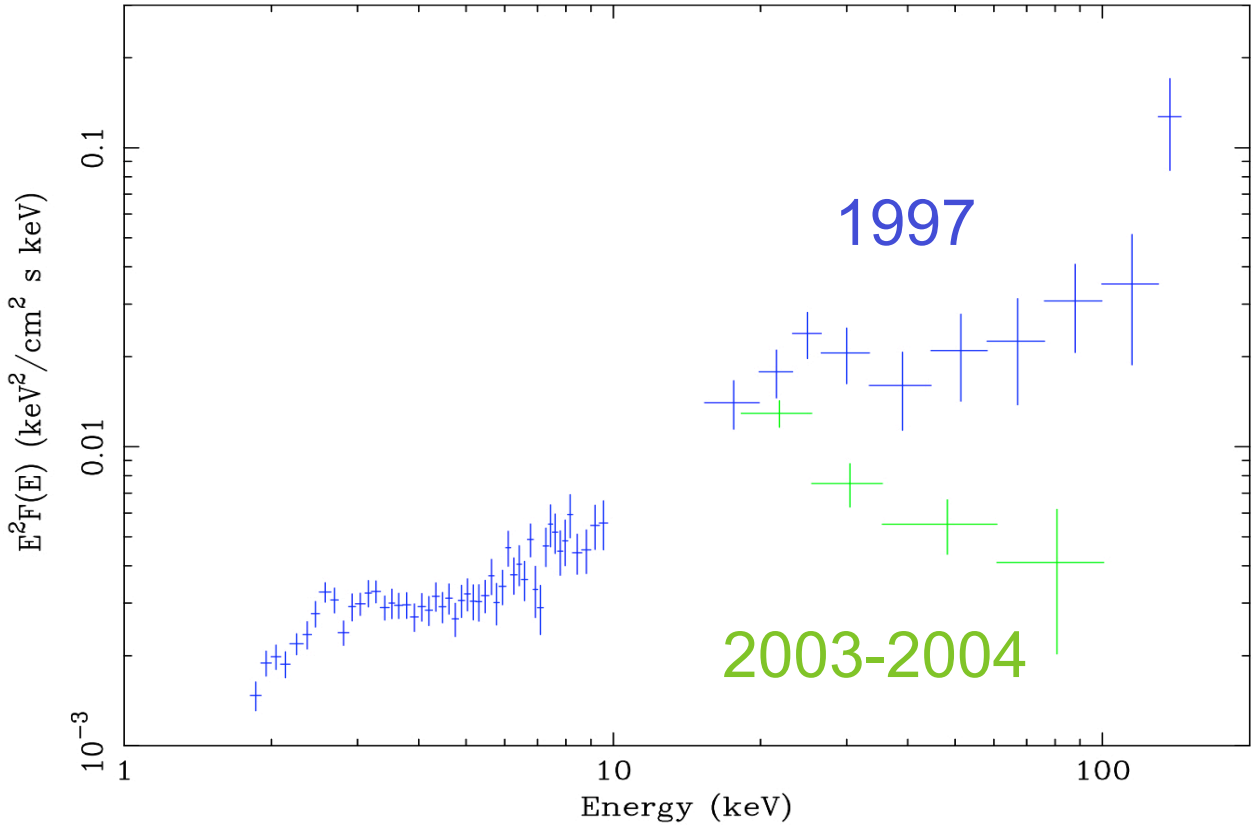
SGR 1806-20 spectral (in?)variability





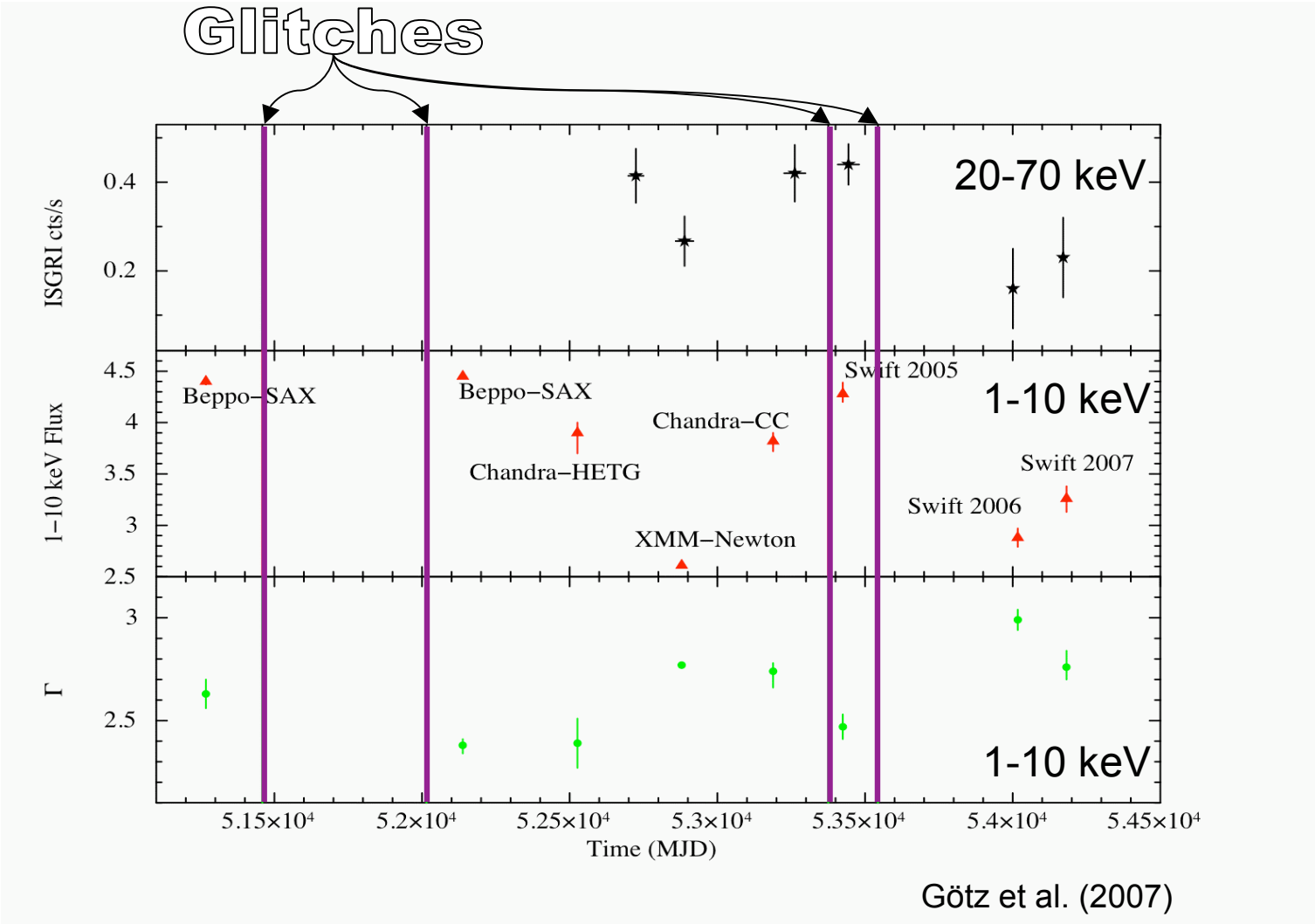
The power law indices are Γ=1.95±0.15 for observation 2 and Γ=1.96±0.10 for observation 4 (while the fluxes vary from (6.2±0.4) to (12.1±0.5)x10^{-11} erg cm^{-2} s^{-1}).

Very long term variability: SGR 1900+14



Esposito et al. 2006 using SAX and INTEGRAL/IBIS data

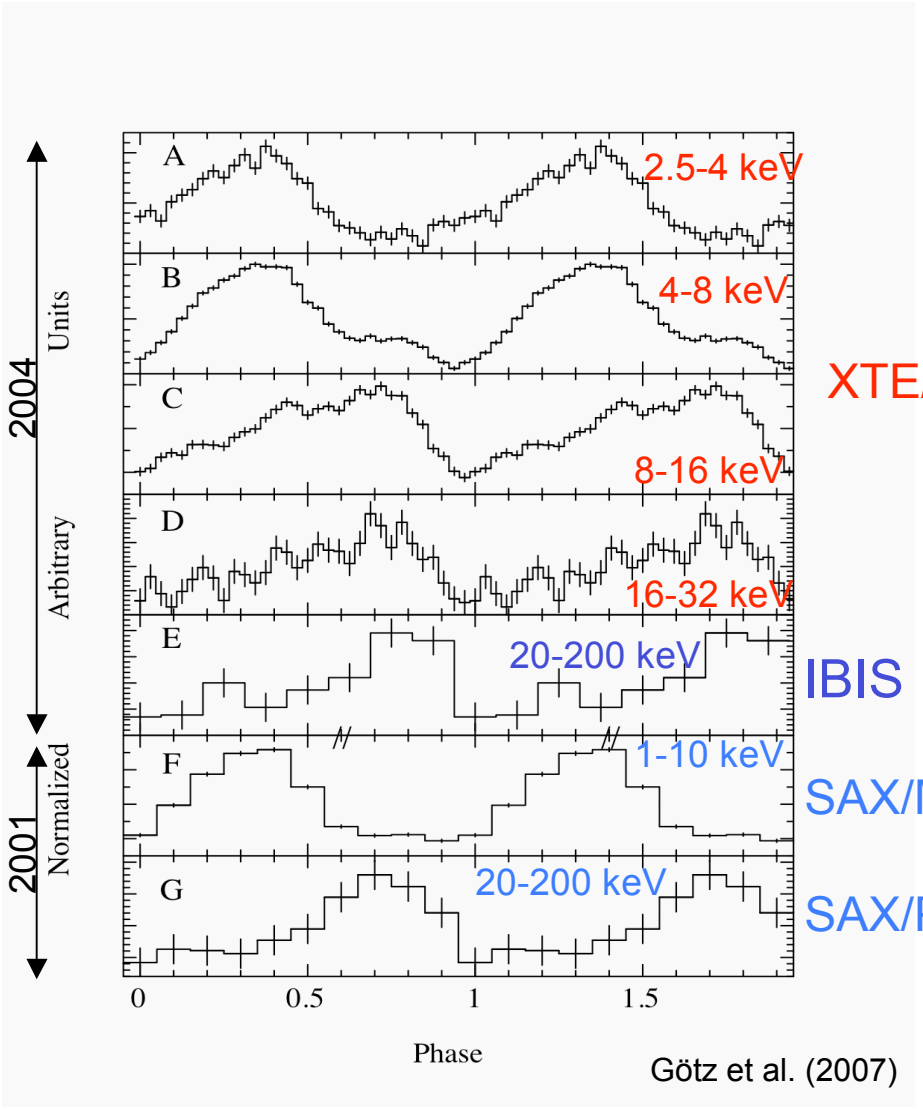
AXP 1708 long term spectral monitoring



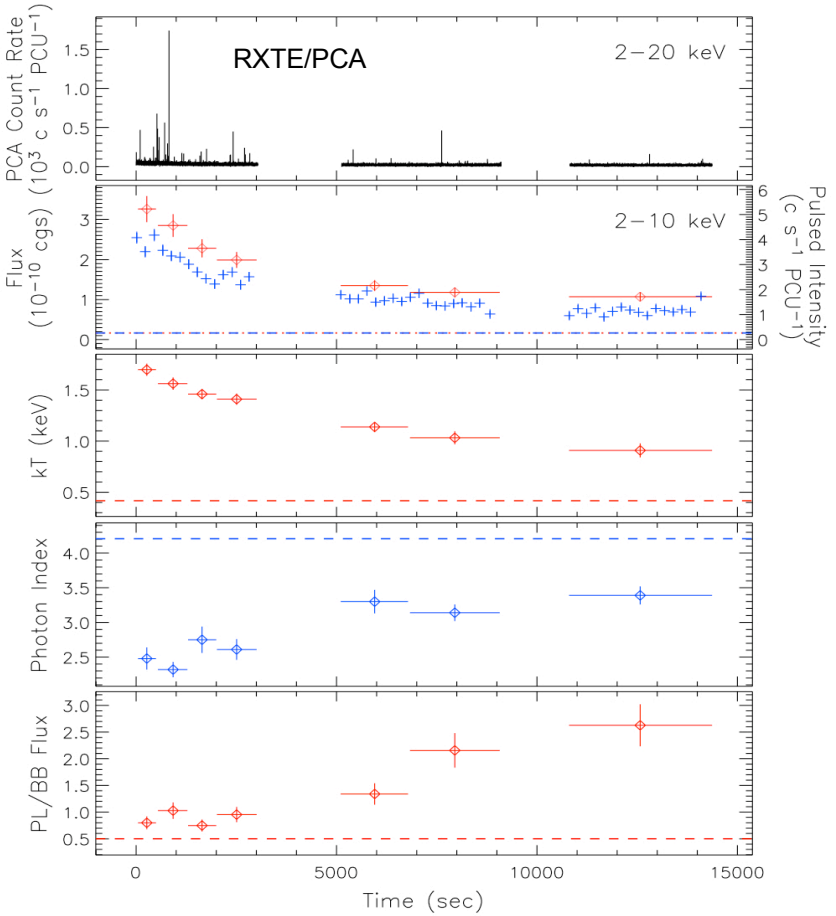
Götz et al. (2007)

No significant spectral changes at hard X-ray detected with IBIS

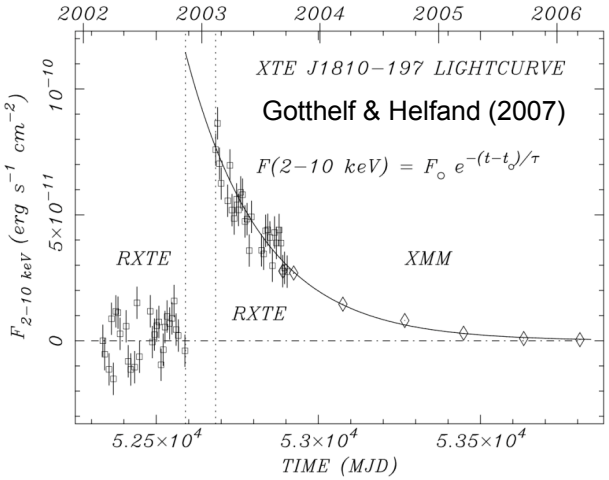
AXP 1708 timing/phase shift



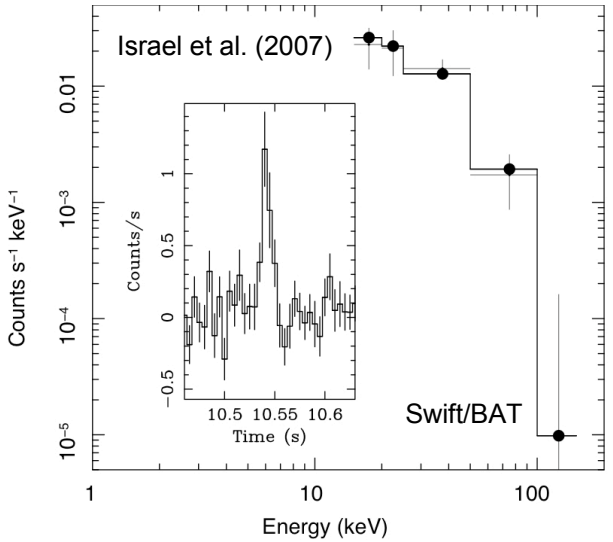
Transient Phenomena in AXPs



1E 2259 Kaspi et al. (2003)

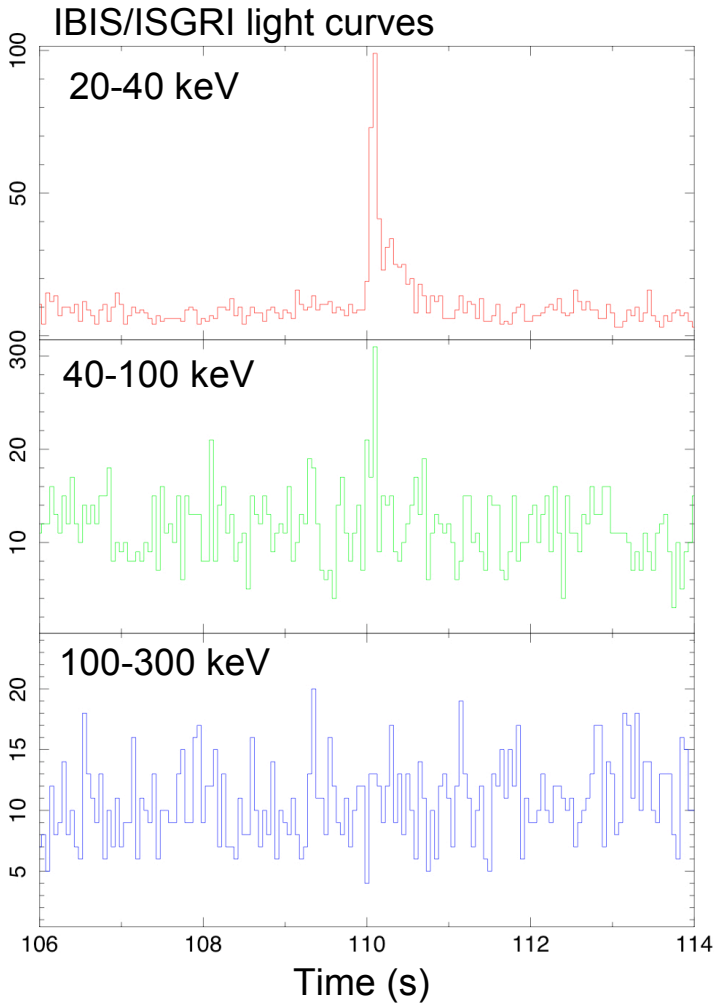


XTE 1810



AXP in Wes 1

071017 the INTEGRAL Anniversary Burst

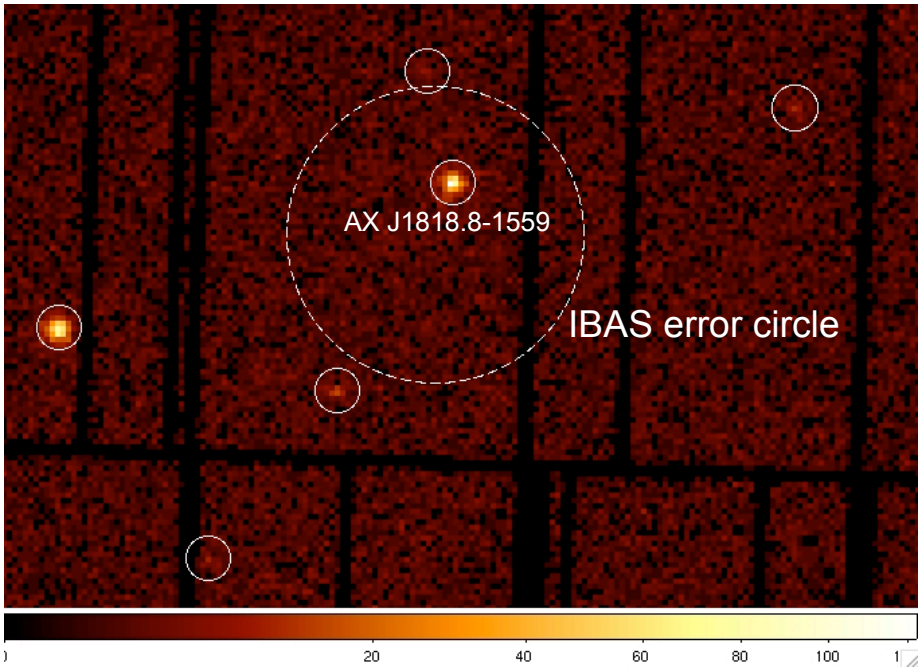


- Detected automatically by IBAS at 2007-10-17 at 00:58:10 UT (GCN 6927)
- Duration < 1s, main peak lasting 300 ms
- 20-100 keV flux 10^{-7} erg cm^{-2} s^{-1}

BUT….

- Soft SGR-like spectrum, detected up to ~100 keV, <u>but short GRBs are usually very hard</u>
- The spectral parameters are very similar to the ones measured by BAT from Wes 1
- Right in the Galactic Plane *b*=-0.25
- In the error box AX J1818.8-1559, a faint ASCA source

Anniversary Burst Follow up - A new AXP/SGR?



XMM/pn archival data

8 ks, taken on March 28 2003 (Atel 1243)

Only AX J1818 in the IBIS error box

BUT….

The spectrum of this source, obtained with the EPIC pn camera is well fit by an absorbed power law with photon index 1.1 ± 0.3, N_H = (3 ± 1) x 10^{22} cm^{-2}, and absorbed flux 1.4 x 10^{-12} erg cm^{-2} s^{-1} (2-10 keV). Too hard for and AXP/SGR!
An intriguing source!

Bad news: XMM cannot observe the field until March 2008, INTEGRAL will not be on the field before Oct 26th.
Good news: Swift XRT observes it today (now). Chandra and XTE TOOs requested (PI P.Woods)

Conclusions

dapnia SAp
cea
saclay

• As proposed by Thompson et al. (2002) an increase in the source activity (bursts, glitches, flux) and a simultaneous spectral hardening may be caused by a growing twist angle in the magnetosphere. If this is the case the data presented here support models in which also the hard tails are produced by mechanisms whose strength increases with the twist angle. Indeed the the hard X-ray components may even dominate and drive those detected at lower energies.

  – Only simultaneous broad band observations will allow us to study and try to understand the nature of the long term variability of these sources (not feasible with the current instrumentation -> Simbol X)

• Study the otburst mechanisms of the transient AXPs by observing them in outburst and quiescence (2 orders of magnitude flux variations!)

  – XTE 1810 and CXO 1647 could not be well studied during their outburst with INTEGRAL, but only at energies below 10 keV. Nothing is known to date about these sources in the hard X-ray band. Are they softer than the persistent one.
  – What about AX J1818.8-1559/IGR J18188-1600? First results show no persistent emission in IBIS data, following the burst

Conclusions

dapnia SAp

cea

saclay

Thanks!