On the nature of *Swift* J1834.9-0846 and its Magnetar Wind Nebula

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Magnetars are magnetically powered NS

- 24 sources to date – six in 2008-2011 – All but two (LMC, SMC) are MW sources (but see Calingham et al. 2012).
- Discovered in X/γ-rays/radio; radio, optical and IR observations - Short, soft repeated bursts, Giant Flares
- $P = [2\text{-}11]$ s, $\dot{P} \sim [10^{-11}\text{-} 10^{-13}]$ 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: $3.2 \times 10^{19} \sqrt{P\dot{P}}$); but: SGR J0418+5729, $B = 6(2) \times 10^{12}$ G and SGR 1822.3-1606->$B \sim 2.7 \times 10^{13}$ G
- Luminosities range from $L \sim 10^{32-36}$ erg/s
- No evidence for binarity
- SNe associations

NS populations comprising Magnetars

Soft Gamma Repeaters (SGRs)

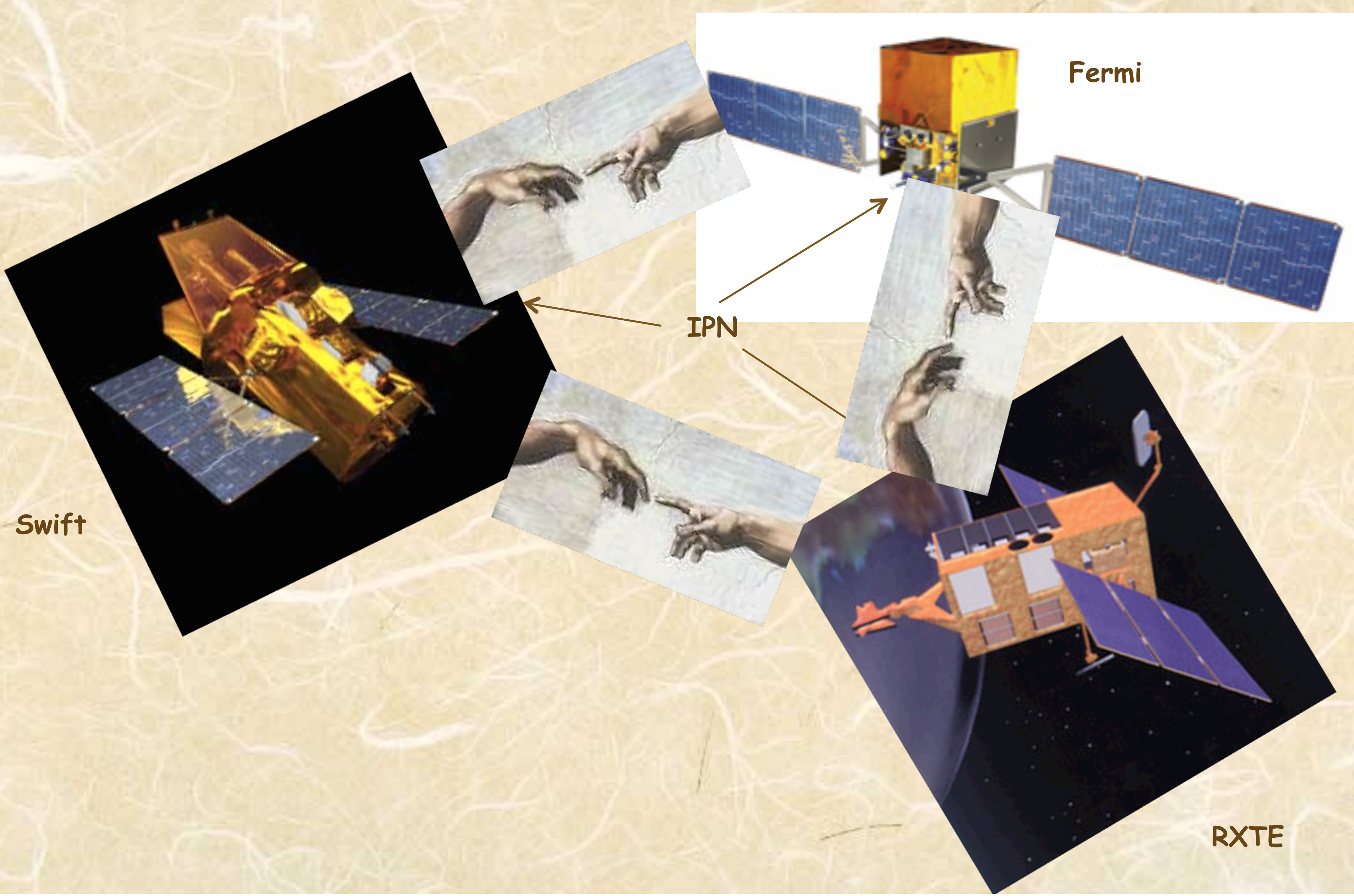
Anomalous X-ray Pulsars (AXPs)

Dim Isolated Neutron Stars (DINs)

Compact Central X-ray Objects (CCOs)

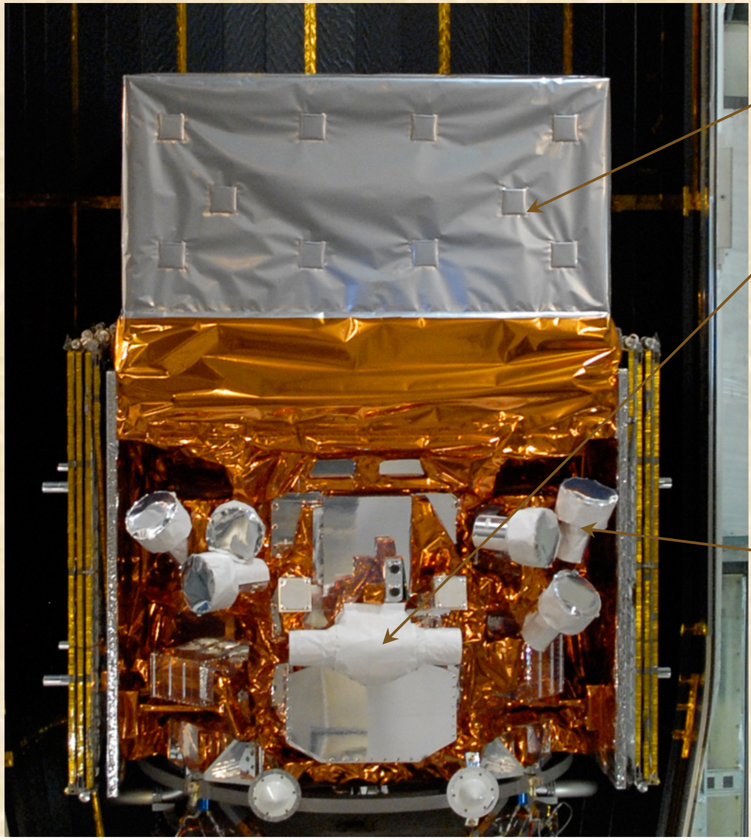
Rotation Powered Pulsars (PSRs J1846–0258 & J1622-4950)

2008-2011: Good years for Magnetars!



The *Fermi*/Gamma-Ray Burst Monitor

- 4 x 3 NaI Detectors with different orientations.
- 2 x 1 BGO Detectors either side of spacecraft.
- View entire sky while maximizing sensitivity to events seen in common with the LAT



The Large Area Telescope (LAT)

GBM BGO detector.
200 keV -- 40 MeV
126 cm^2, 12.7 cm
Triggering, Spectroscopy
Bridges gap between NaI and LAT.

GBM NaI detector.
8 keV -- 1000 keV
126 cm^2, 1.27 cm
Triggering, Localization, Spectroscopy.

GBM Magnetar Observations

Magnetar	Active Period	Triggers	Comments
SGR J0501+4516	Aug/Sep 2008	26	New source at Perseus arm
SGR J1550-5418	Oct 2008 Jan/Feb 2009 Mar/Apr 2009	7 117 14	Known source – first burst active episodes
SGR J0418+5729	June 2009	2	New source at Perseus arm
SGR 1806-20	Mar 2010	1	Old source - reactivation
AXP 1841-045	Feb 2011 June/July 2011	3 4	Known source – first burst active episodes
SGR 1822-1606	July 2011	1	New source in galactic center region
AXP 4U0142+61	July 2011	1	Old source - reactivation
SGR 1834-0845	Aug 2011	1	New source in galactic center region

SGR 1834.9-0846 stats

- **Discovery**: *Swift* triggered on 2011 August 7. Fermi/GBM triggered 3.3 hours later on a second burst. *Swift* triggered one more time on 2011 August 30. Total of 3 bursts.

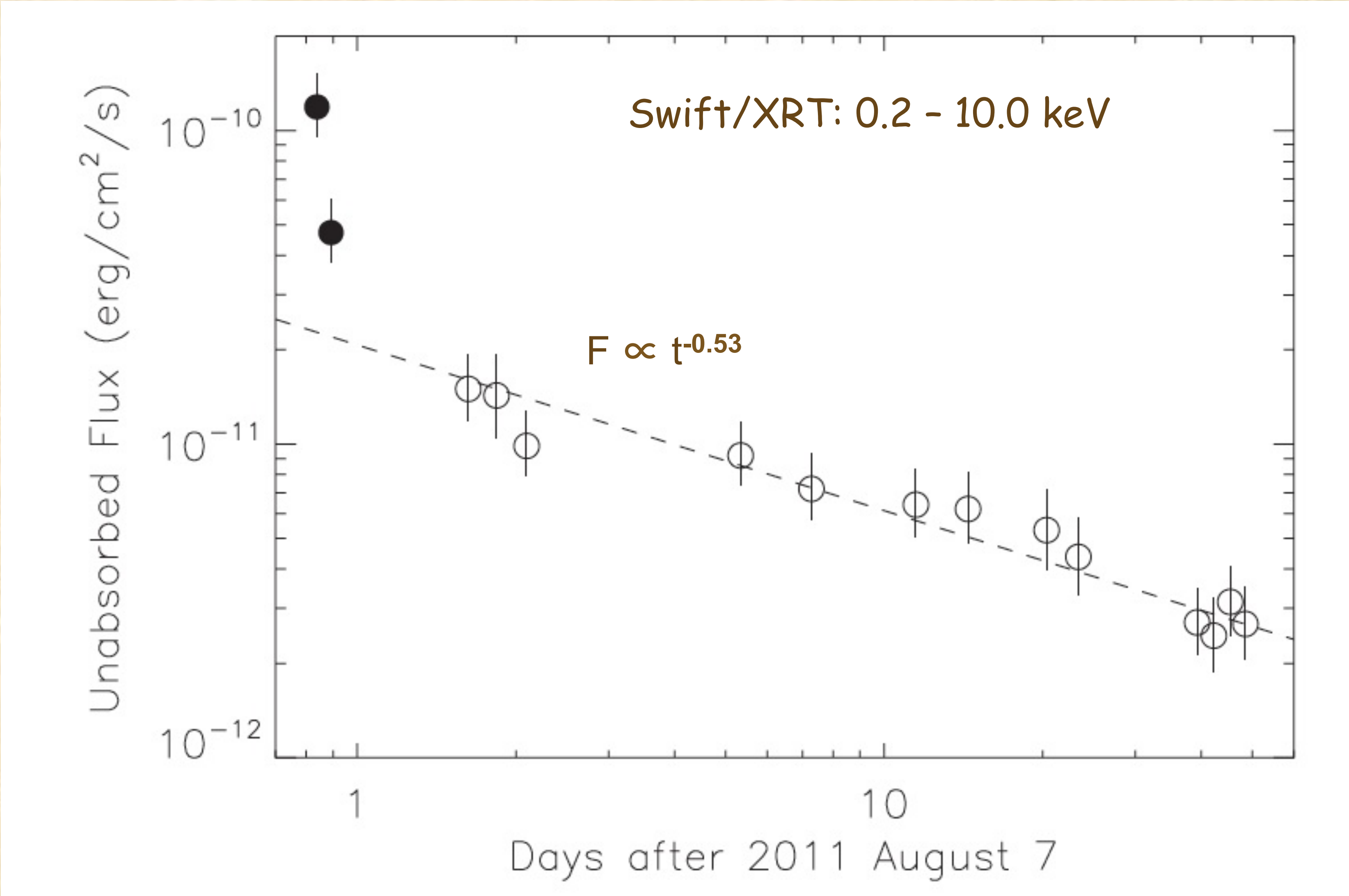
- **Counterparts:** No optical or IR counterpart detection

- **Location:** *Chandra* ToO 11/08/22, CXOU J183452.1-084556
  R.A. = $18^h\ 34^m\ 52^s.118$, dec = -08° 45′ 56″.02

- **Timing:** *RXTE/PCA* ToO 11/08/9-10 reveals coherent pulsations at
  $\nu = 0.402853(2)$ Hz -> $P = 2.4823018(1)$ s
  Continuous *RXTE/PCA* monitoring over 2 weeks revealed
  $\dot{\nu} = -1.3(2) \times 10^{-12}$ Hz/s => $B = 1.4 \times 10^{14}$ *G*

- **Source field:** Very rich with high-energy sources:
  SNR W41, HESS J1834-087, 2FGL J1834.3-0848, PSR/PWN XMMU J183435.3-84443/CXOU J183434.9-084443

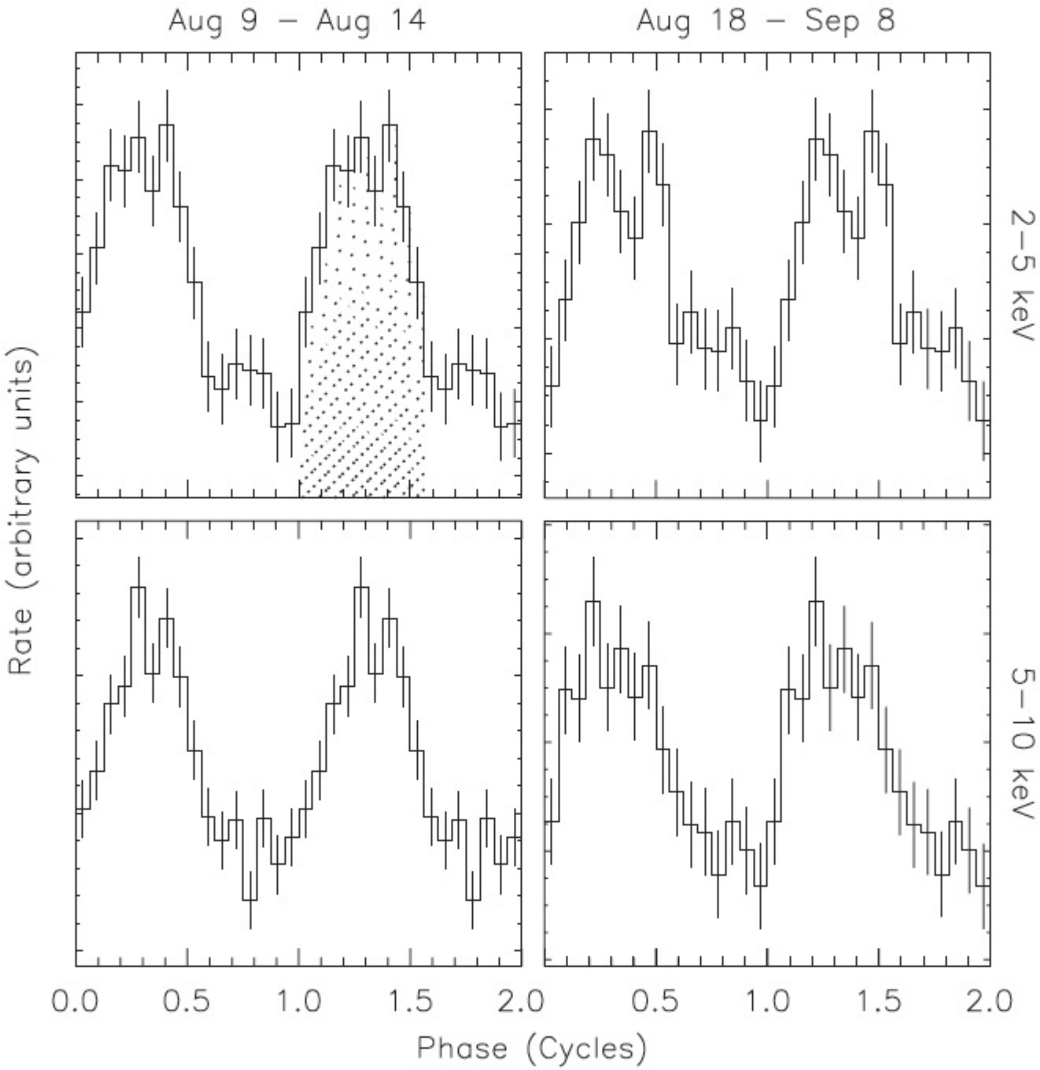
X-ray observations



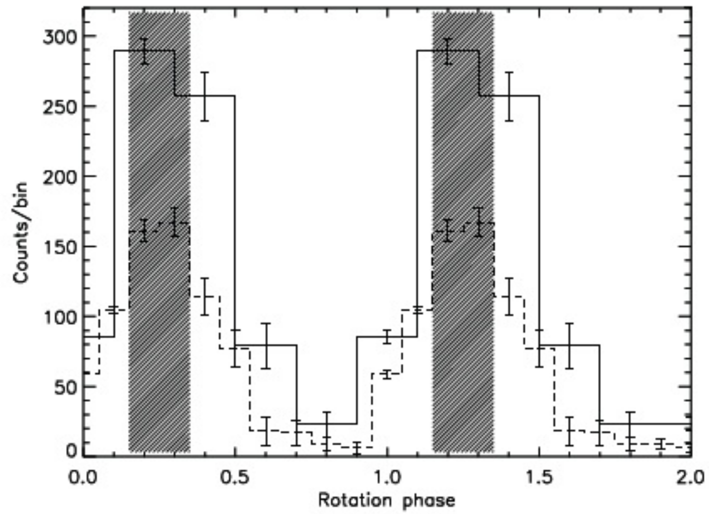
Kargaltsev et al. 2012

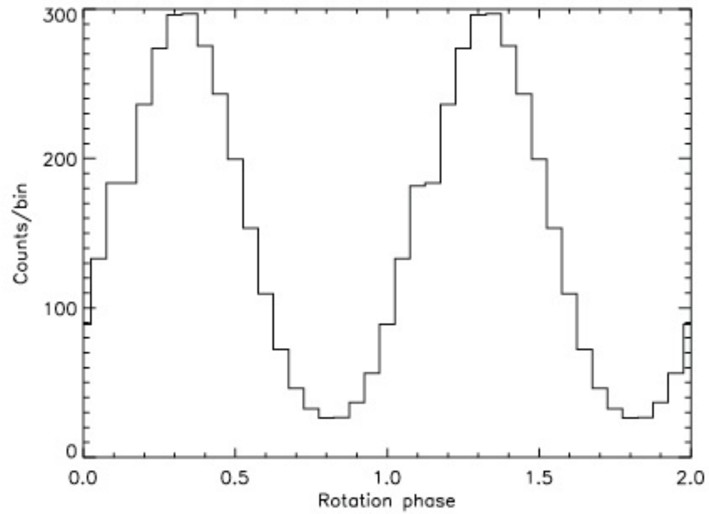
X-ray Pulse Profiles

RXTE/PCA



CXO, 11/08/22, 2-10 keV

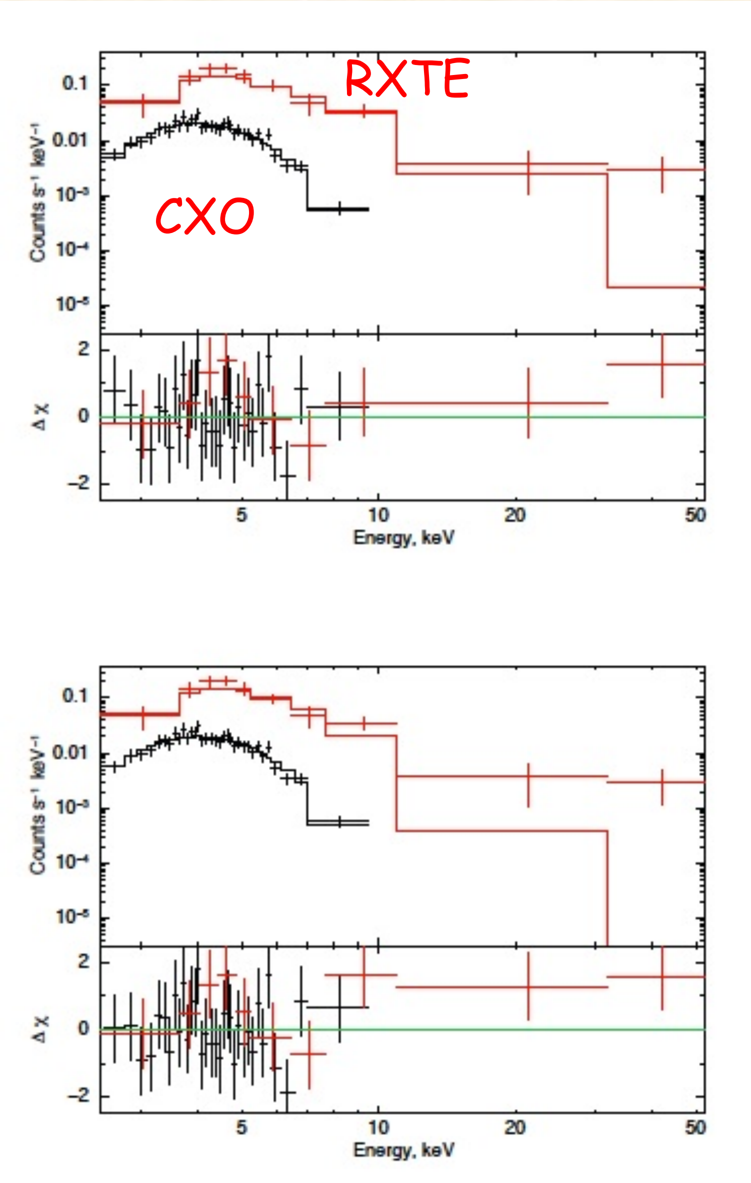




τ = 4.9kyr, E = 2.1x10^{34} erg/s, **p=85 (10)%** (P = 2.4823018(1)s, $\dot{P}$ = 7.96(12)x10^{-12}s/s)

X-ray Spectra

2-10 keV



CXO Spectral Fits

PL:

N_H = 20.3 x 10^{22} cm^{-2}

Γ = 3.5

F_{un} = 1.6 x 10^{-12} erg/s

L = 3.1 x 10^{34} erg/cm^2s (@4 kpc)

BB:

N_H = 12.0 x 10^{22} cm^{-2}

kT = 1.1 keV

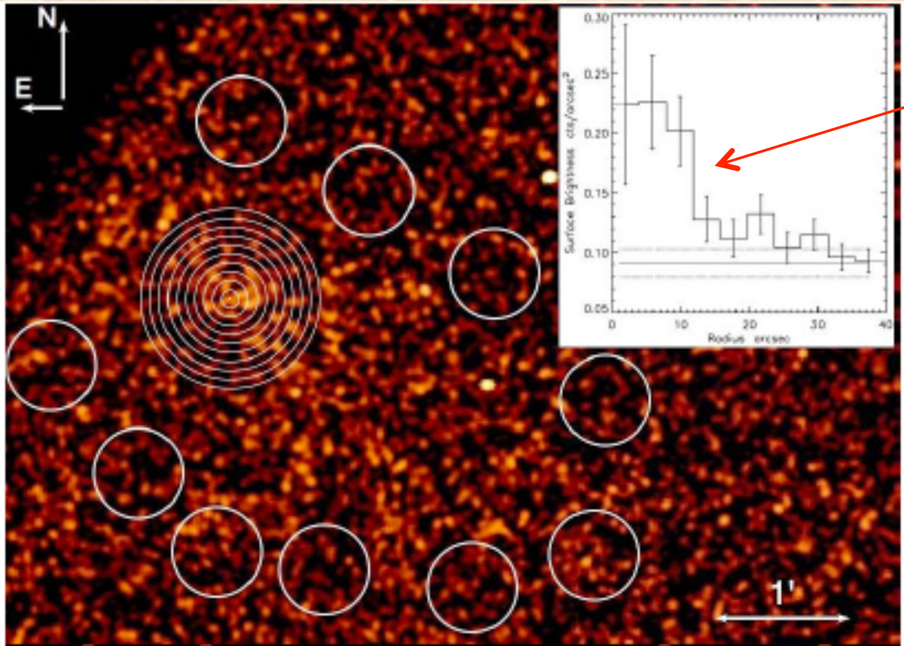
F_{un} = 5.8 x 10^{-12} erg/s

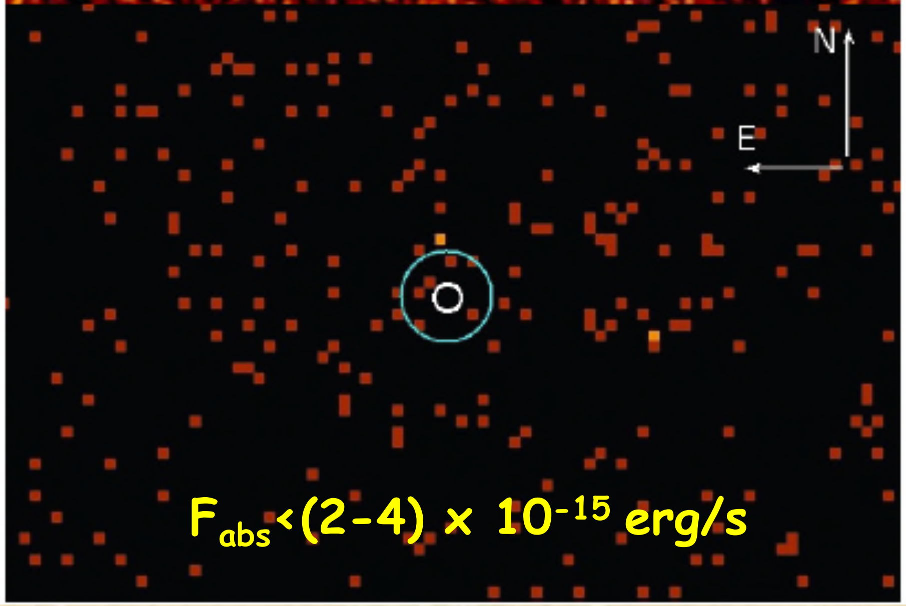
L = 0.33 x 10^{34} erg/cm^2s (@4 kpc)

R = 0.26 km

The extended emission

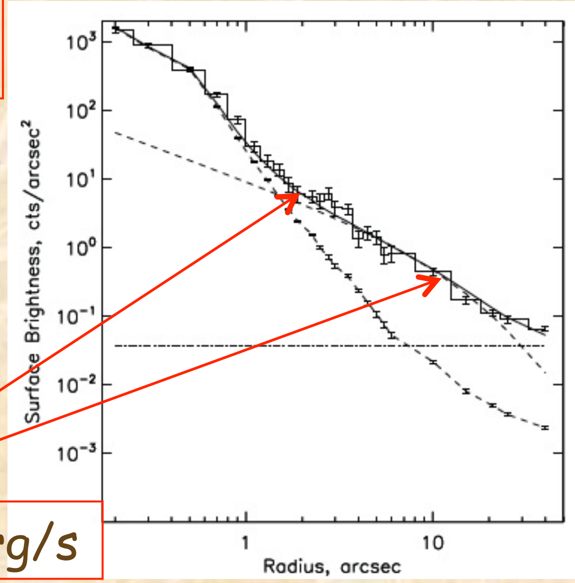
CXO - 2005



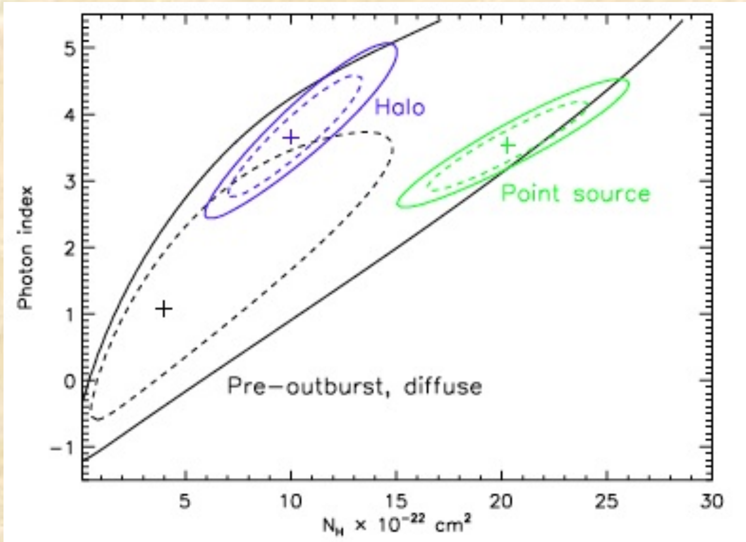


<12" @5.1σ
12"<r<30" @3σ

CXO - 2011

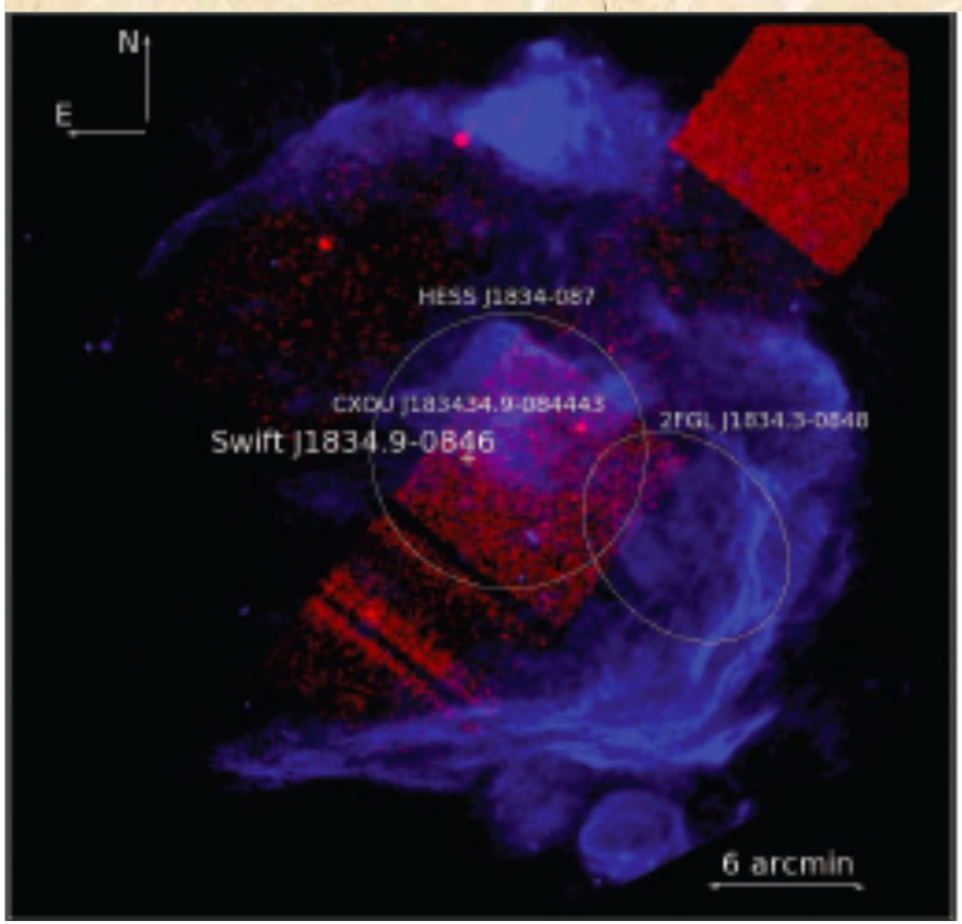


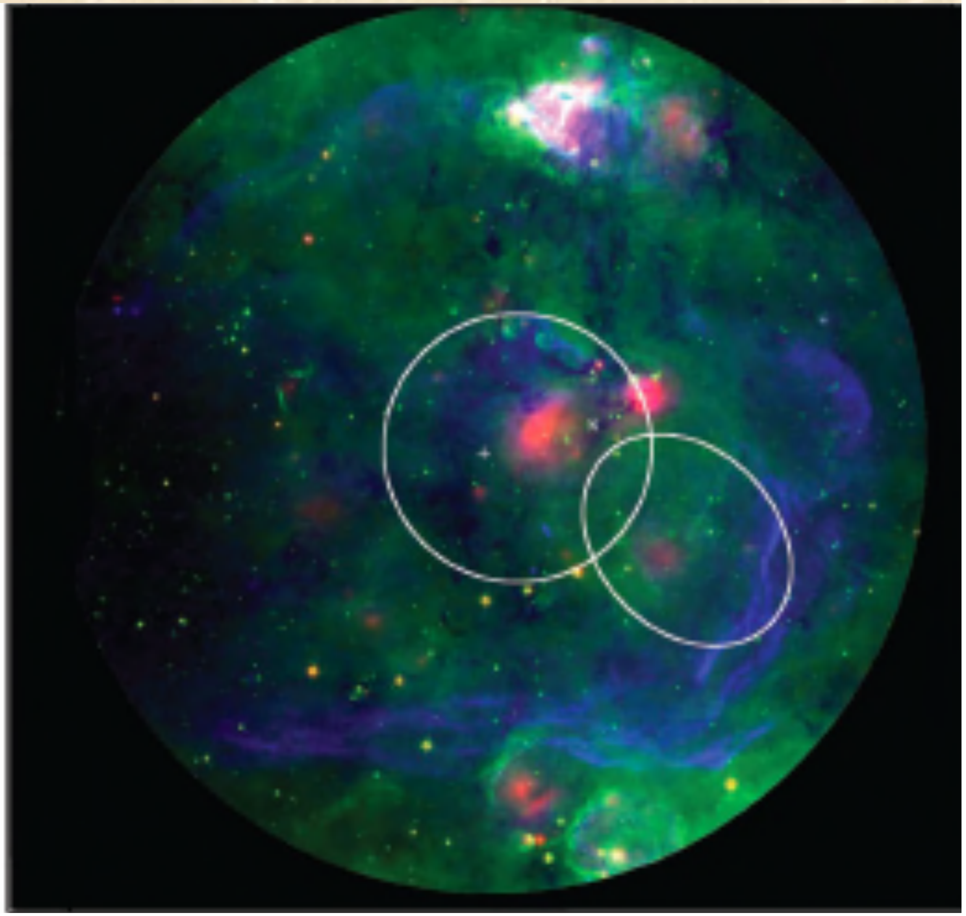
F_{un} = 1.6x10^{-12} erg/s



The environment of Swift J1834.9-0846

- Close to the center of SNR W41
- Close to the center of the error box of HESS J1834-087 (circle)
- Near the GeV source 2FGL J1834.3-0848 (ellipse)
- PWN XMMU J183435.3-84443/CXOU J183434.9-084443 (similar $N_H \sim 3 \times 10^{23}$ cm^{-2})





Conclusions

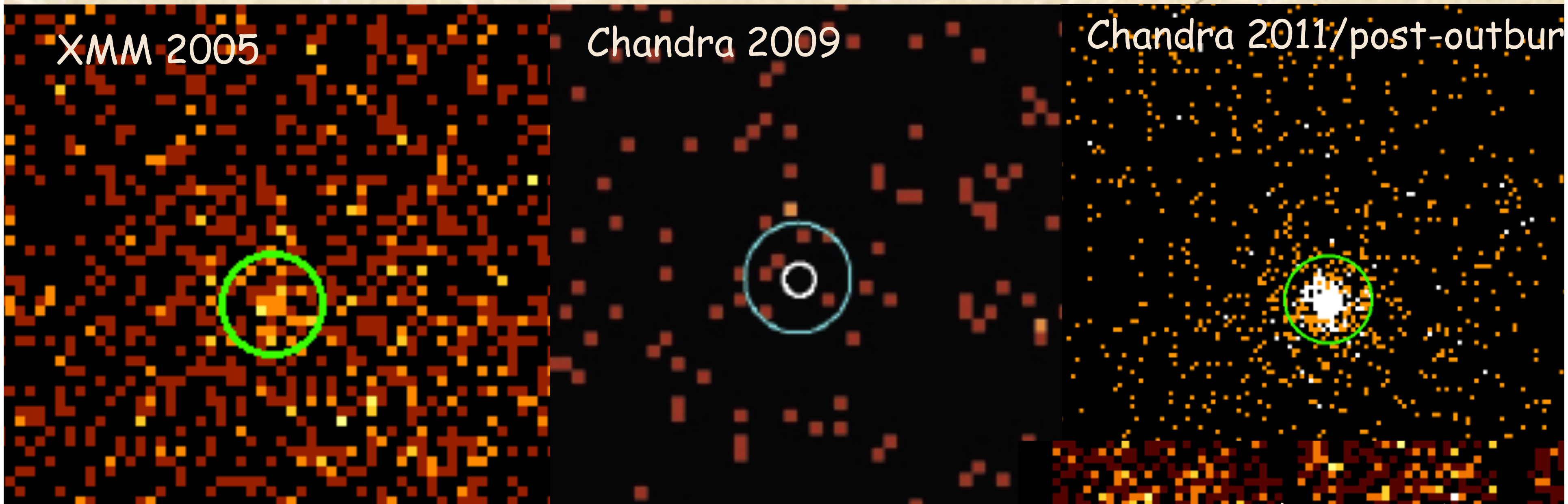
The small emitting area (0.26 km) could be a hot spot on the surface of the NS. The high pulsed fraction indicates that it should be near the magnetic pole. The single peak indicates that the magnetic dipole is probably not centered.

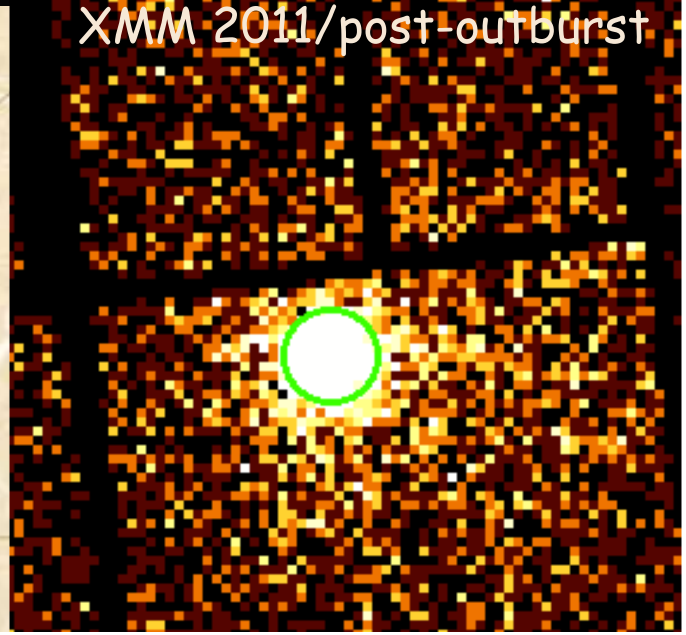
The flux variation between quiescence and activation can be of the order of 10^3 (see also Calingham et al. 2012)-> effects on magnetar population.

The environment of the source is very rich in HE sources – is there a connection between 1834 and the HESS/FGL sources?

What is the nature of the extended emission?

XMM and Chandra Observations





Quiescent flux limit (Chandra 2009):

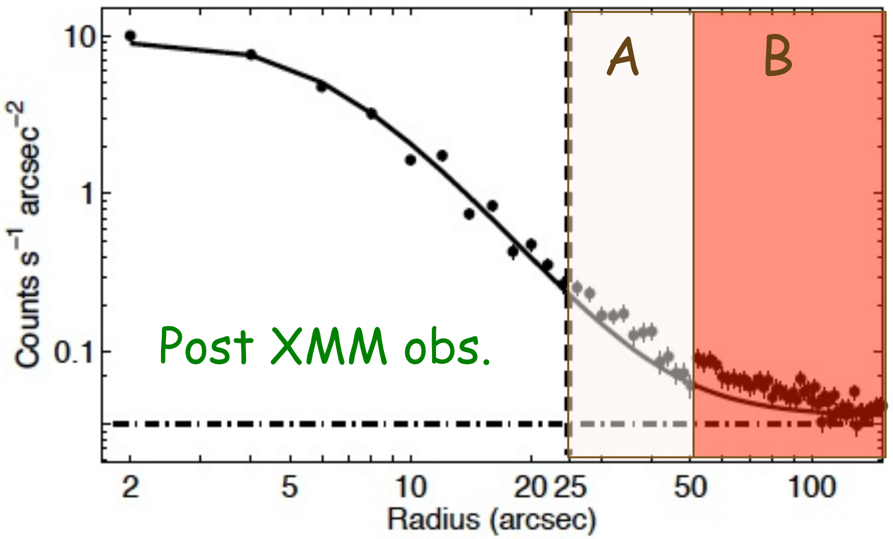
$$F < 4 \times 10^{-15} erg\, s^{-1}\, cm^{-2}$$

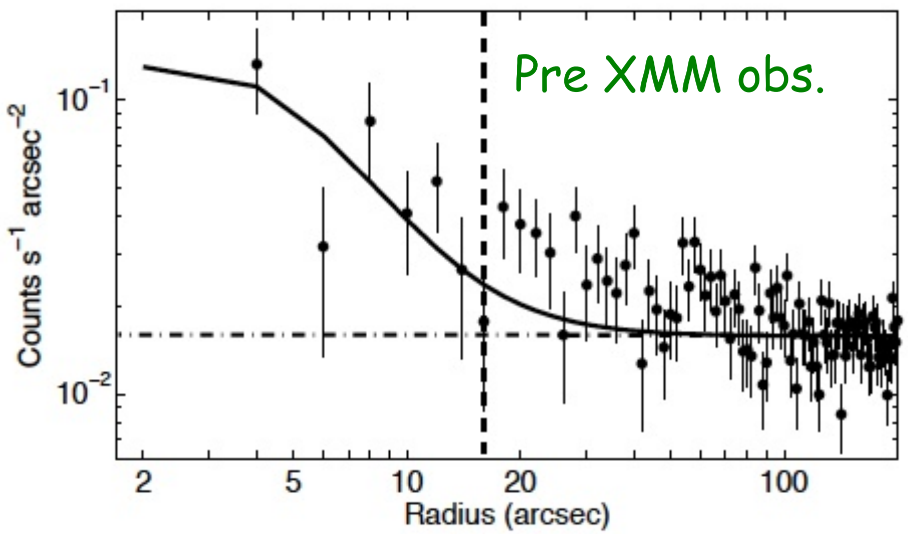
Flux after activity onset (Chandra 2011):

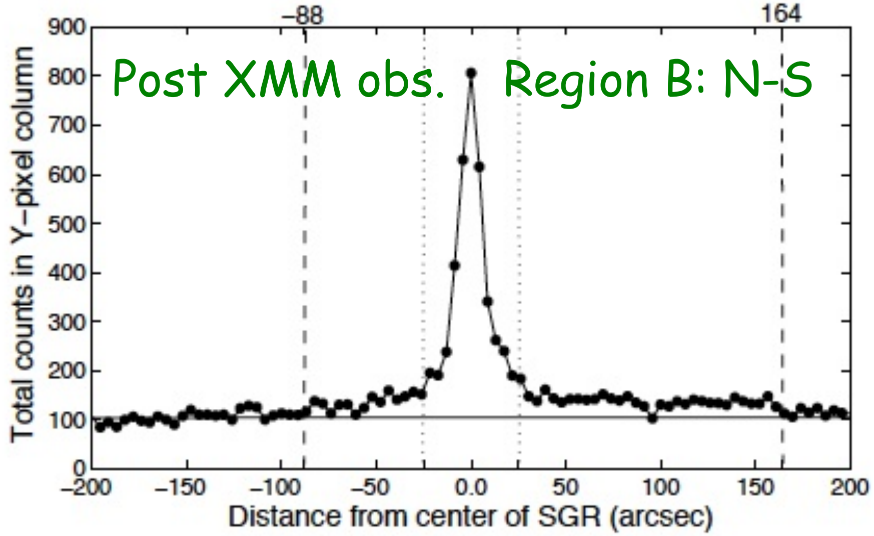
$$F = 1.6 \times 10^{-12} erg\, s^{-1}\, cm^{-2}$$

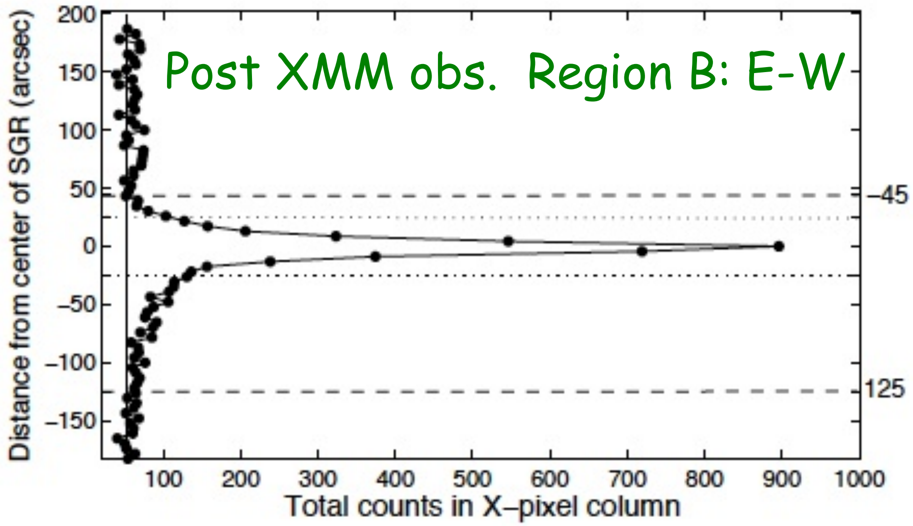
Younes et al. 2012

XMM Pre-, Post- Extended emission

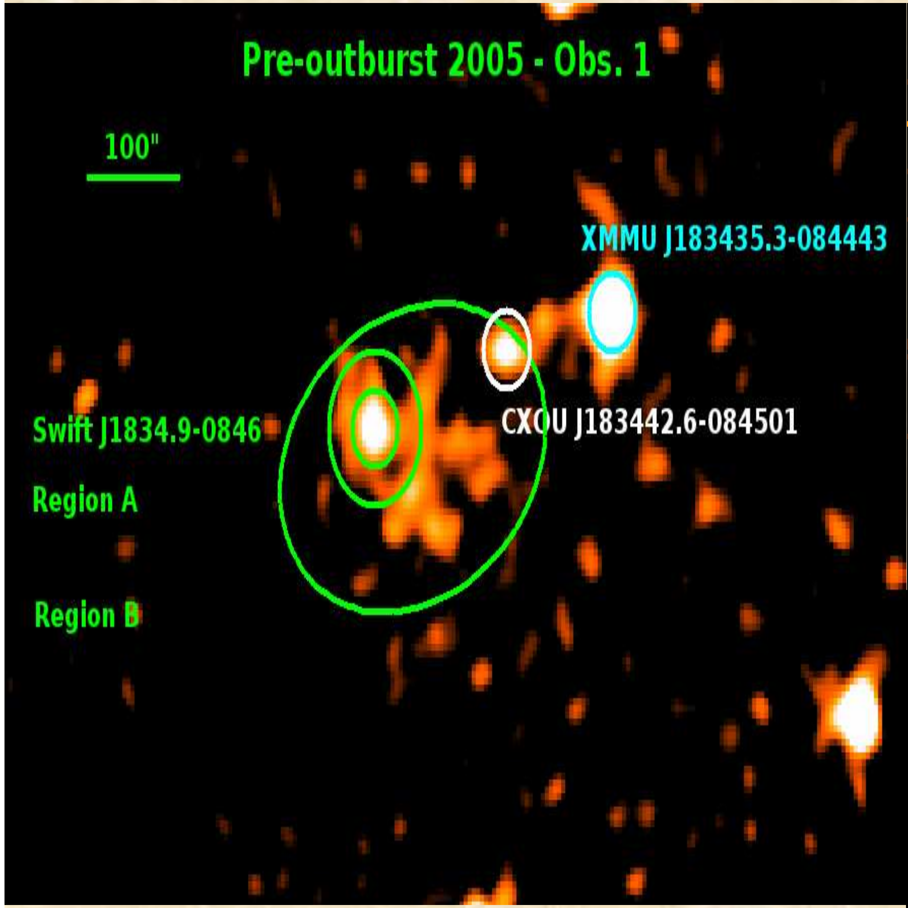


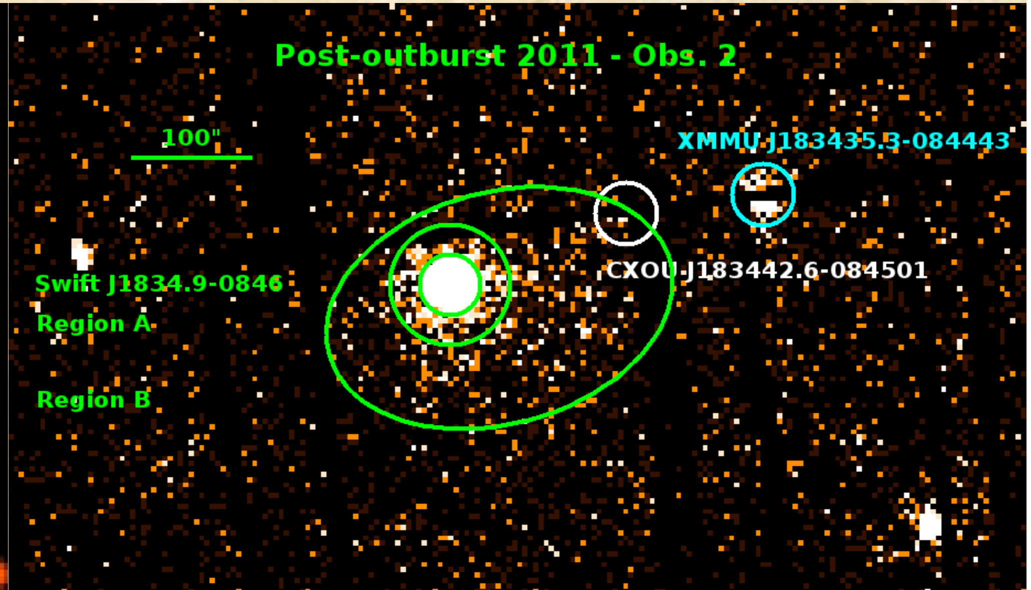


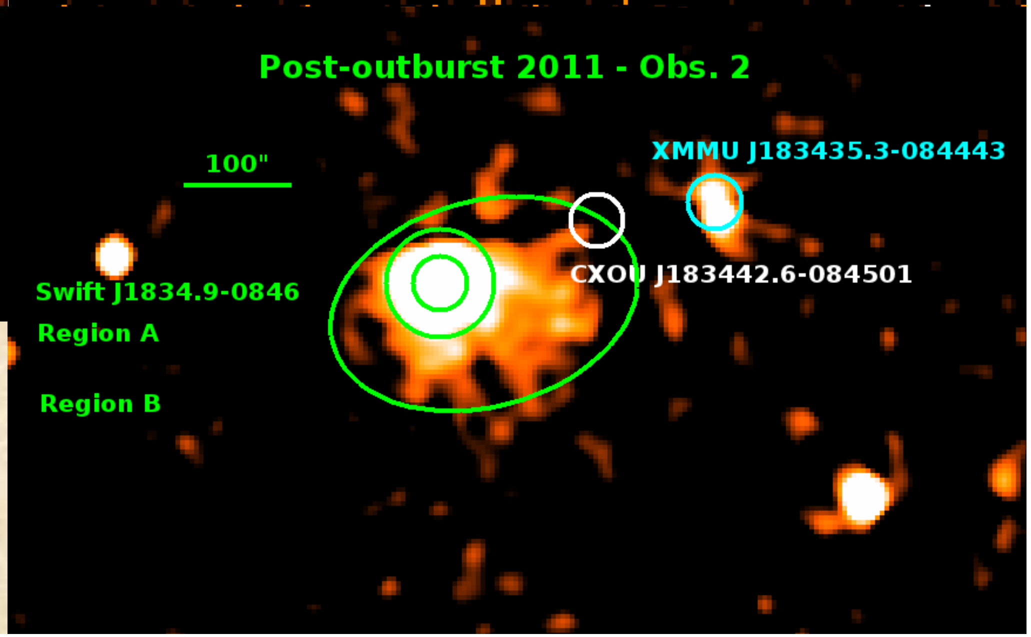




XMM Pre and Post Regions A and B





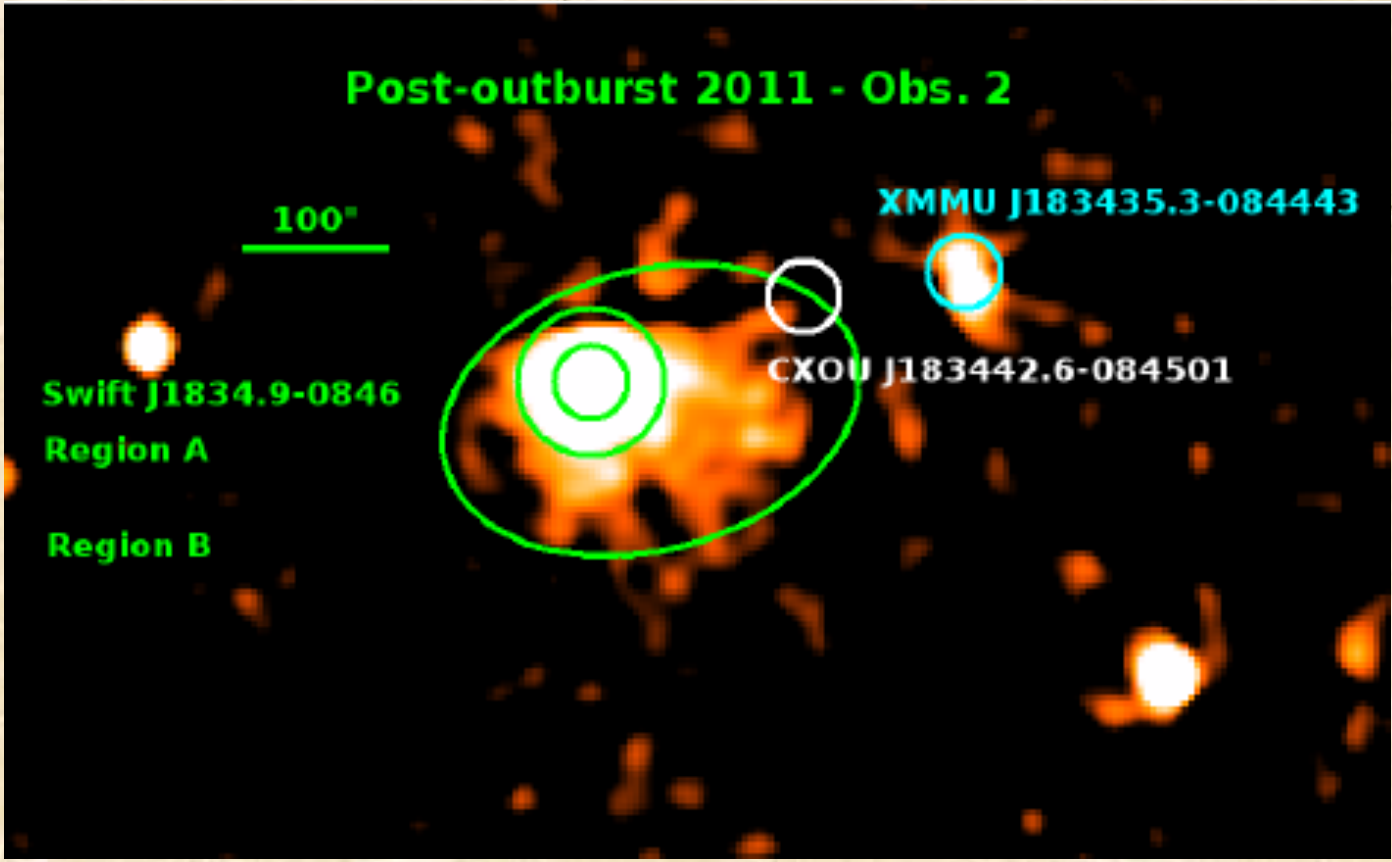


PreSrc F_{abs}=4×10^{-14} erg/cm^{2}s (4.6σ)

REGION A, circle: 25"<r<50" (1pc)

REGION B, ellipse: 145" (95") major (minor) axis (1-3 pc)

SPATIALLY RESOLVED SPECTRA



Spectra (0.5 – 10 keV) for Region A and B are fit with an absorbed power-law:

Same N_H: $N_H \approx 10^{23}\ cm^{-2}$

Different Γ: $(\Gamma_{SGR} = 4.1),\ \Gamma_A = 4.6,\ \Gamma_B = 3.2$

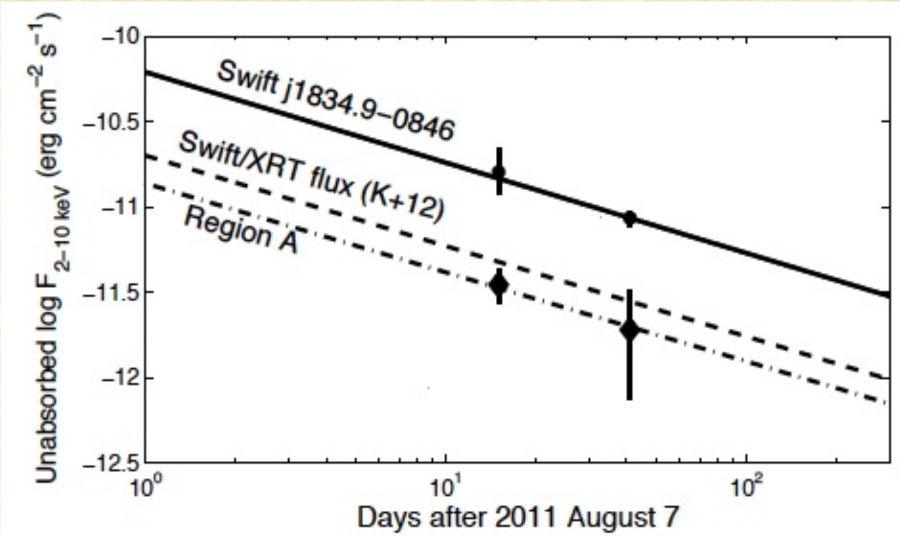
HALO A and/or B?

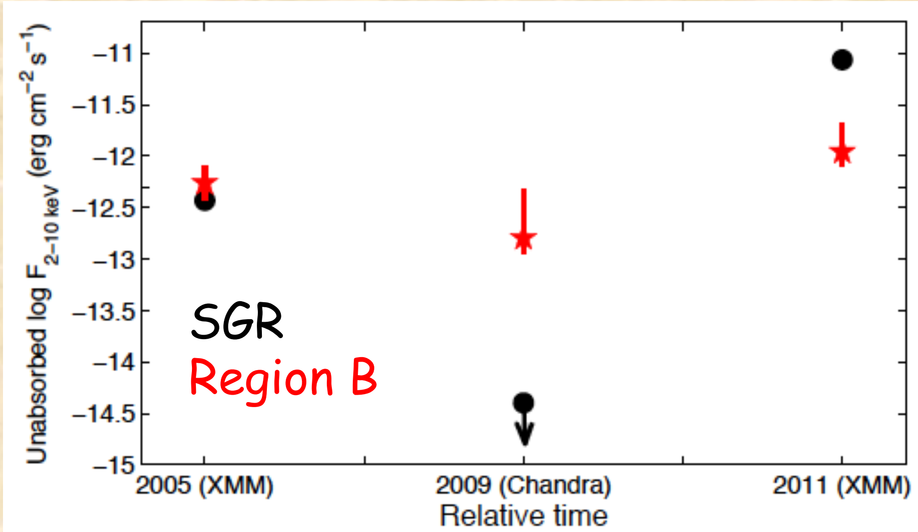
SCATTERING HALO PROPERTIES:

a. Symmetrical by definition, unless under exotic conditions
b. Needs high density scatterer – indeed Giant Molecular Cloud in the los
c. X-ray spectrum is expected to be softer than the source
d. Halo flux should vary proportionally to source flux (lag depends on distance)

Region A fits this picture perfectly

Region B is inconsistent with these properties





Region A flux decays following the same power-law as the source: $\alpha\, t^{-0.5}$

Region B was detected pre-outburst, with a slightly weaker flux compared to post-outburst observation

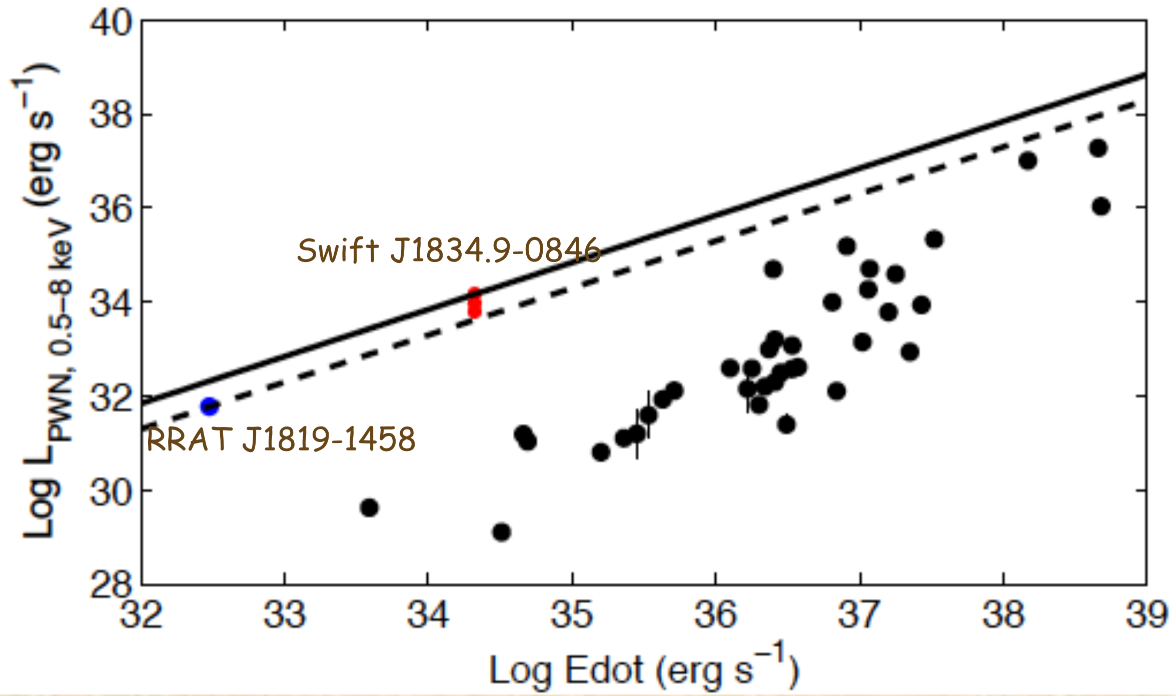
On the Nature of Region B

PWN are produced by RPPs by rotational energy losses; the efficiency of this process is characterized by: $\eta_X = L_{X,PWN} / \dot{E}_{rot}$ $(10^{-6} < \eta_X < 10^{-2})$

Swift J1834.9-0846 has a very high η_X (0.7) similar to RRAT J1819-1458 (0.2)

However if a MWN, it is much softer compared to typical PWN (index 3.2 vs 1-2), suggestive of a very steep electron spectrum (-6). B-field line reconnection?

Assuming that during bursts magnetar η_X is similar to RRPs, Region B could be interpreted in terms of a MWN emitting synchrotron emission in a few 10s of μG field at the shock radius of about 25", **when the source is in an active state.**



Conclusions/Questions

- The synchrotron cooling time for B~60 μG is ~ 30 yrs => MWN could be observed in X-rays even when the central source is undetectable!
- Are MWNe detectable in other wavelengths? Radio, low-frequencies?