Magnetars in the Fermi Era

On behalf of the *Fermi*/GBM Magnetar Team

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Magnetars are magnetically powered neutron stars

- ~16 are discovered to date – two in the last year (2008-2009) – Only 2 extragalactic sources
- Discovered in X/γ-rays; radio, optical and IR observations: Short, soft repeated bursts
- $P = [2\text{-}11]$ s, $\dot{P} \sim [10^{-11} - 10^{-13}]$ s/s
- $\tau_{spindown}(P/2\dot{P}) = 2\text{-}220$ kyrs
- $B \sim [1\text{-}10] \times 10^{14}$ G (mean surface dipole field: $3.2 \times 10^{19} \sqrt{P\dot{P}}$)
- Bright sources, $L \sim 10^{33\text{-}36}$ erg/s , >> rotational E-loss
- No evidence for binarity so far (fallback disks?)
- SNe associations?

Neutron star populations which may comprise Magnetars:

Soft Gamma Repeaters (SGRs)

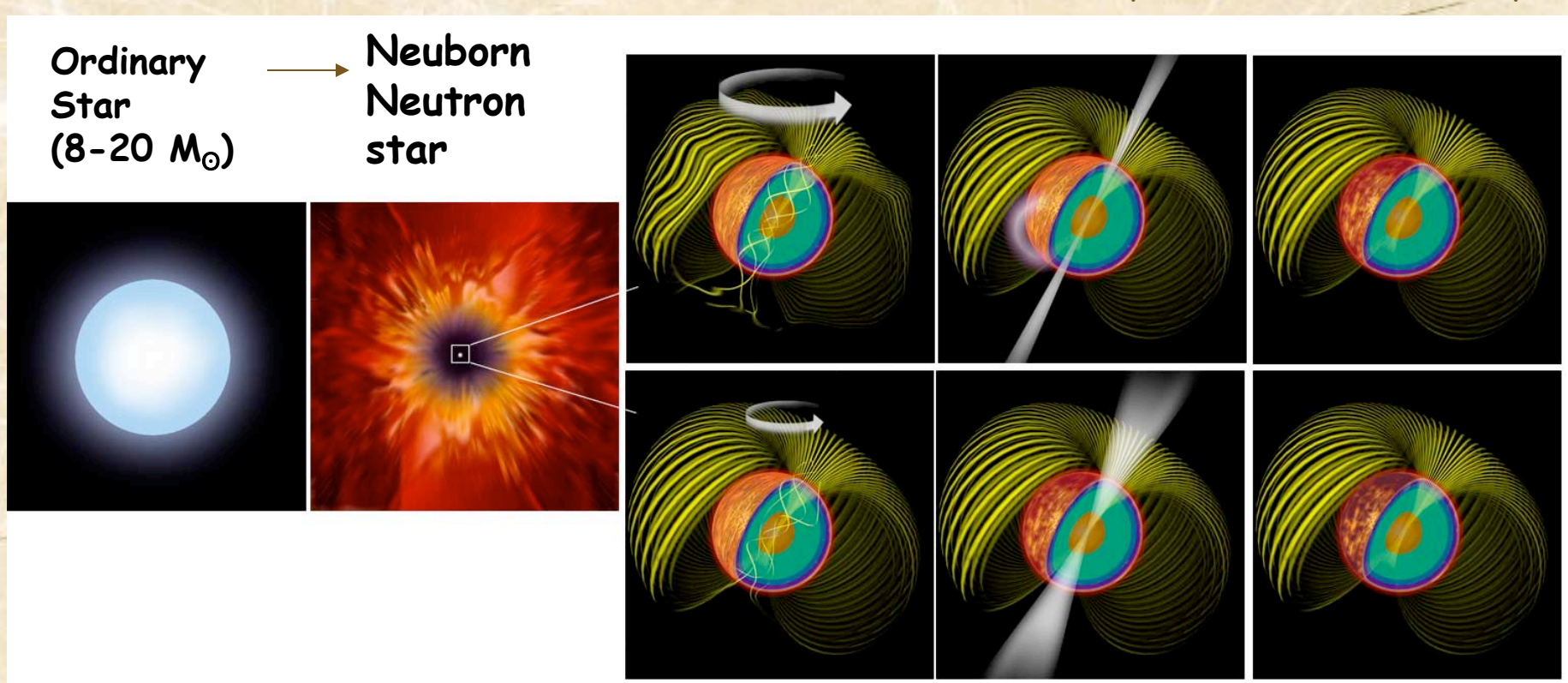
Anomalous X-ray Pulsars (AXPs)

Dim Isolated Neutron Stars (DINs)

Compact Central X-ray Objects (CCOs)

MAGNETARS

AGE: 0-10 s 0-10,000 years above 10,000 years

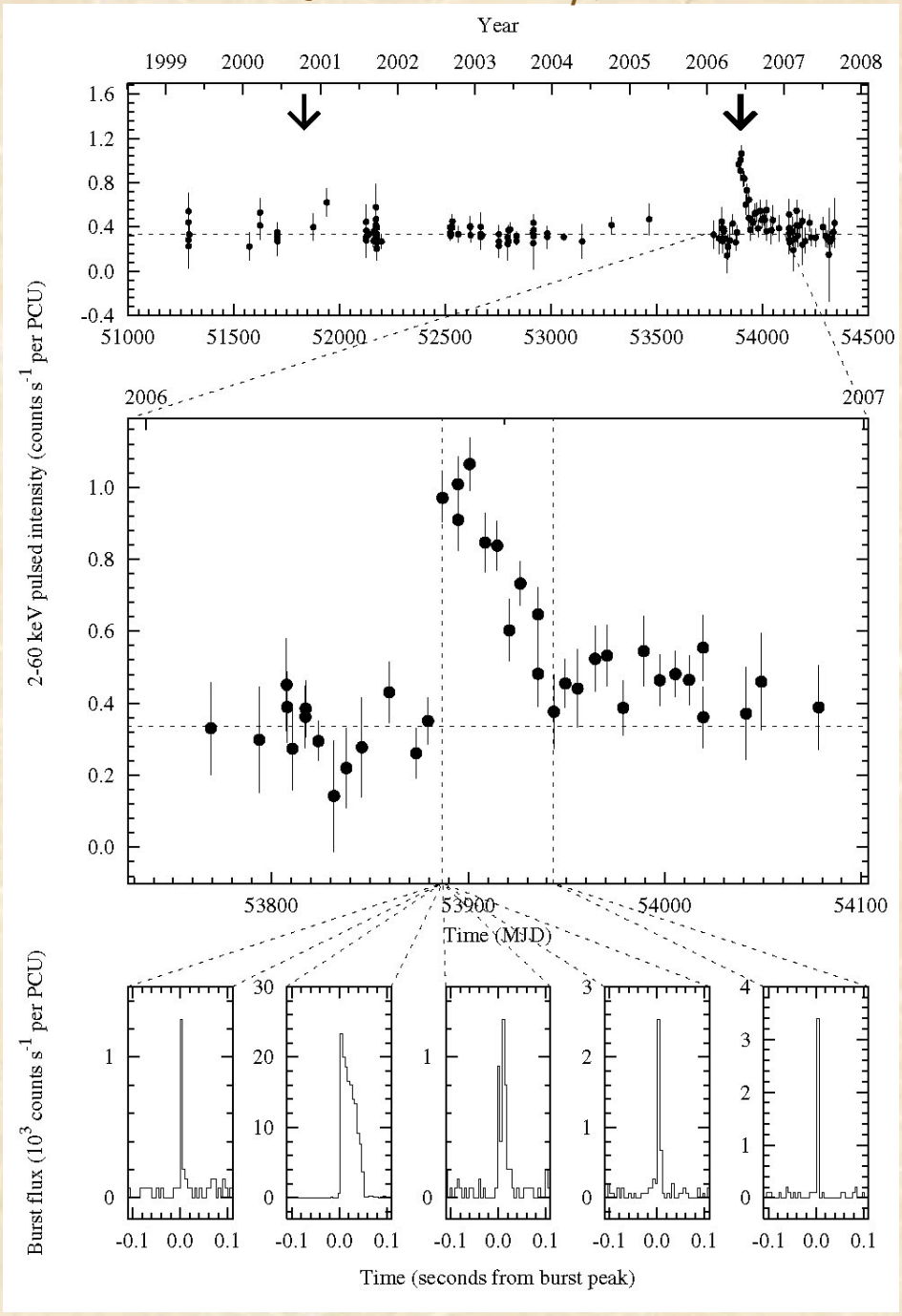


AGE: 0-10 s 0-10 million years above 10 million yrs

RADIO PULSARS

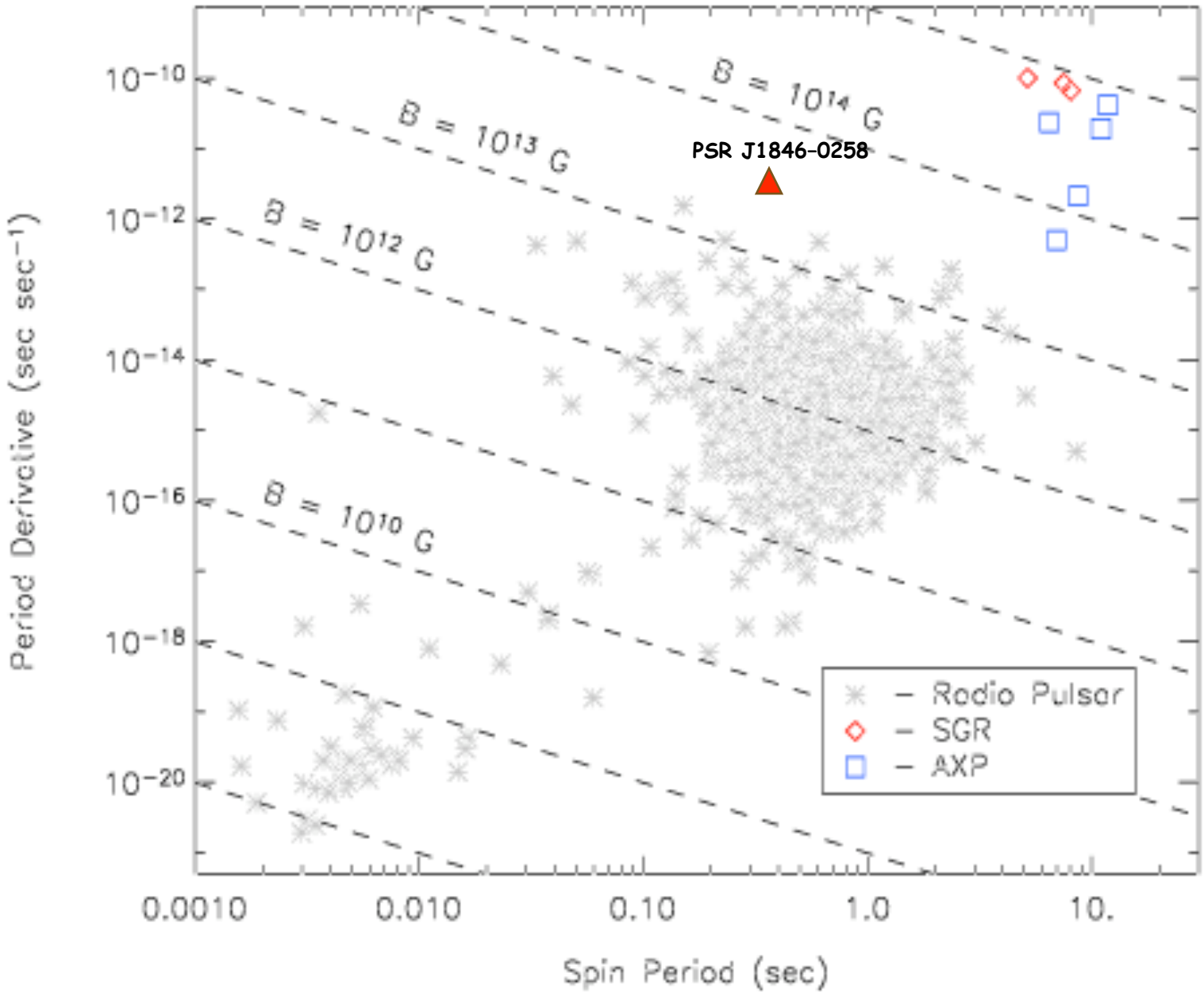
Kouveliotou, Duncan & Thompson, Scientific American

PSR J1846-0258/Kes 75

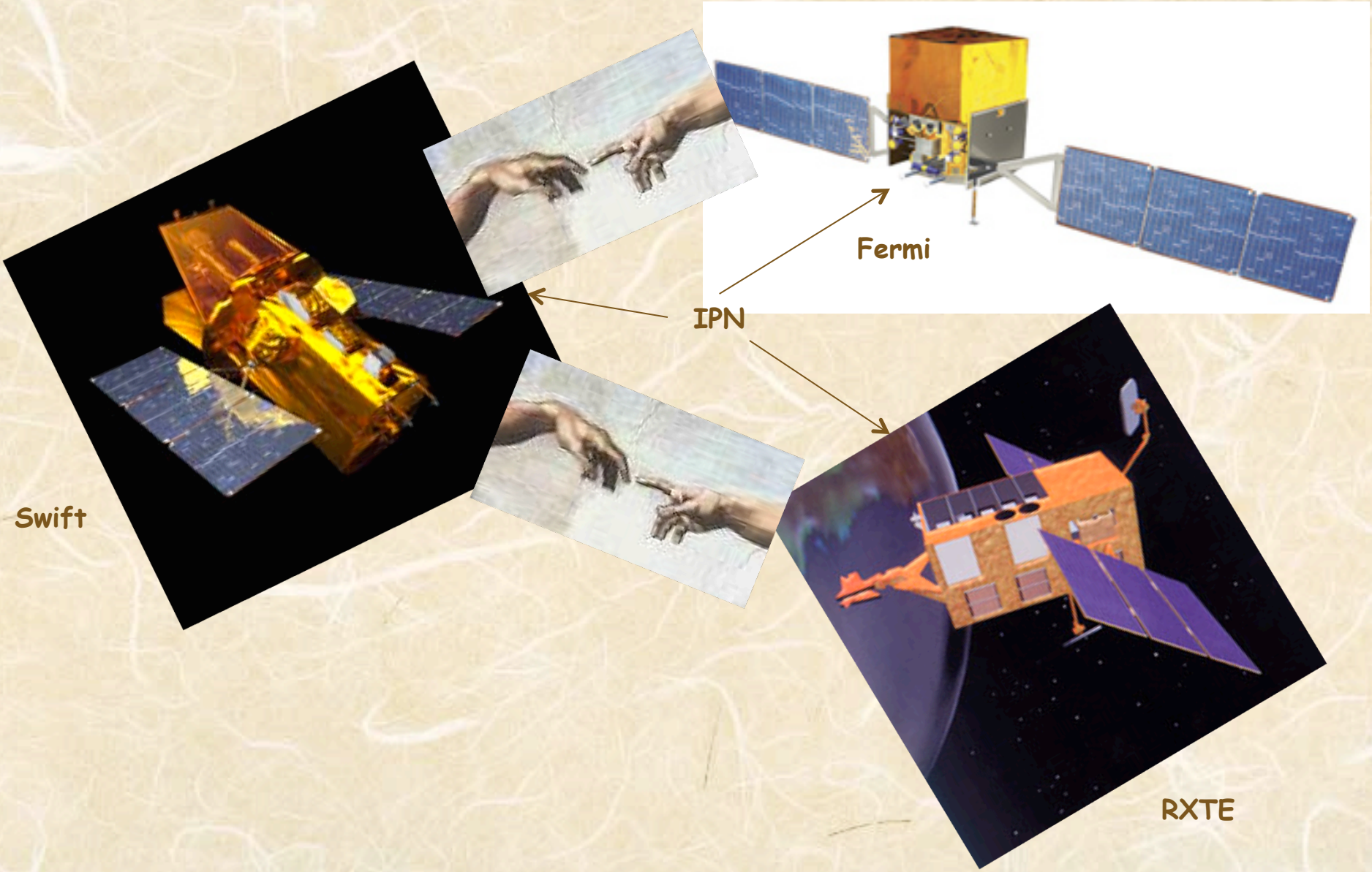


- Magnetar-like X-ray bursts were detected from the young pulsar PSR J1846-0258.
- Rotation-powered PSR with an inferred surface dipolar magnetic field of 4.9×10^{13} G, P_s=0.3 s, Age ~ 900 yrs
- Bursts accompanied by a sudden flux increase ($200L_x$) and unprecedented change in timing behavior (spin up->spin down).
- Is there a continuum of magnetic activity that increases with inferred magnetic field strength?

Gavriil et al 2008


B = 10^14 G
B = 10^13 G
B = 10^12 G
B = 10^10 G
PSR J1846-0258
10^-10
10^-12
10^-14
10^-16
10^-18
10^-20
Period Derivative (sec sec^-1)
0.0010
0.010
0.10
1.0
10.
Spin Period (sec)
– Radio Pulsar
– SGR
– AXP

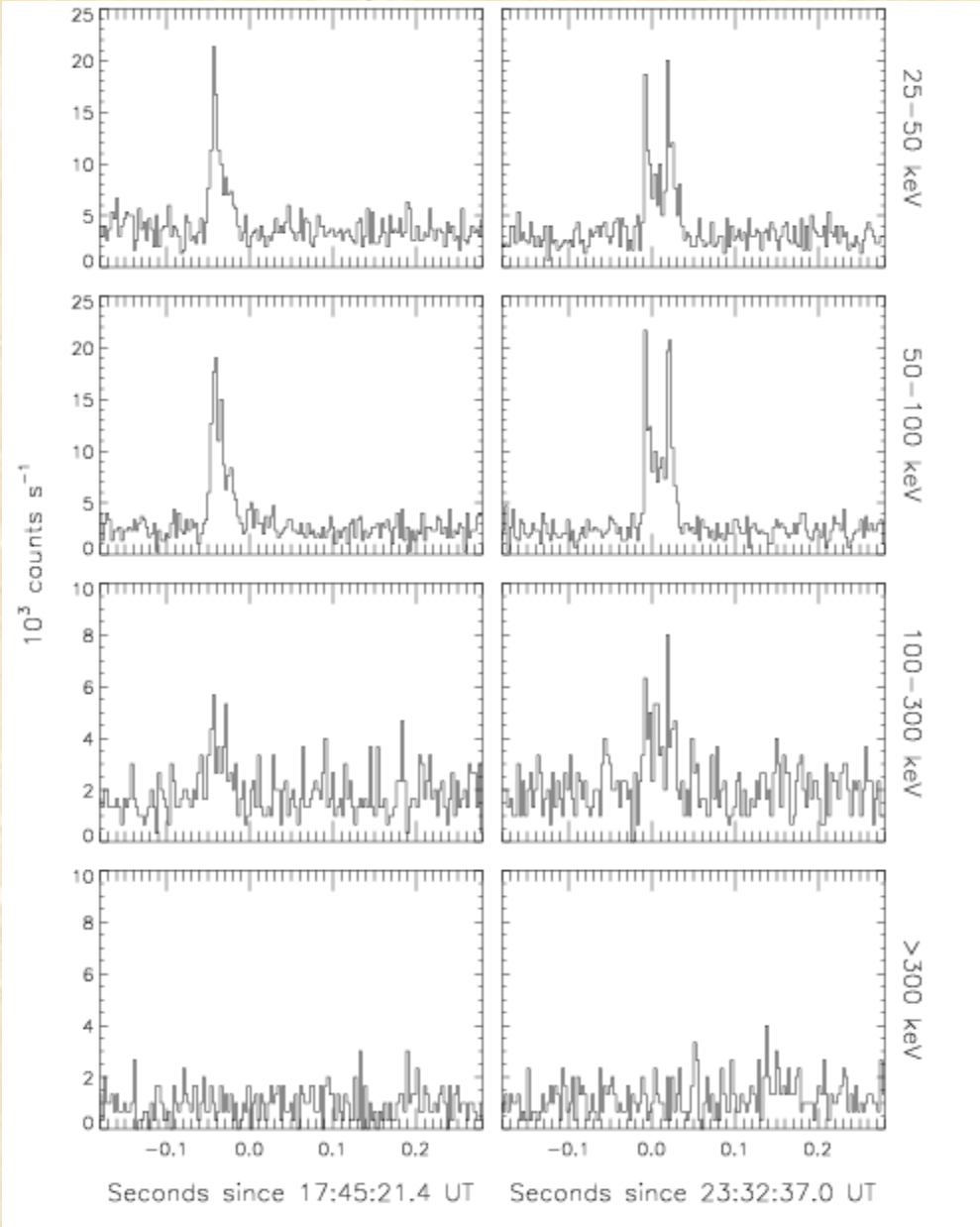
2008-2009: A good year for Magnetars!



SGR 0501+4516

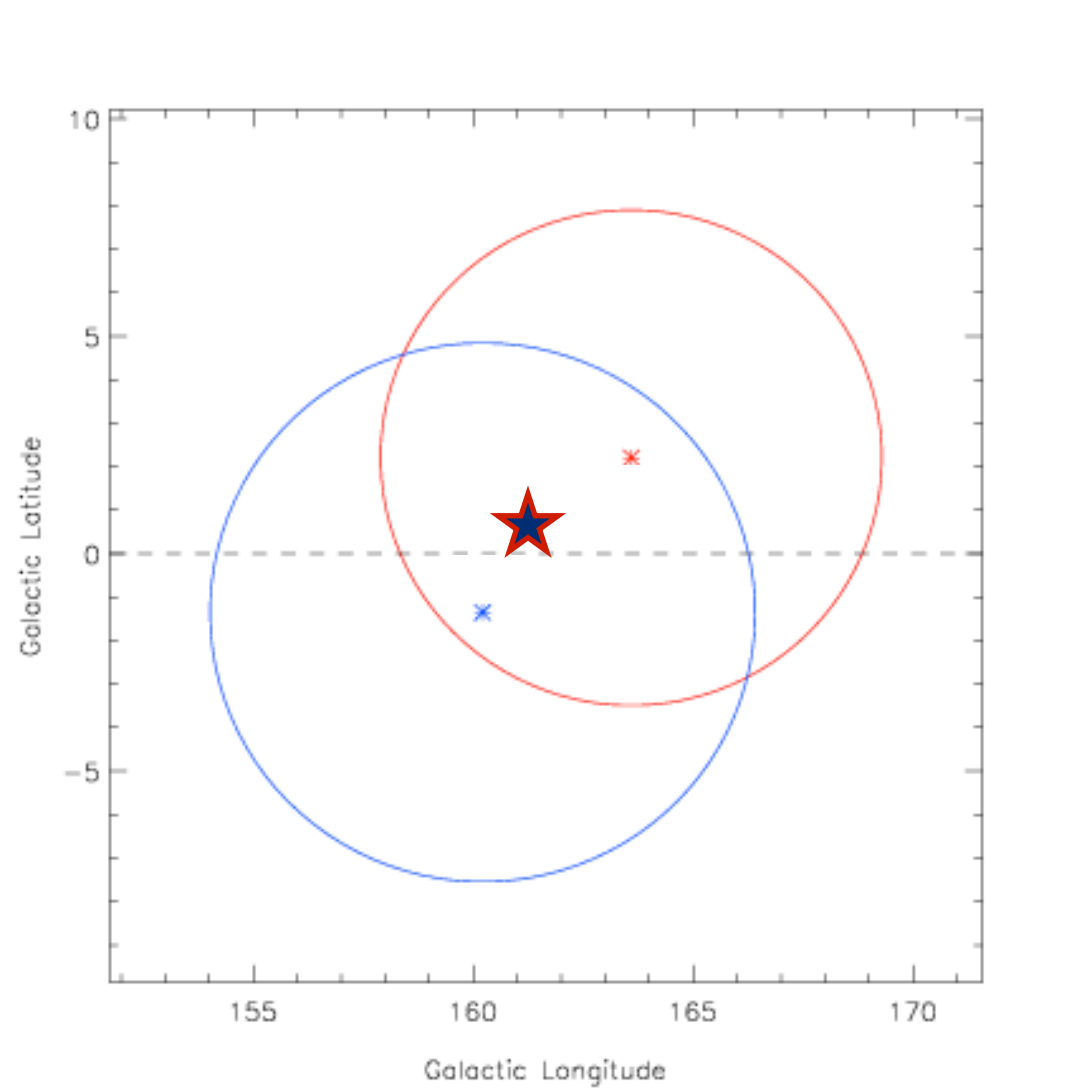
- Swift triggered on 4 bursts on 22 August 2008
- RXTE ToO program triggered ~4 hours after the first Swift trigger for 600 s
- P = 5.769s ± 0.004 s was reported ~ 9 hours after the first Swift trigger!
- $\dot{P} = 1.5 \times 10^{-11}$ s/s and B = 3×10^{14} G
- CXO HRC location: RA = 05h 01m 06.756s DEC = +45d 16m 33.92s (0.1" error)
- IR Counterpart with UKIRT, K~18.6 (Tanvir & Varricatt 2008)
- GBM triggered on 26 events from the source – total of 56 events in ~ 3.5 days

1st Outburst of SGR 0501+4516 in July 1993!

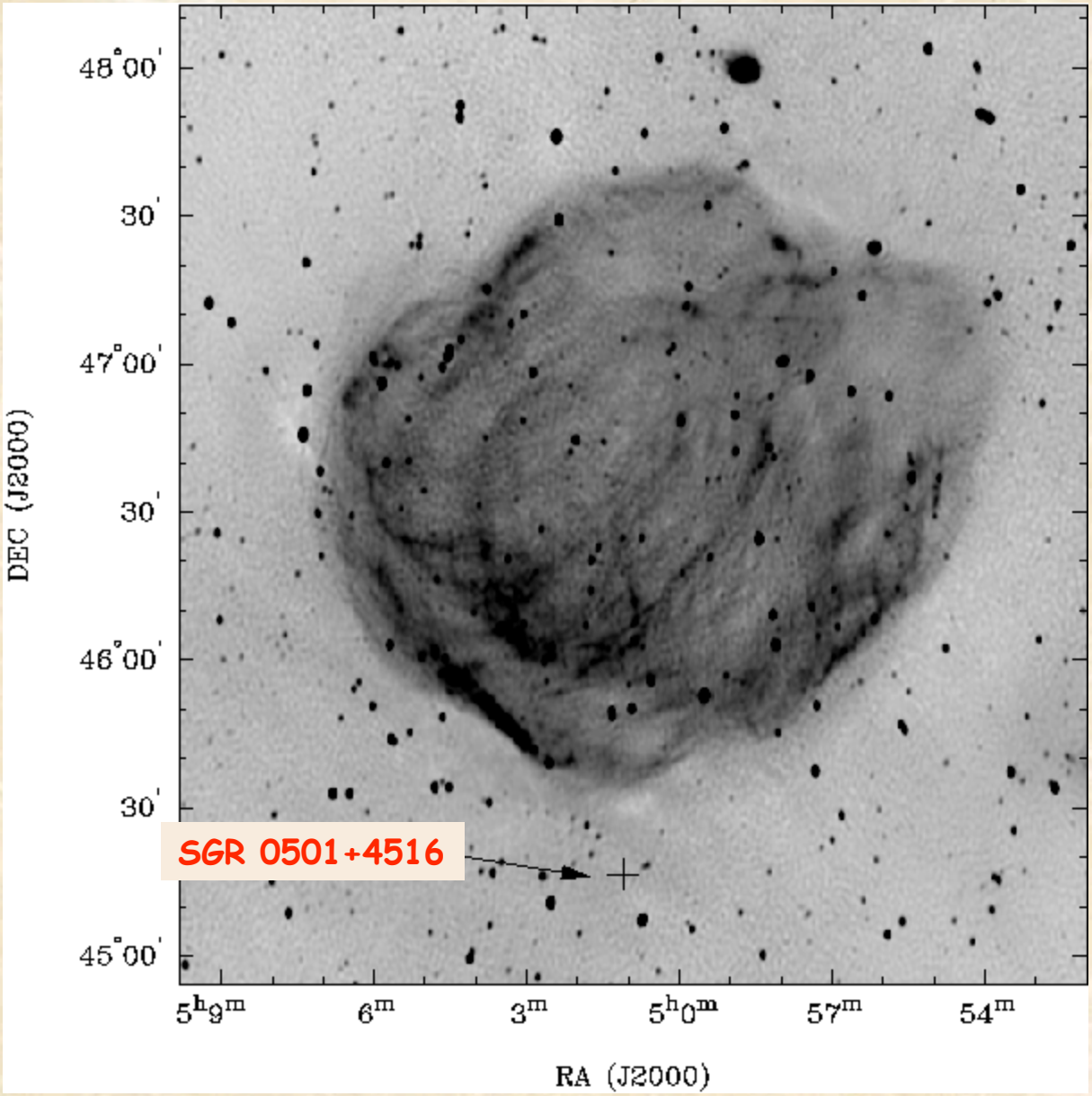


CGRO/BATSE

1st Outburst of SGR 0501+4516

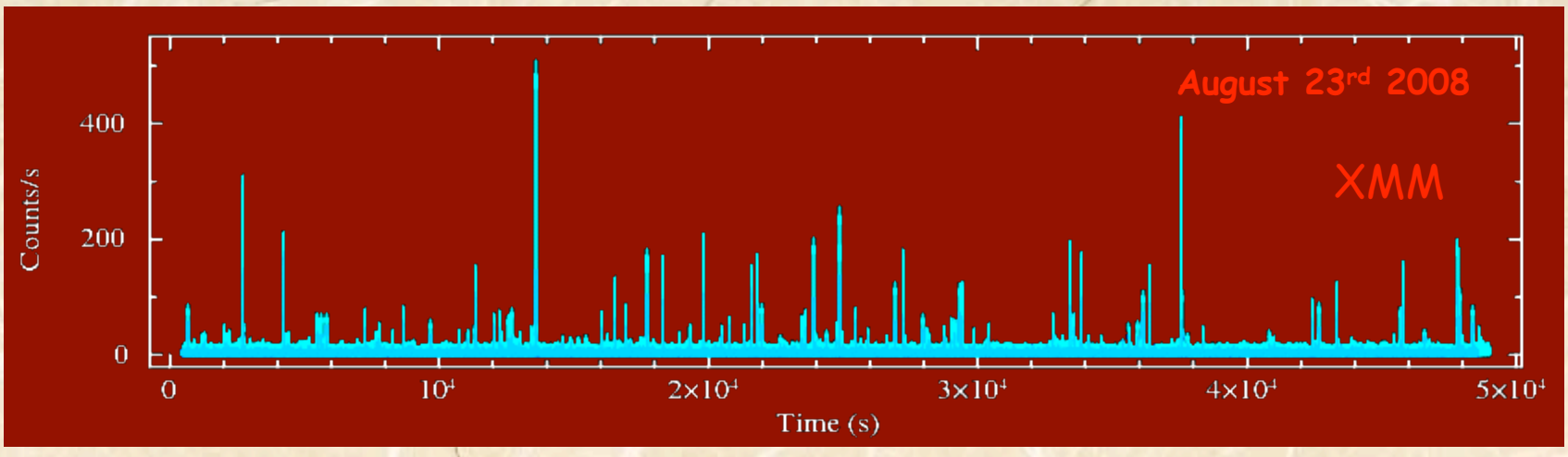


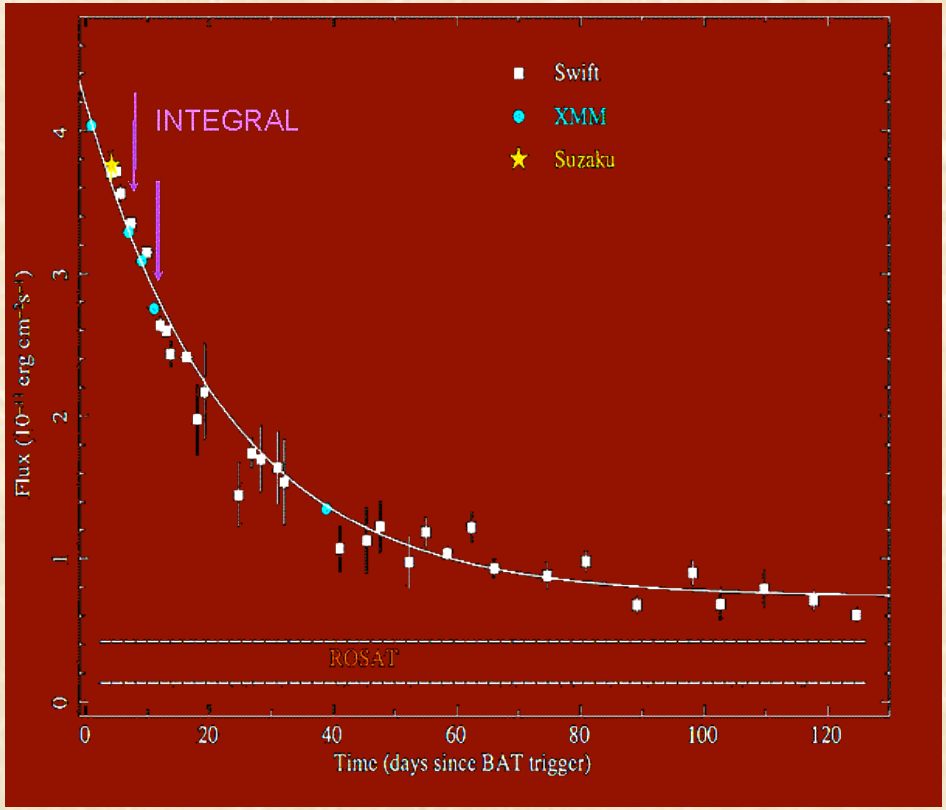
SNR HB9/G160.9+2.6 (1.4 GHz)



Angular separation from the SNR center ~80 arcmin => projected space velocity = 1700km/s (for a distance to the SNR of 1.5 kpc and an age of 8000 years; Leahy & Aschenbach, 1995)

Gaensler & Chatterjee 2008





Flux decay with time:

$F(t)=0.66+3.52\times10^{-11}\ \exp-(t/23.81)$

Pure exponential for the first 160 days

5 XMM-Newton observations

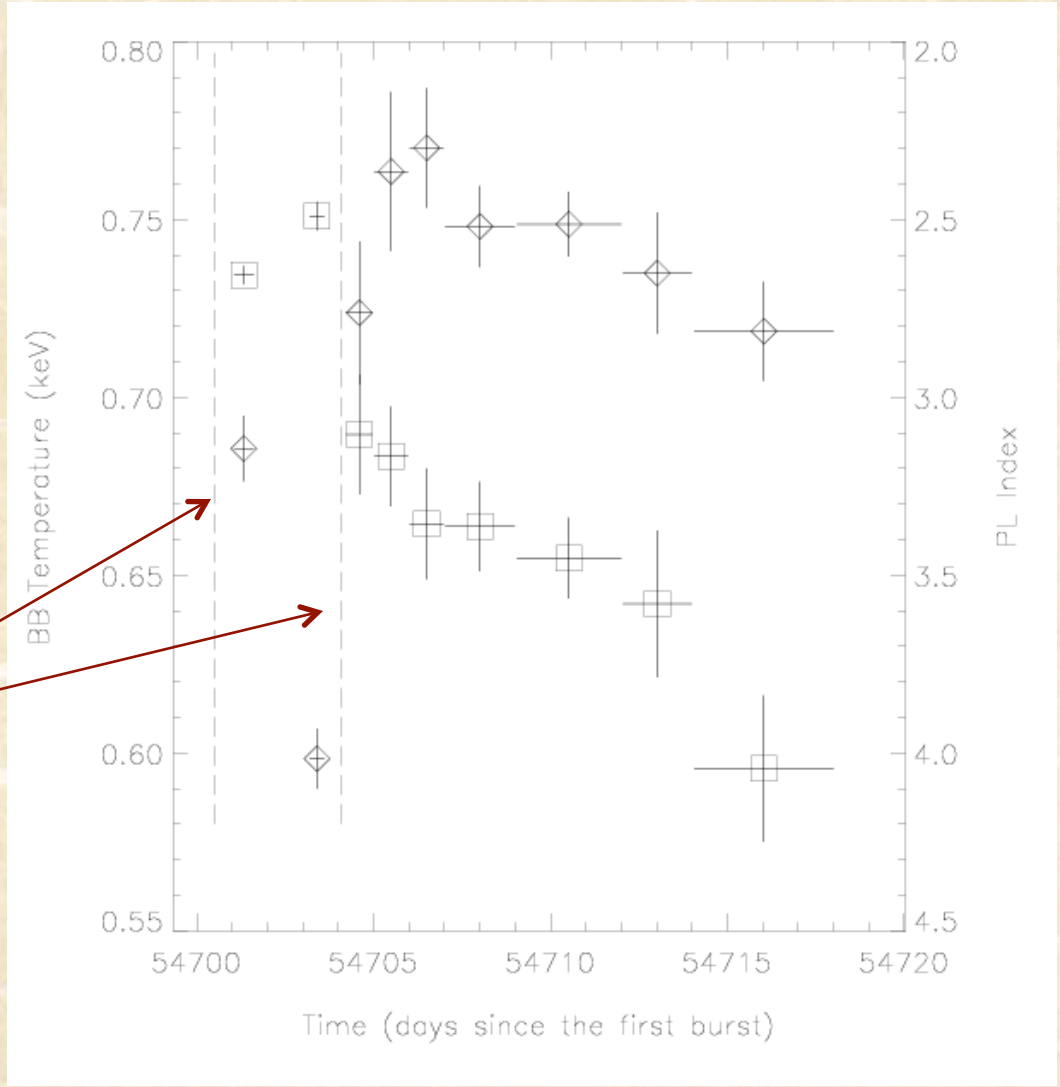
~40 Swift observations

1 Suzaku observation

2 INTEGRAL observations

Rea et al. 2009

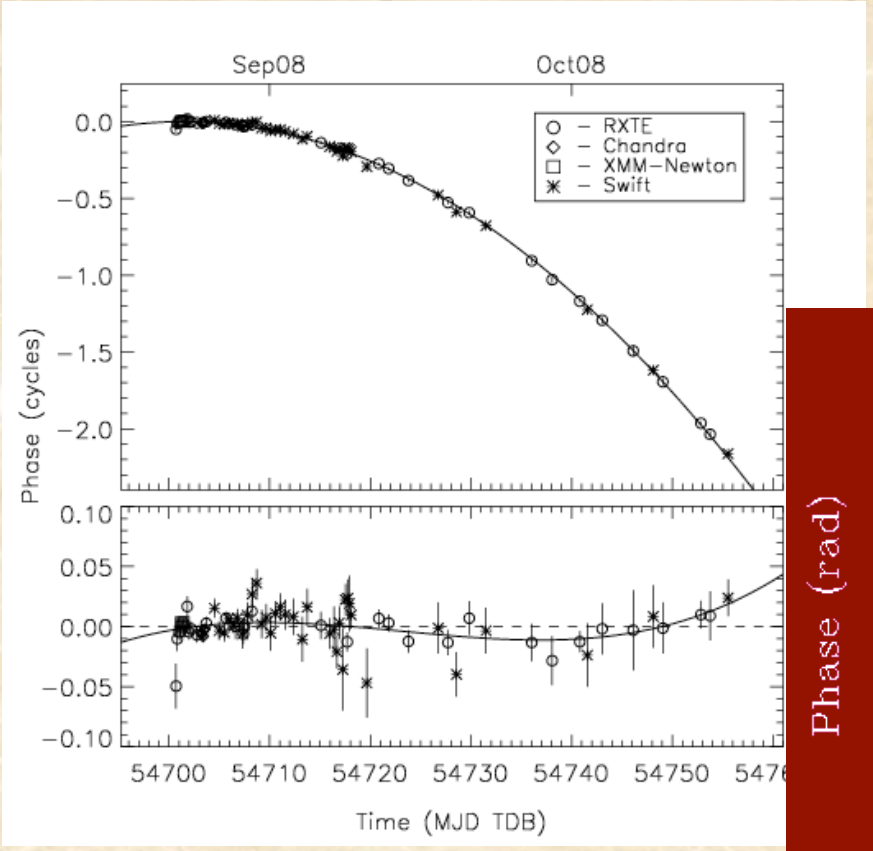
Persistent Emission: Rapid Spectral Variations



87 hours of bursting activity

Source cools while bursting?

Gogus et al. 2010

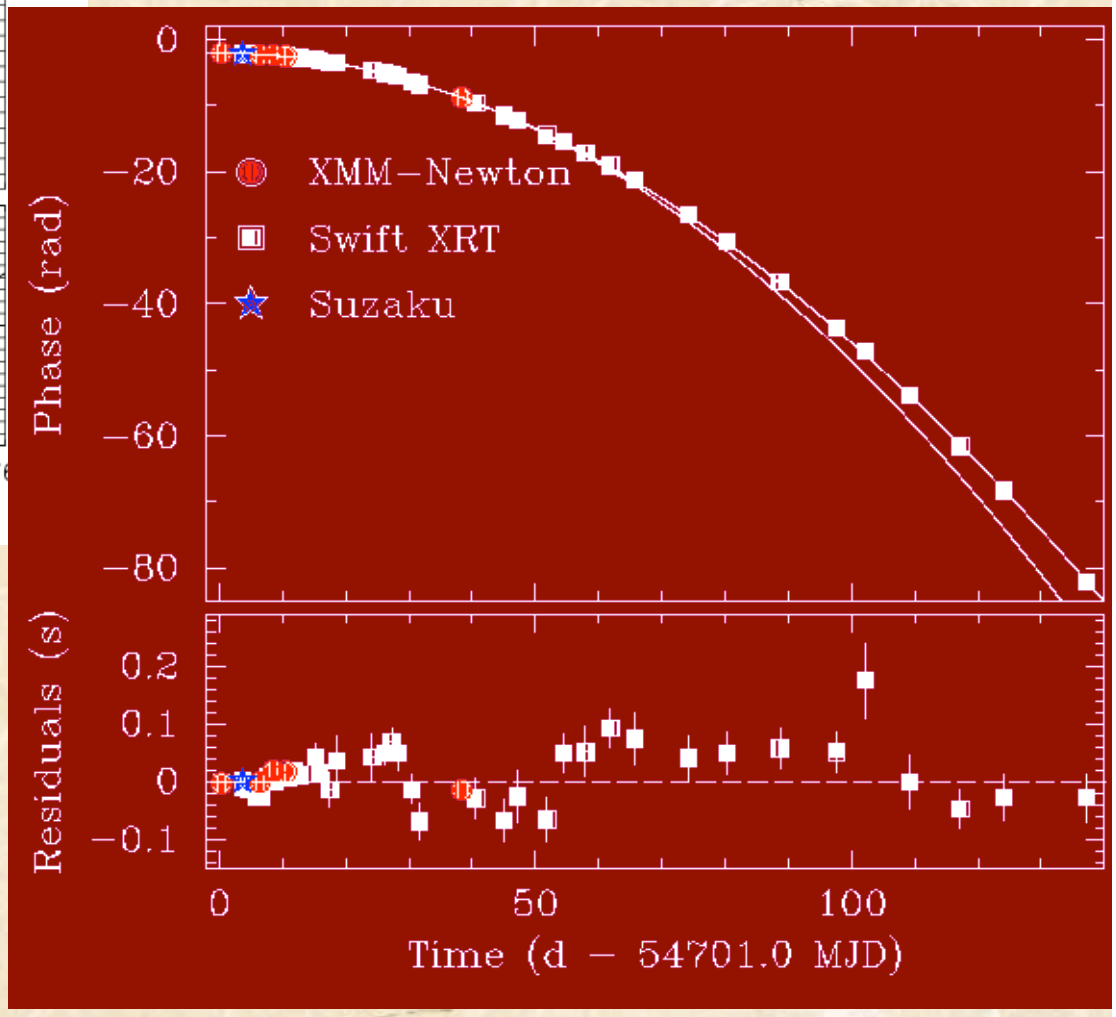


$P = 5.7620689446 +/- 1.66\times10^{-07}$ s

$\dot{P} = 7.4980\times10^{-12} +/- 2.51\times10^{-13}$ s/s

B field = 2.1×10^{14} G

Gogus et al 2010



$P = 5.7620690(1)$ s

$\dot{P} = 6.77(8) \times 10^{-12}$ s s^{-1}

$\ddot{P} = 1.9(4) \times 10^{-19}$ s s^{-2} → decreasing spin-down

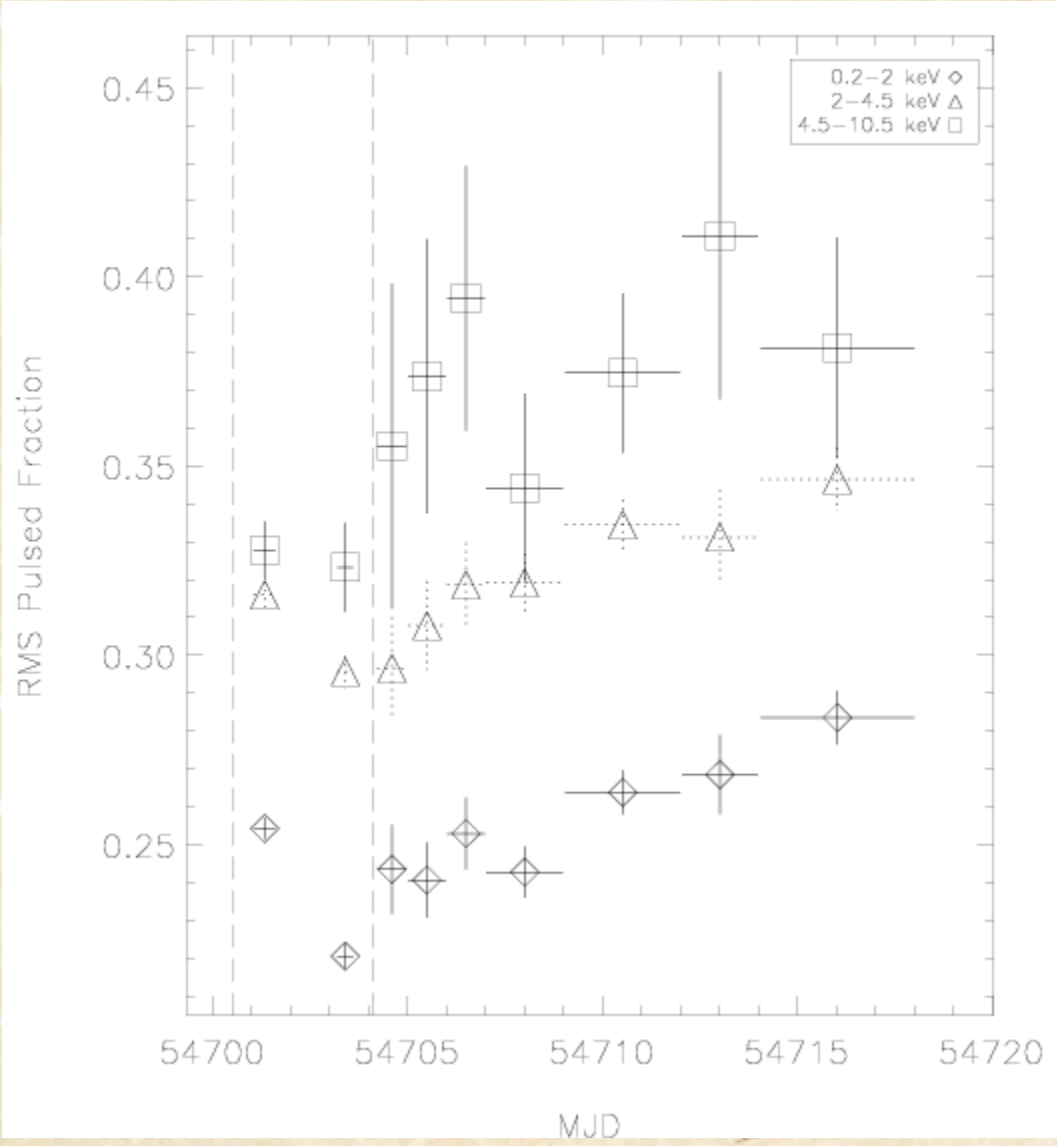
Consistent with a post-glitch

(not observed!) recovery time

of ~1yr

Rea et al. 2009

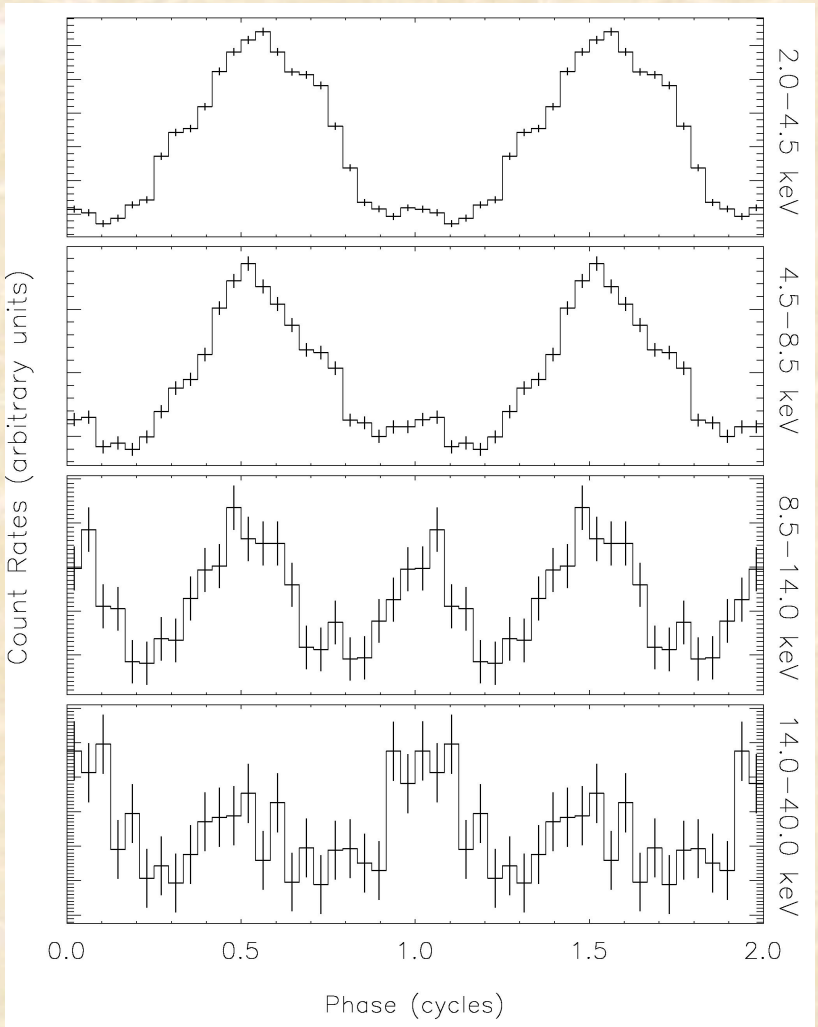
Pulsed Emission: Pulsed Fraction Variations

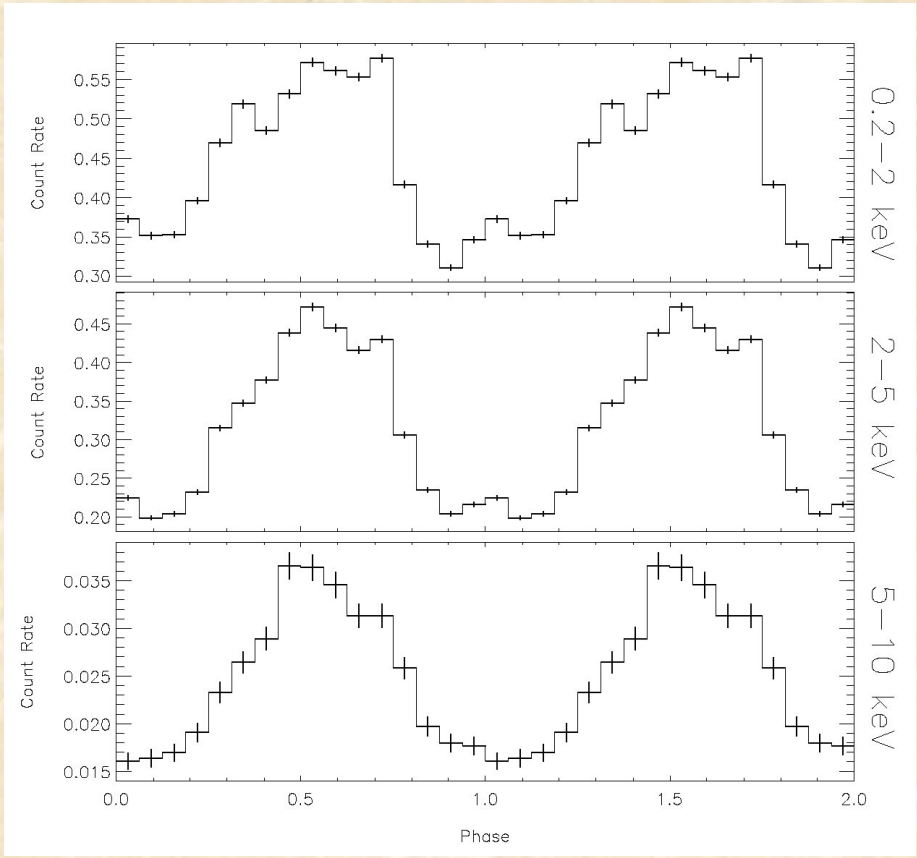


Gogus et al. 2010

SGR 0501+4516: Evolution of pulse profile with energy

RXTE/PCA
~40 days average

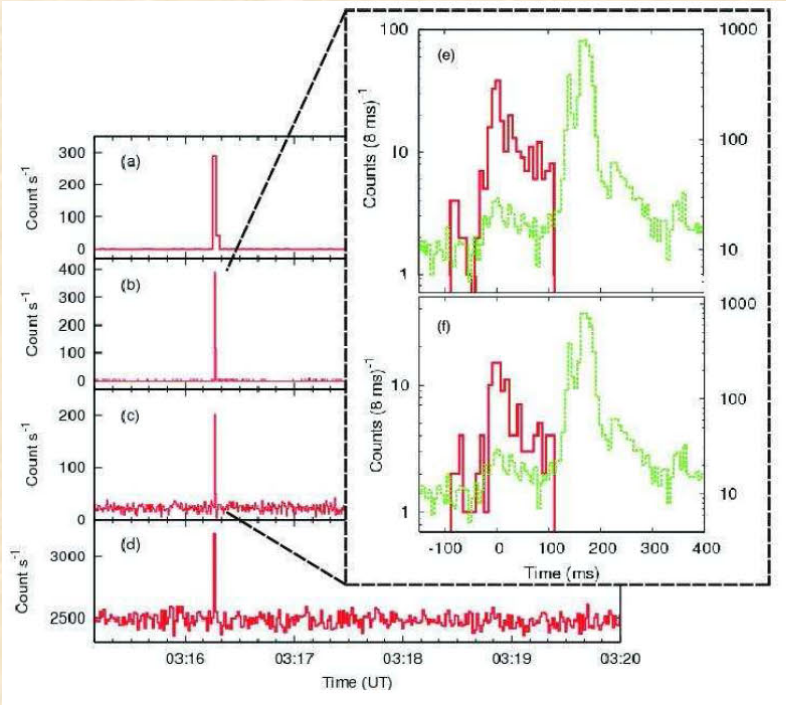


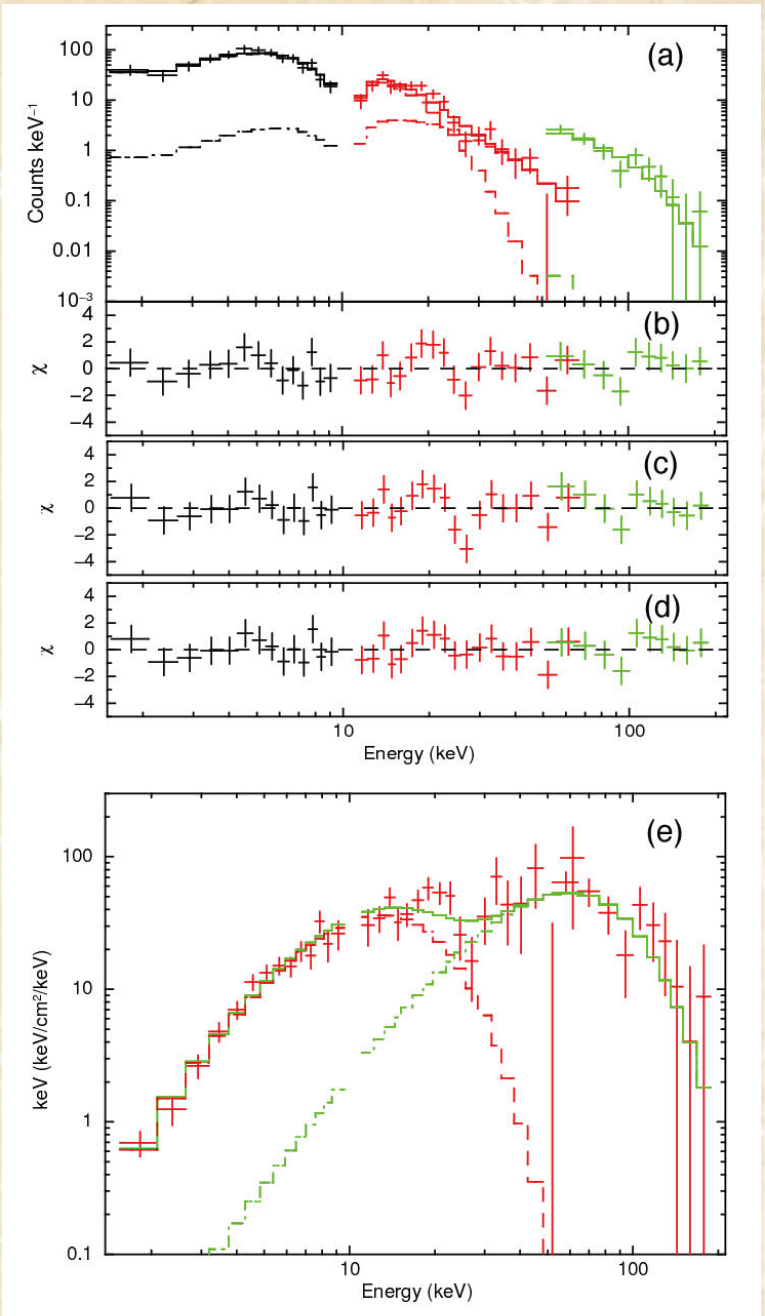


Swift/XRT

Gogus et al 2010

BURSTS



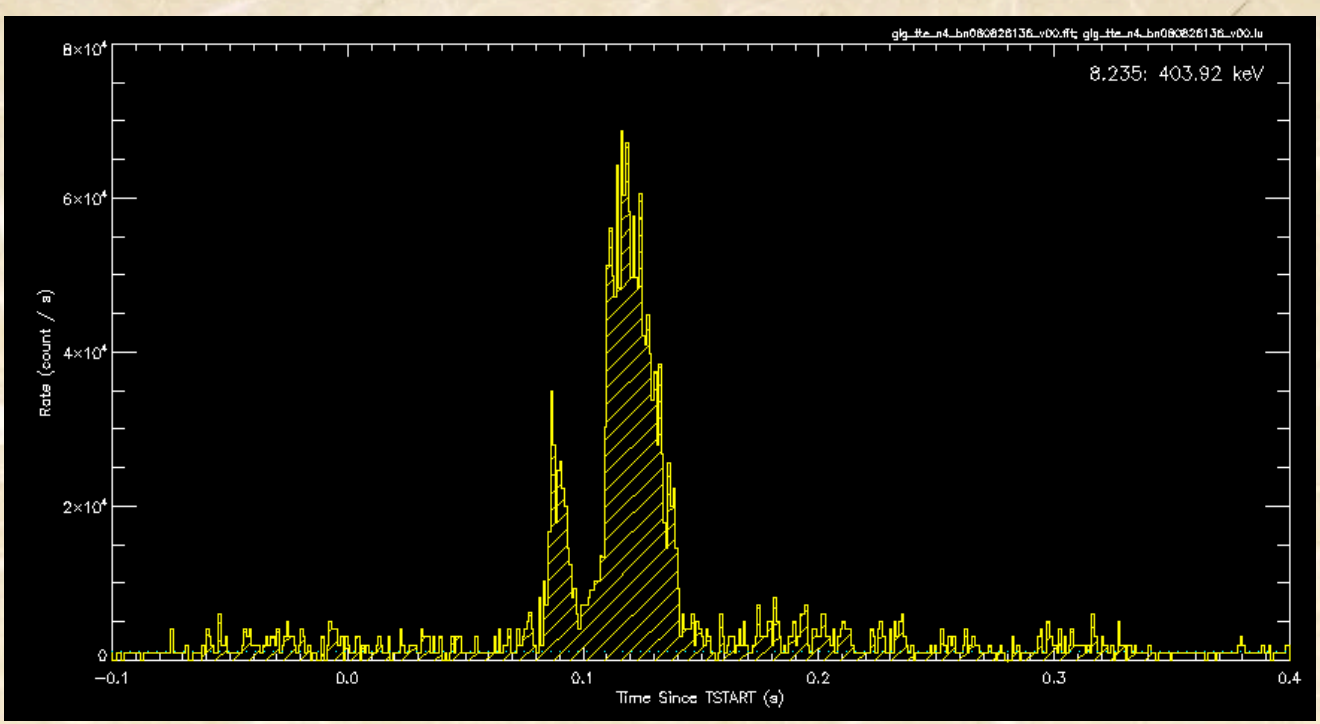


Suzaku data for 080826_136:

Integrated spectrum best fit by 2 BB:

kT1 = 3.3 keV, kT2 = 15.1 keV

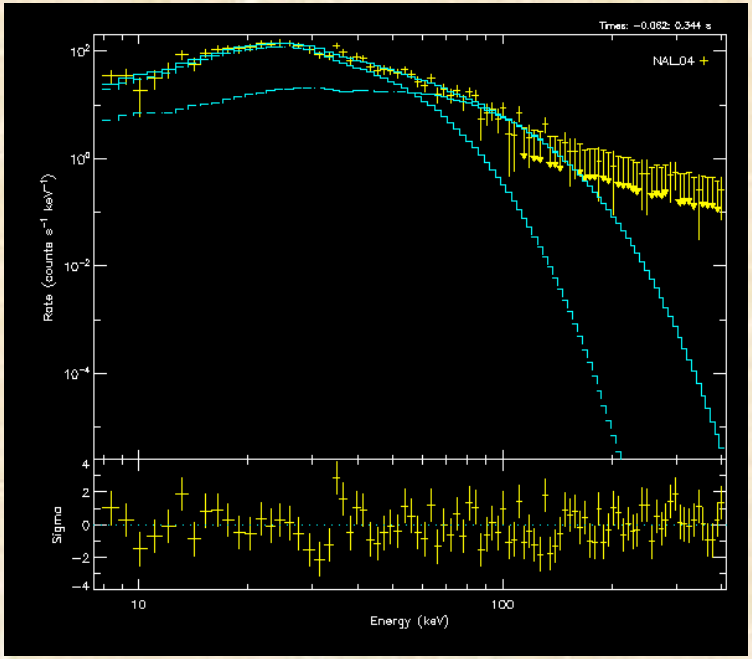
Enoto et al. 2009

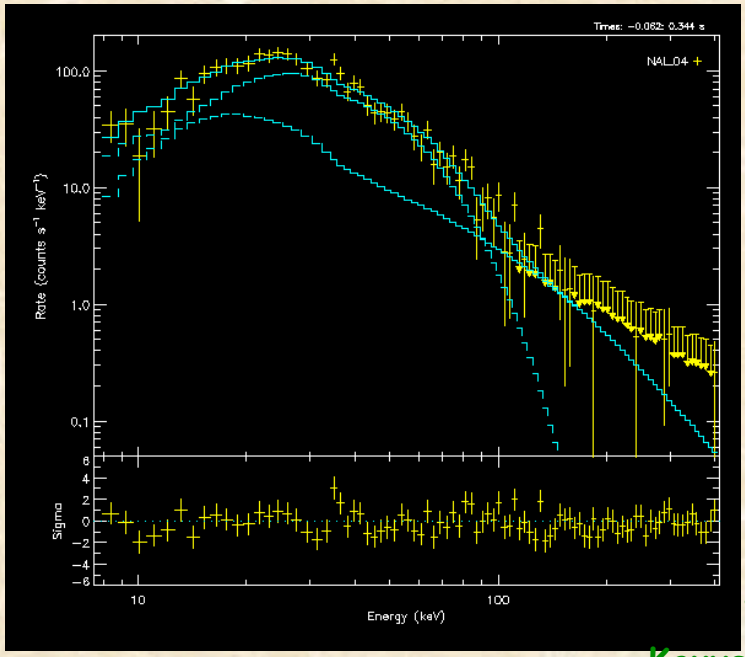


GBM data for 080826_136 (common with Suzaku):

Integrated spectrum can be fitted with two BB or one BB + PL

kT_1 = 8 keV, kT_2 = 18 keV or
kT = 11 keV, γ = -2.4



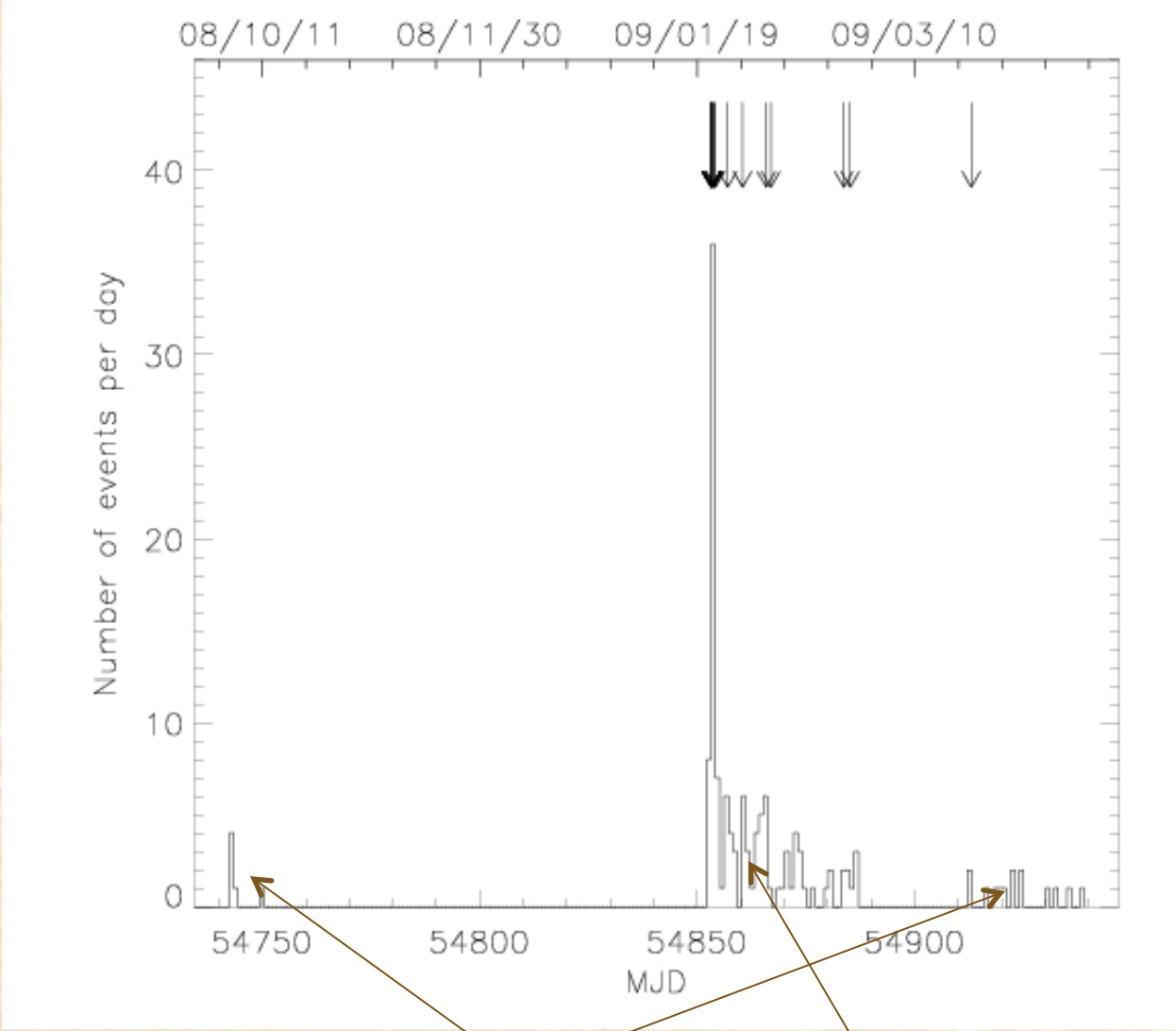


Watts et al. 2010
Kouveliotou et al. 2010

SGR 1550-5418
formerly known as AXP 1E1547.0-5408
formerly known as an ASCA CCO in G327.0-0.13

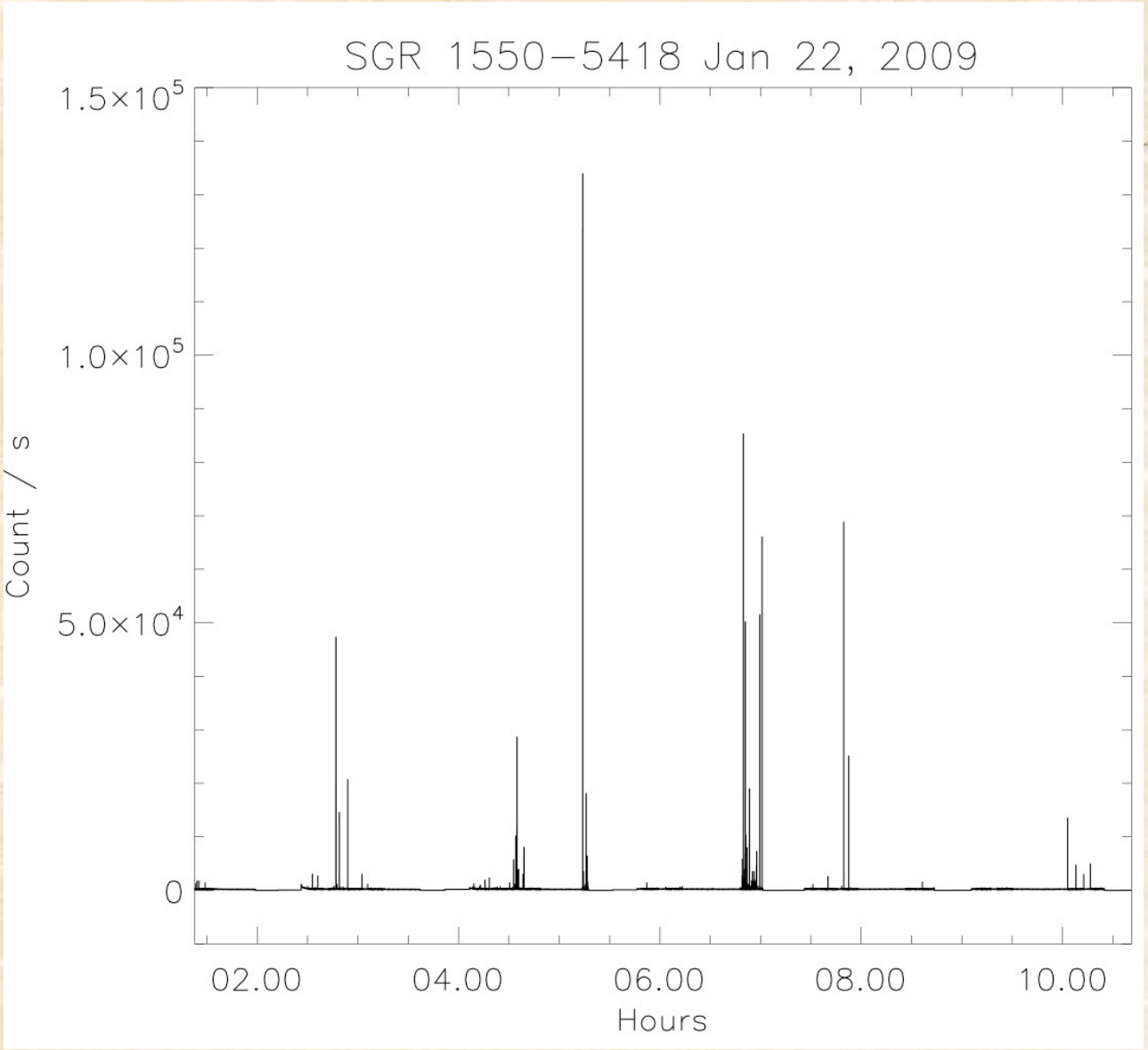
- Three episodes detected with GBM: Oct. 2008, Jan. & Mar. 2009
- $P = 2.069s$
- $\dot{P} = 2.318 \times 10^{-11}$ s/s and $B = 2.2 \times 10^{14}$ G
- Near IR detection, Ks = 18.5±0.3
- GBM triggered on 131 events from the source; many more in the data

SGR 1550-5418 Bursting Activity



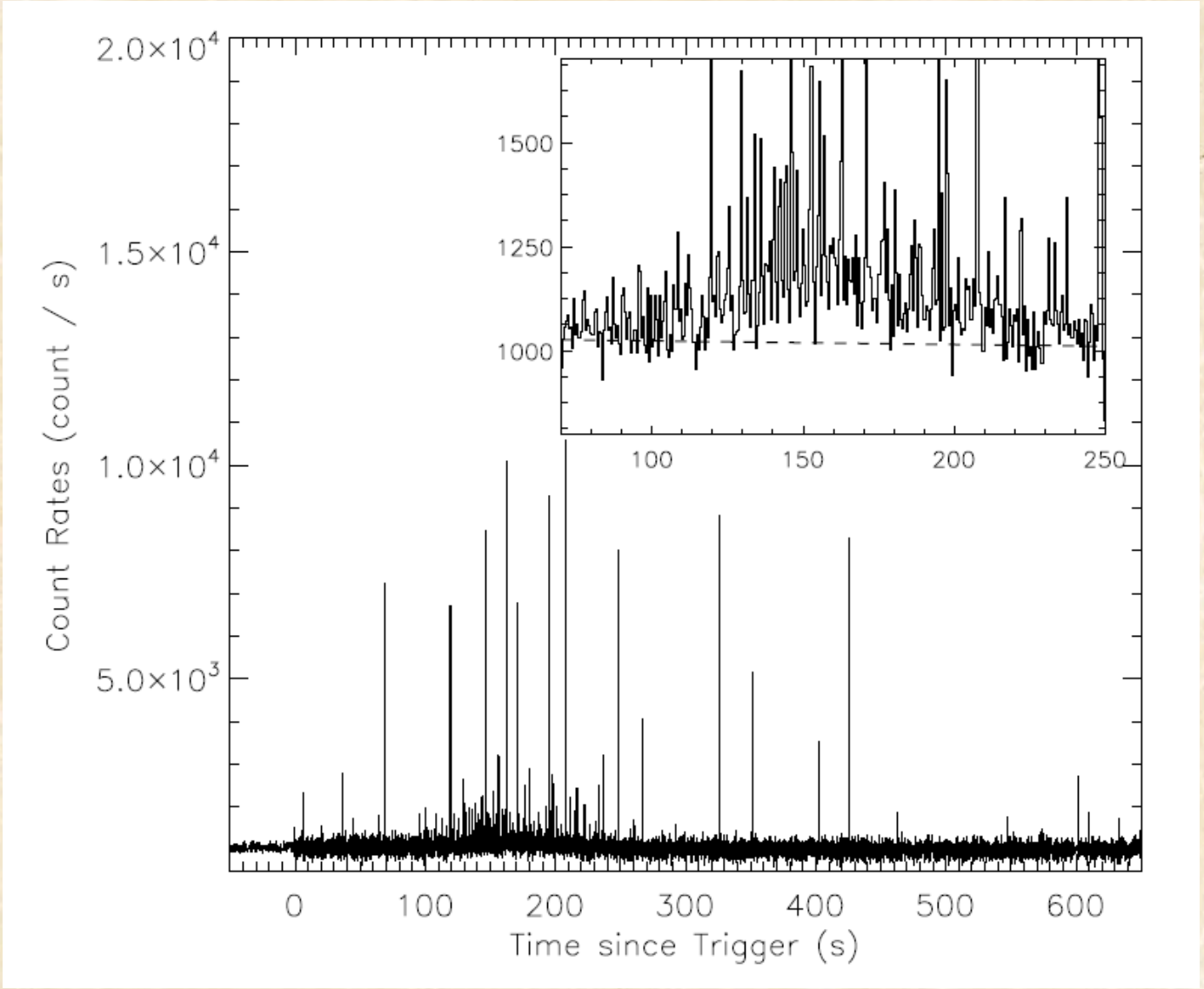
See posters by A. von Kienlin (P2 78) and A. van der Horst (P2 234)

Bursting Activity during 22 January 2009: ~450 bursts in 24 hours



van der Horst et al. 2010

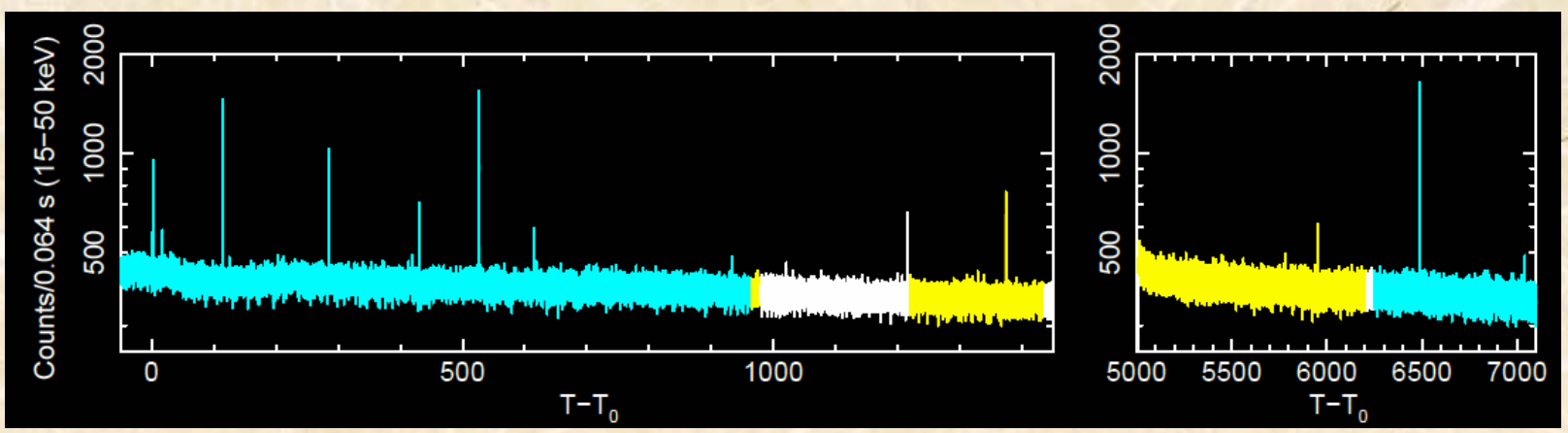
Magnetar twist and shake…



Talk by Ersin Gogus tomorrow

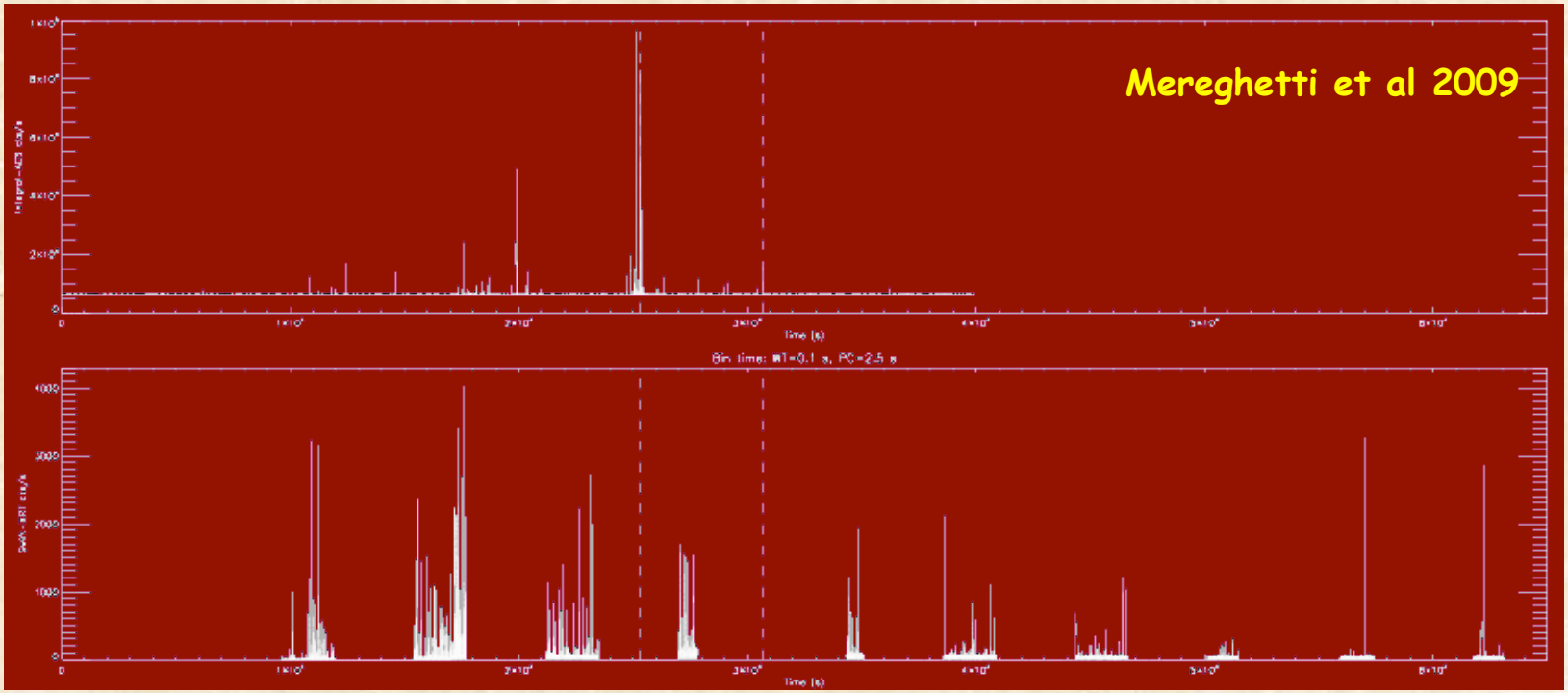
Kaneko et al. 2010

1E1547.0-5408 outbursts: Swift, XMM, CXO, INTEGRAL, Parkes, VLT-IR



Oct 08
$\Delta L \sim 50$

ToO:
Swift
INTEGRAL

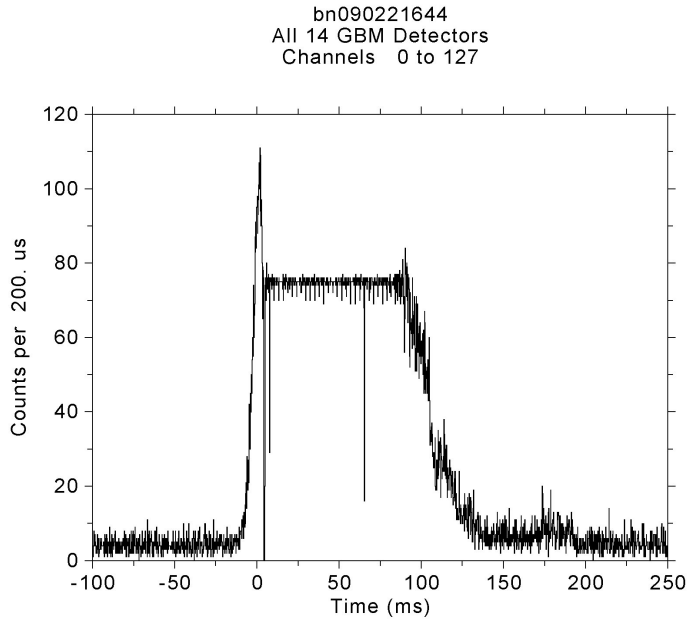


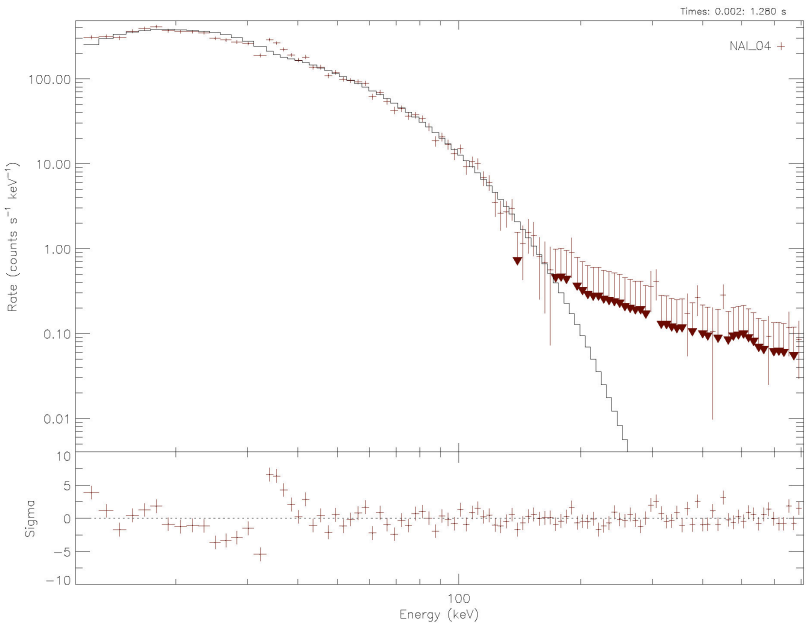
Jan 09
$\Delta L > 1000$!

ToO:
Chandra
XMM
Parkes
VLT-IR
Swift

Israel et al 2009

GBM Dead time and pulse pile-up effects in bright SGR bursts





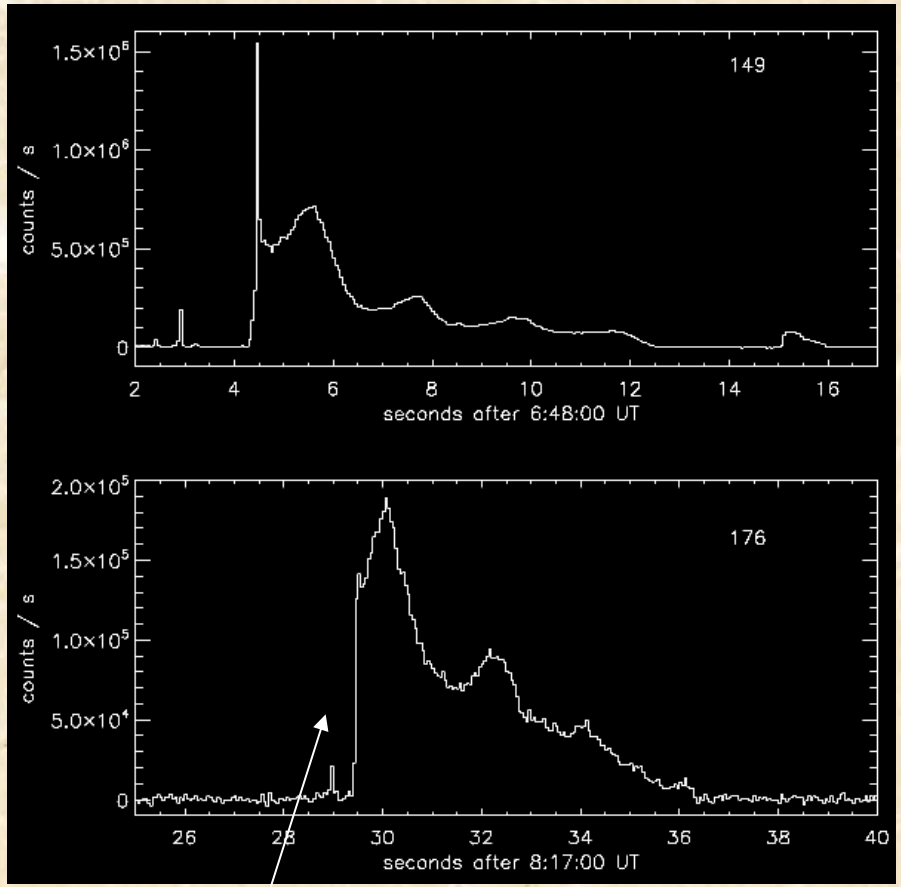
WARNING: Flat area is due to instrumental effects

TTE light curves saturate at a total of detector count rate of 375 kHz

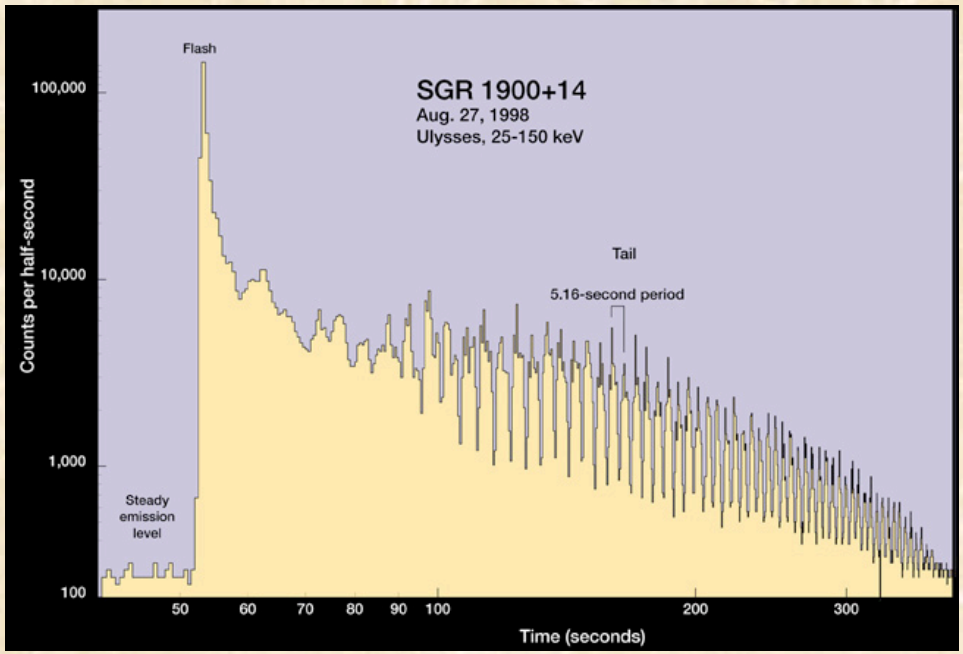
K-edge corrections need fine tuning

Pulse pile-up effects are currently being studied with simulations of burst spectra and intensities

~10^{43} ergs



few 10^{44} ergs

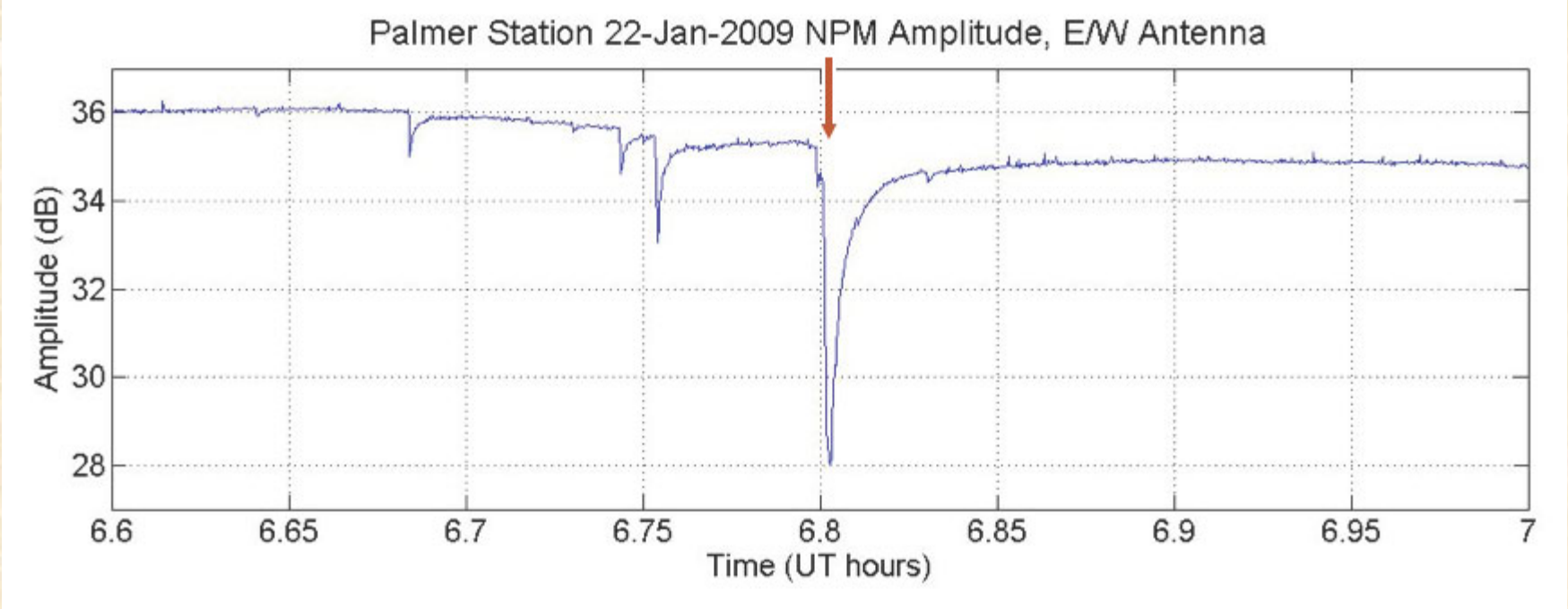


Rise time of ~ 50ms testifies of a different mechanism with respect to GFs (ms rise time)

Mereghetti et al. 2009

SGR bursts observed via VLF propagation disturbances!

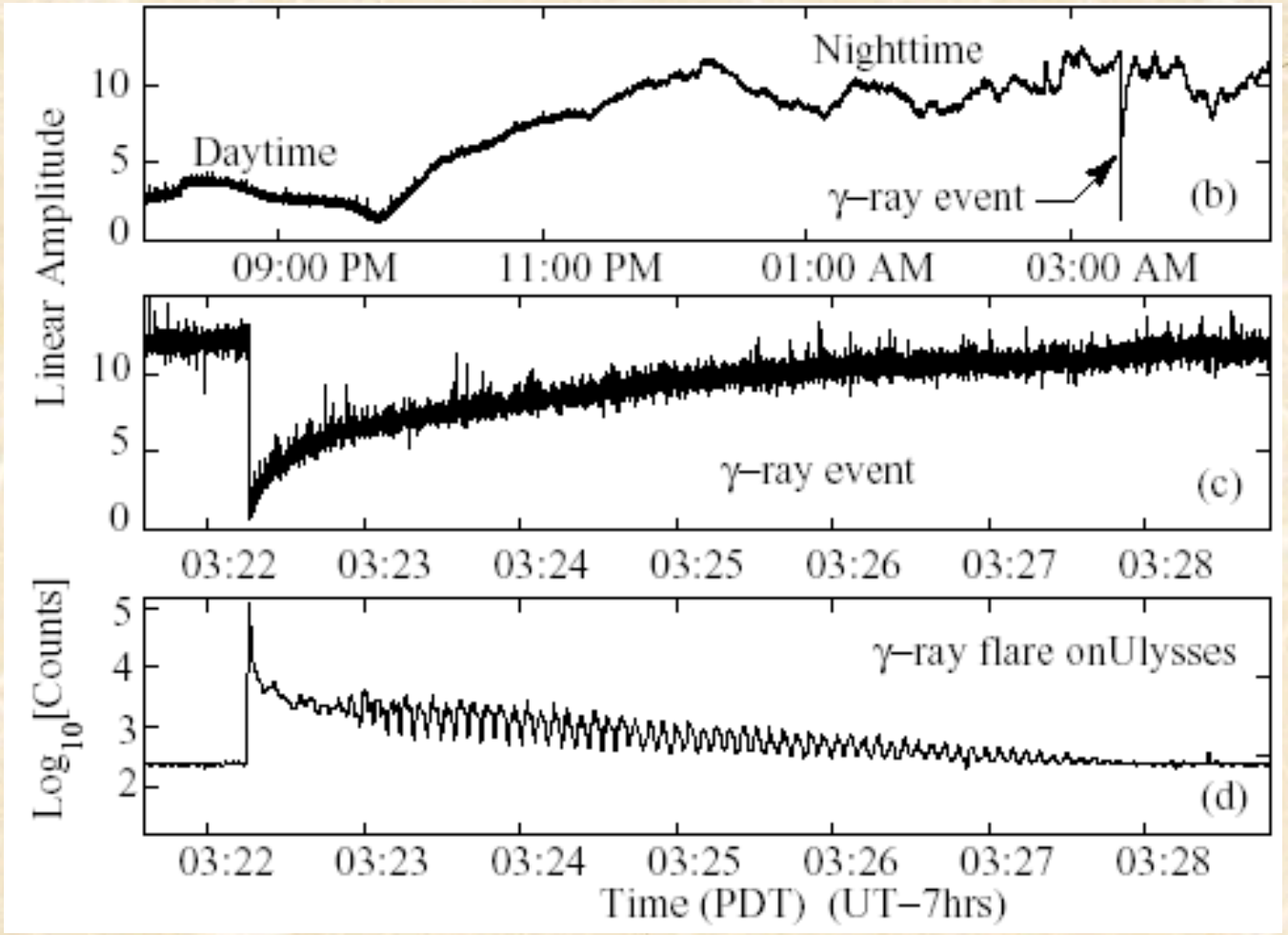
Provide a unique measure of the total ionizing fluence of X-rays above 0.05keV



Cohen et al. 2009

Fishman et al. 2010

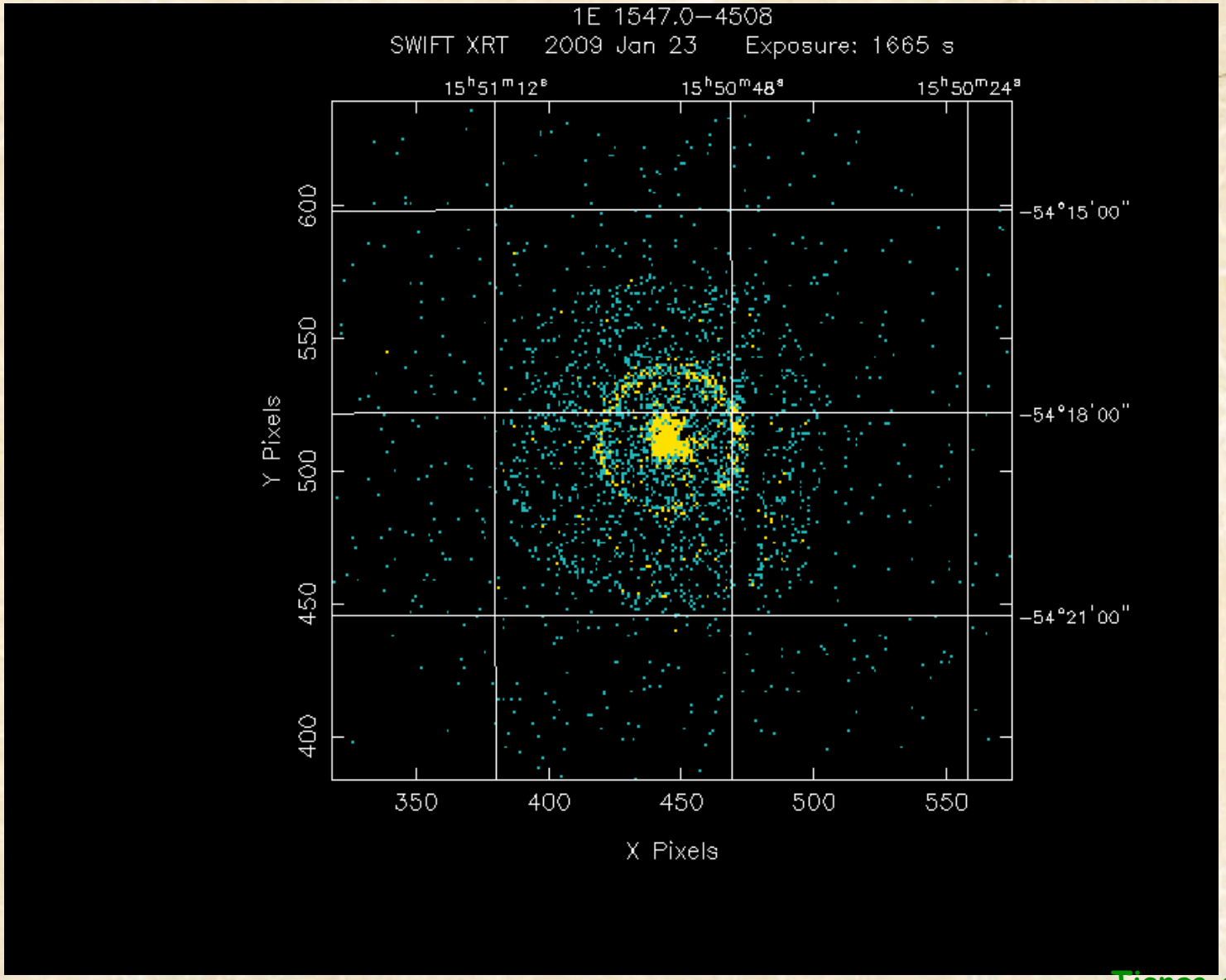
The 27 August 1998 Giant Flare from SGR 1900+14



(Inan et al. 2009)

An expanding light echo clearly detected in Swift XRT

See also Poster by Vianello et al. P2 80)

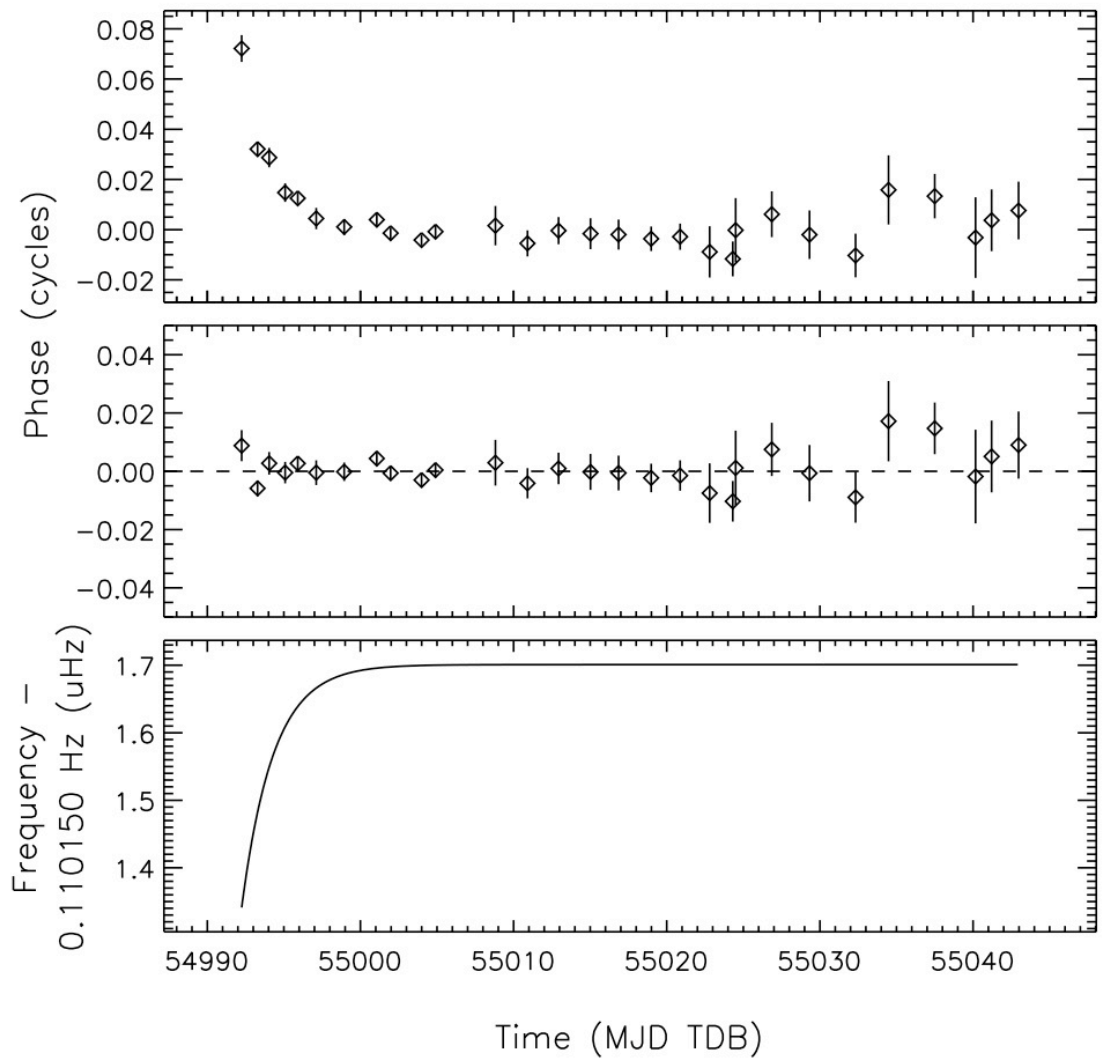


Tiengo et al. 2009

SGR 0418+5729

- GBM triggered on 5 June 2009 – **new source confirmed with IPN**
- RXTE ToO program triggered ~ 4 days after the GBM triggers
- P = 9.0783(1) sec
- $\dot{\nu} \sim 2 \times 10^{-14}$ Hz/s at 3σ and B < 10^{14} G
- CXO location: RA = 04h 18m 33.867s, Dec = +57d 32' 22.91"
- No IR (Ks > 21.3, Wachter et al 2009) or optical (R > 24, Ratti, Steeghs & Jonker 2009) counterpart detected
- GBM triggered on 2 events from the source

Apparent Glitch



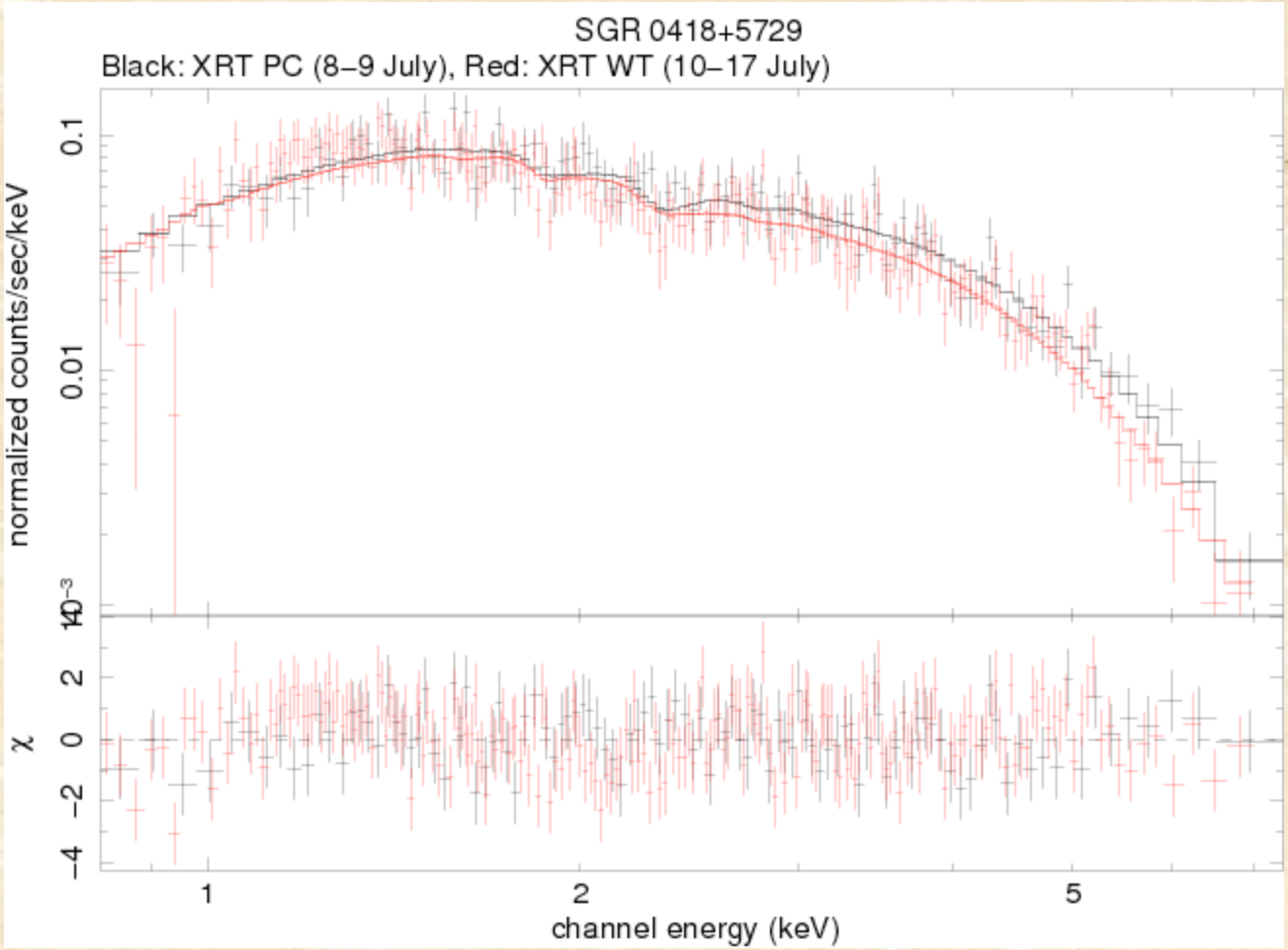
$\Delta\nu/\nu = 2\times10^{-5}$

ν-dot > 3.8×10^{-15} Hz/s at 3σ

B~5 x 10^{13} G
(Israel et al. 2009)

Woods et al 2010

Swift/XRT Persistent source spectrum

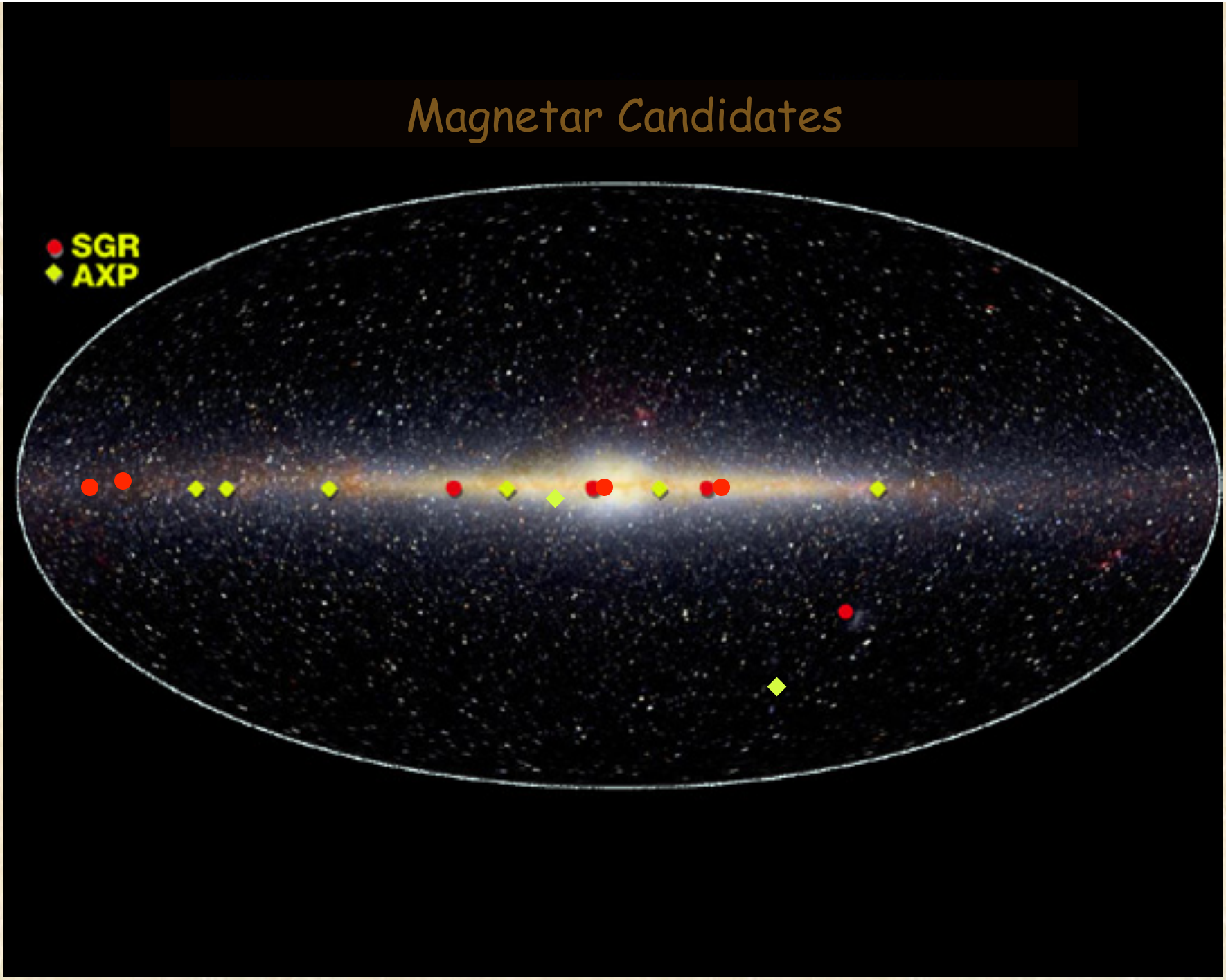


Absorbed blackbody: $N_H=(0.13\pm0.03)\times10^{22}$ cm^{-2}, kT=0.88±0.01 keV

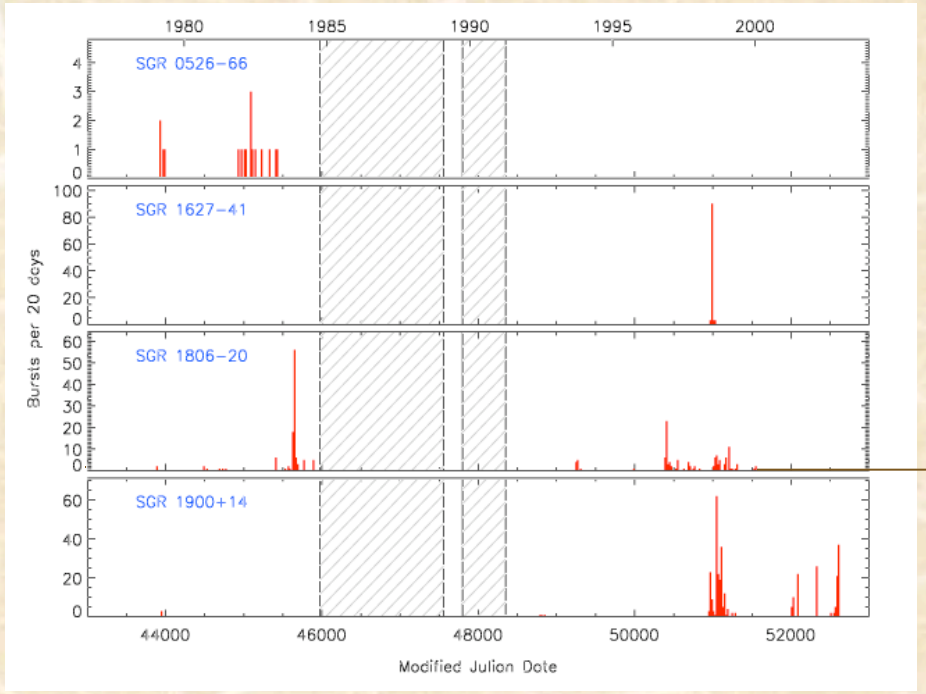
Unabsorbed flux (0.8-10 keV) = 1.1×10^{-11} ergs/cm^2/s.

Woods et al 2010

Magnetar Candidates



SGR burst time history with Fermi/GBM



(2)

SGR 1550-5418 (7/131)

SGR 0501+4516 (26)

SGR 0418+5729 (2)

Conclusions

We need to understand:

The differences – if any – between AXPs, SGRs and rotationally powered pulsars, in:

persistent emission spectra

glitching properties

magnetic field strengths

burst fluences and spectra

The associations of magnetars with SNRs, and their environments and track possible proper motions, now with two best candidates

The progenitor properties of magnetars, such as mass and cluster memberships

Magnetar Key Project status; very ambitious: 7 papers in progress, more ideas welcome!

Abstracts due: December 1st

Information, abstract submission and registration:

www.confcon.com/head2010/

Astrophysics of Neutron Stars 2010

ASTRONS 2010

2 – 6 August 2010
Çeşme – Izmir

Fermi results are welcome!

visit

www.astrons2010.org