The Fermi GBM detection of pulsed emission from four AXPs

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Outline of presentation

- Context: 2004+ discovery of high-energy emission from AXPs/SGRs (persistent) total and pulsed

- Sources: AXPs with established HE-emission

  1E1841-045
  1RXS J1708-4009
  4U0142+614
  1E1547.0-5408 (Transient HE-emission)

- Instruments & Data selection/analysis

1)	RXTE HEXTE (15-250 keV)	update	pulsed
2)	INTEGRAL ISGRI (15-300 keV)	update	total/ pulsed
3)	Fermi GBM (8 - 2000 keV; NaI detectors)	new	pulsed

- Results

- Summary & conclusions

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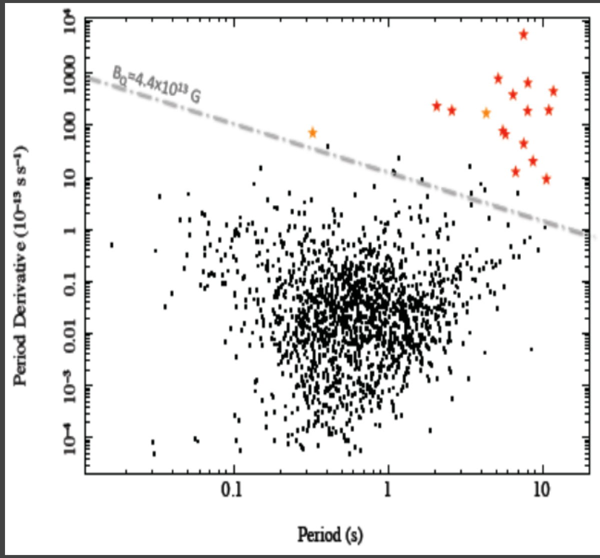
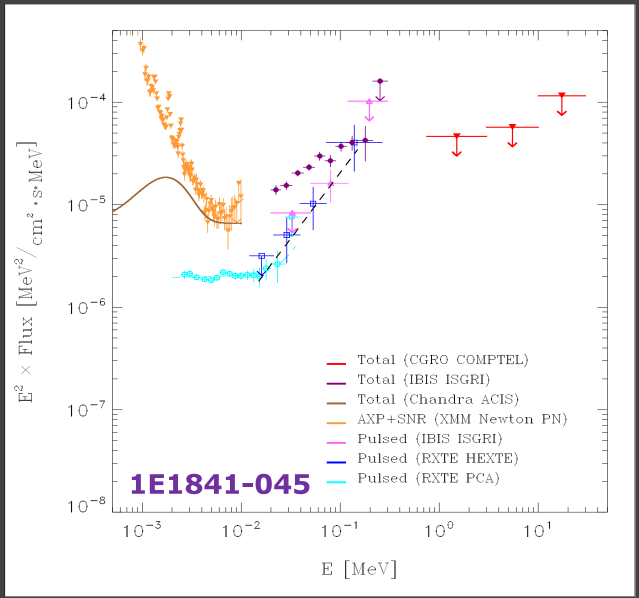
Context

AXPs & SGRs are believed to be magnetars i.e. neutron stars powered by the decay of a huge internal field (Thompson & Duncan)

Support for this:

1) P - dP/dt diagram
2) No XRB: absence of Doppler modulation in timing data
3) No RPP, because $L_x >> L_{sd}$
4) (frequently) glitching; pulsed flux variations





Before 2004: Ignorance of hard X-ray regime because of very soft spectrum < 10 keV (AXPs)

After 2004: **INTEGRAL** discovery of point-sources (> 20 keV) positionally consistent with AXPs

Kuiper et al. (2004,2006) significant fraction is pulsed up to ~150 keV. Total/pulsed spectra are very hard ($\Gamma \sim 1$) breaking above ~100 keV and luminous

Nowadays: 5 systems (3 AXPs / 2 SGRs) with persistent HE emission and 2 (1 AXP/1 SGR) with transient HE emission

Challenges: production sites/mechanisms

Best developed model within magnetar framework is from A. Beloborodov (2010) Untwisting of external B-field → "J-bundle" quasi-stable configuration of charge carrying particles above polar cap region up to ~10 R_s

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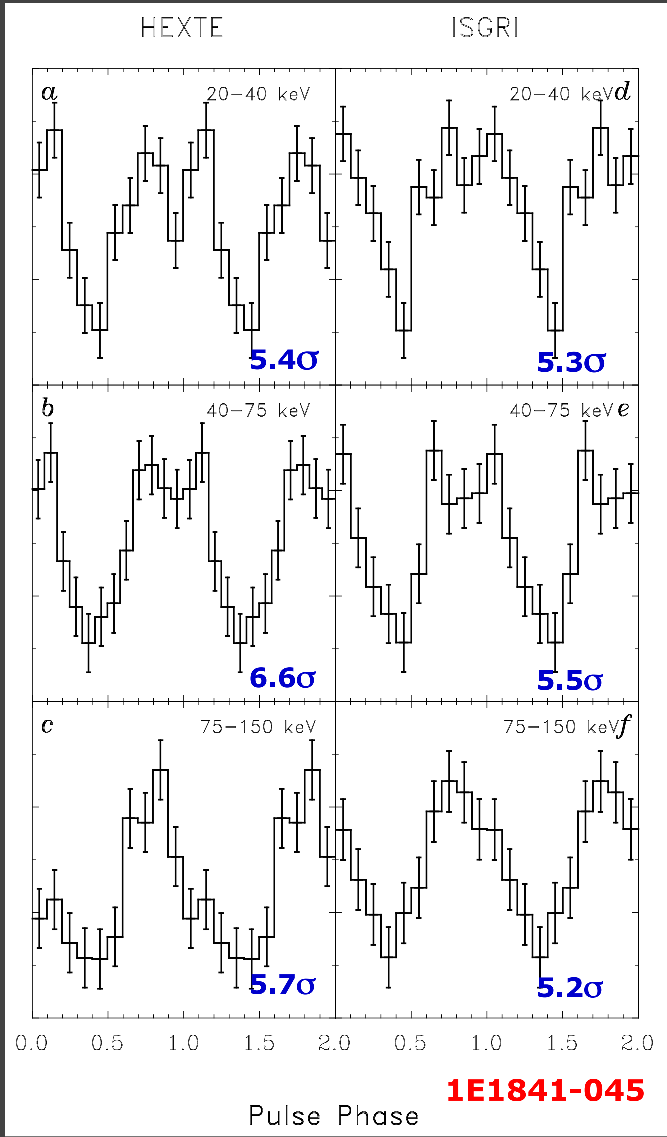
RXTE HEXTE and INTEGRAL ISGRI updates for 1E1841-045 and 4U0142+614



4U 0142+614

HEXTE exposure increase since Kuiper et al. (2006)

103.6 ks → 515.9 ks

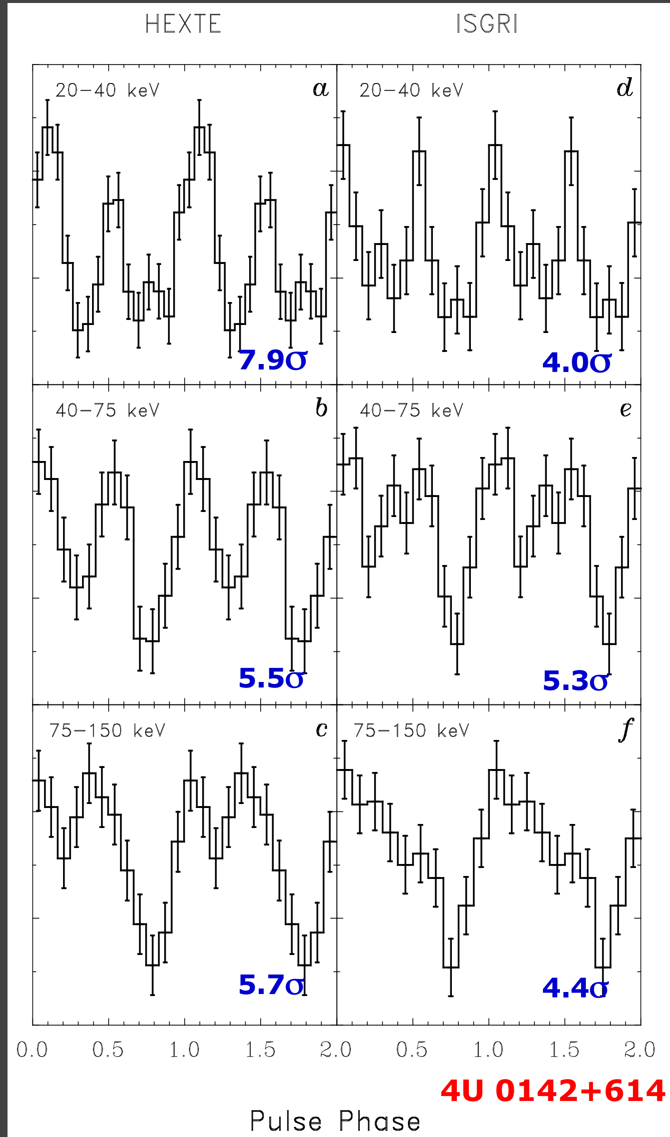
20-50 keV: 3.4σ
50-100 keV: 2.1σ

Now,

20-40 keV: 7.9σ

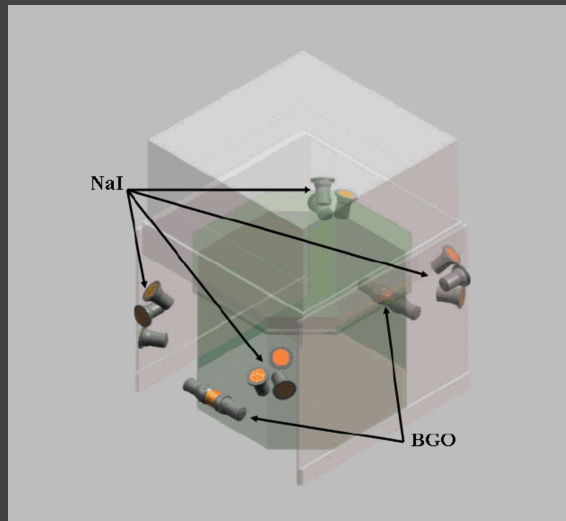
ISGRI exposure increase only moderately since den Hartog et al. (2008)

2.1 Ms → 3.2 Ms



Fermi GBM data selection and analysis

- Timing Analysis for those AXPs with established HE-emission and with valid contemporaneous phase-coherent timing solutions (RXTE monitoring): 1E1841-045, 4U 0141+614, 1RXS J1708-4009 and 1E1547.0-5408
- Only CTIME data (256 ms; 8 energy channels, 8 -2000 keV) from 12 NaI detectors are used ➔ source angle selections
- Extend the pre-defined SAA window by ± 300 s
- Remove short-duration events like bursts/flares
- Source angle $\alpha \leq 45^0$ and Earth zenith angle $\zeta \leq 180\text{-}70\text{-}\alpha = 65^0$ optimum angles as derived from GBM timing analysis of X-ray binary Her-X1 (P ~ 1.0 s)



- Phase folding of selected bary-centered count-rate data on proper timing model (Aug. 2008 – Dec. 2010; 2.3 y)

Source	Start [MJD]	End [MJD]	Screened exposure (Ms)
4U 0142+614	54690	55496	41.686
1RXS J1708-4009	54690	55516	40.505
1E 1841-045	54690	55524	51.106
1E 1547.0-5408	54855	54890	1.5673

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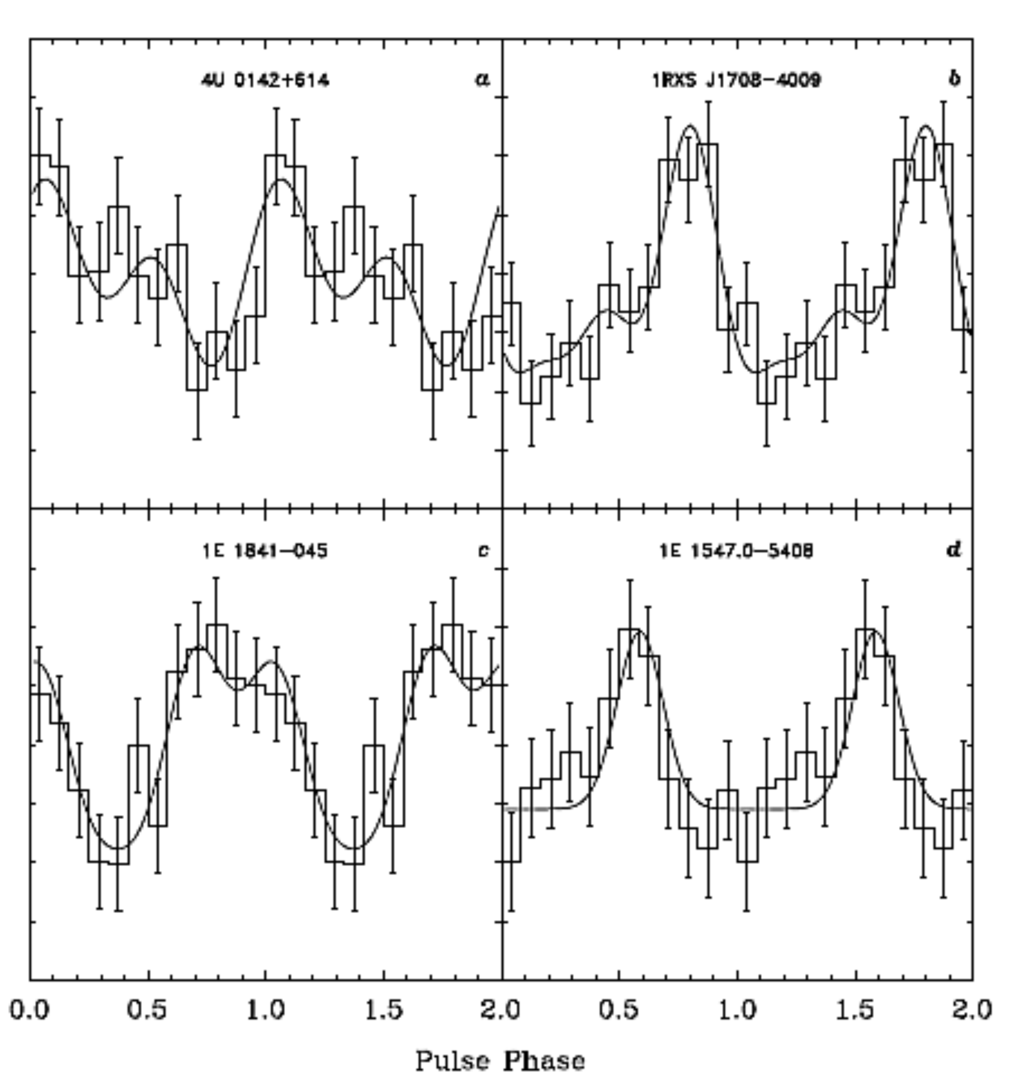
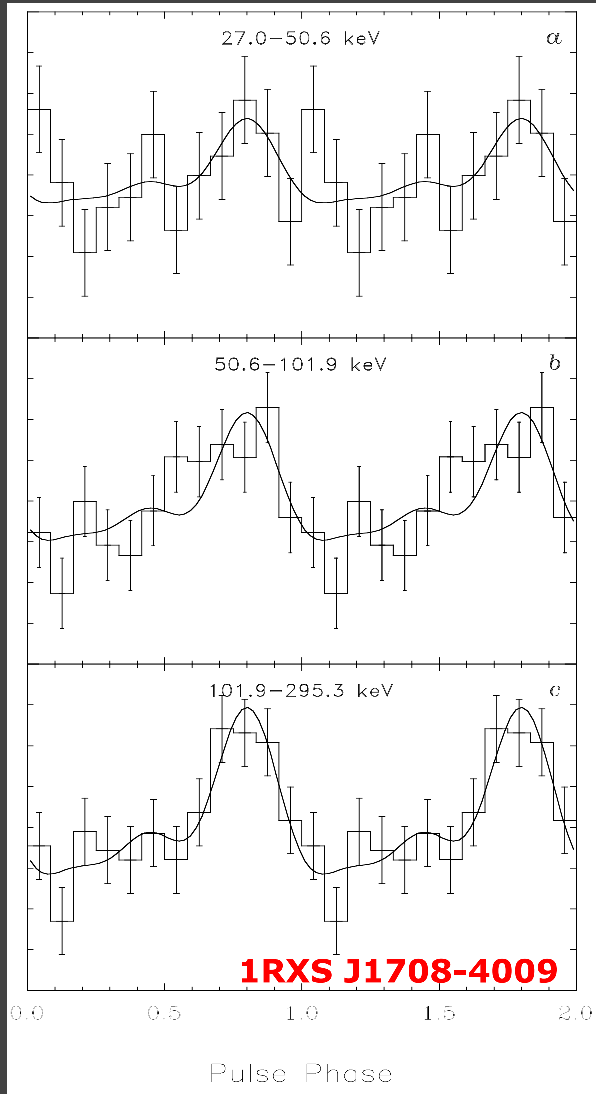
Fermi GBM results on AXPs



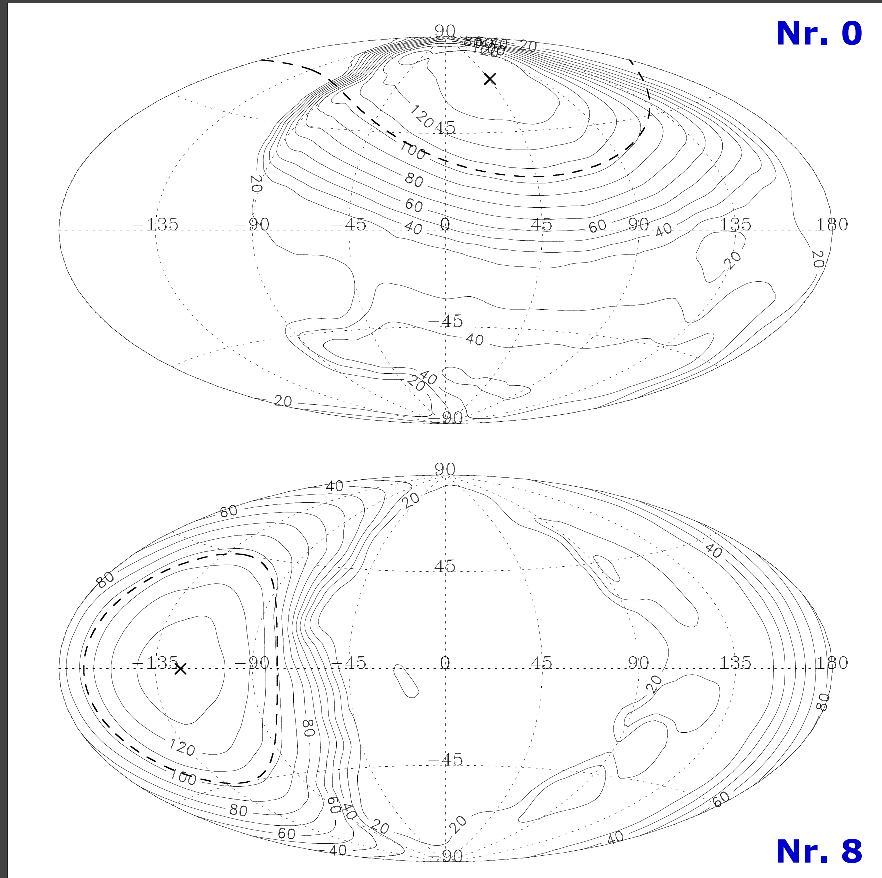


GBM pulse-profiles: Sum of channels 2-4
~ 27-300 keV

From ① the extracted pulsed count rates per energy channel and ② the angular averaged response information

⇓

the photon spectrum can be reconstructed adopting certain model shape



Simulated instrument response for NaI detectors 0 and 8 (Kippen et al. 2007)

Power-law:

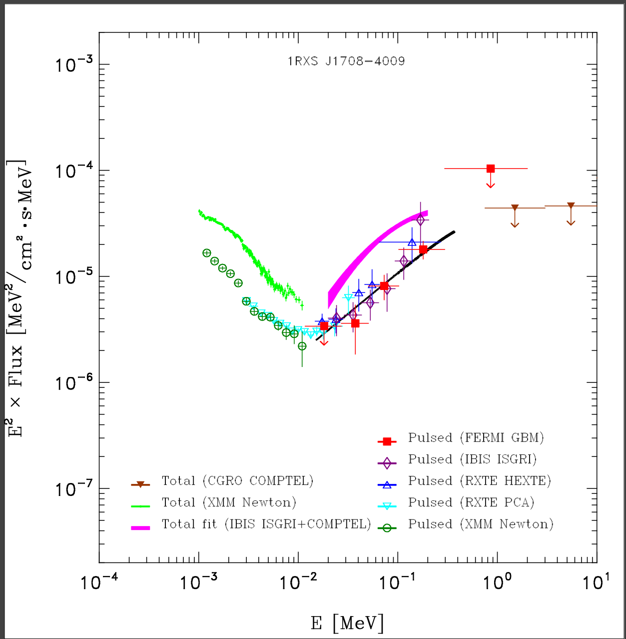
$$F(E) = F_0 \cdot (E/E_0)^{\alpha}$$

Power-law with super-exponential cutoff

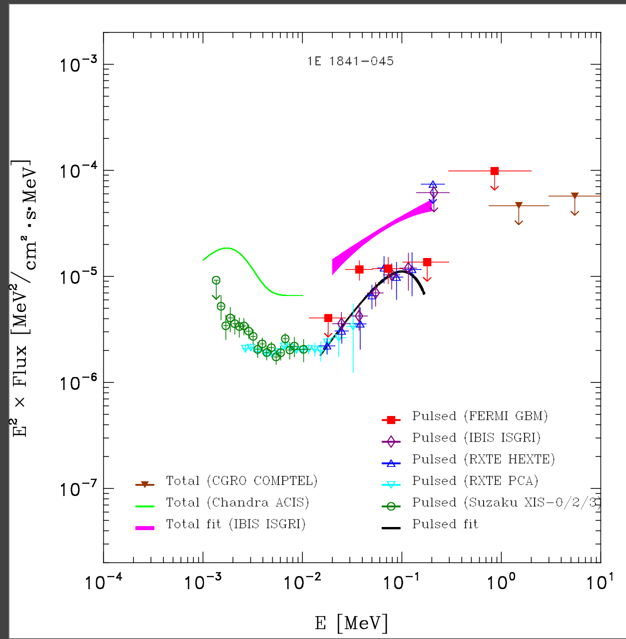
$$F(E) = F_0 \cdot (E/E_0)^{\alpha} \cdot \exp(-(E/E_c)^2)$$

(resembling the spectrum of model calculations by A. Beloborodov within his activated magnetar magnetosphere model – "J-bundle")

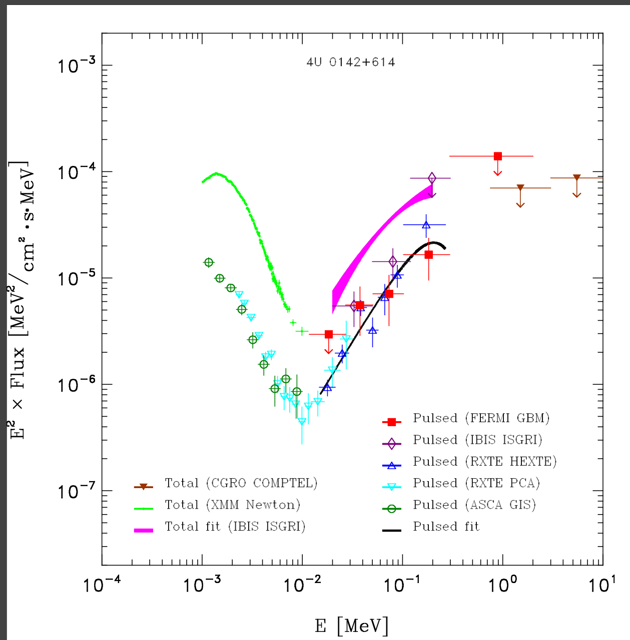
Total and Pulsed high-energy spectra of persistent AXPs



No break required (yet)
Lower limit: 429 keV



Break required at 125^{+26}_{-20} keV



Break required at 231^{+64}_{-52} keV

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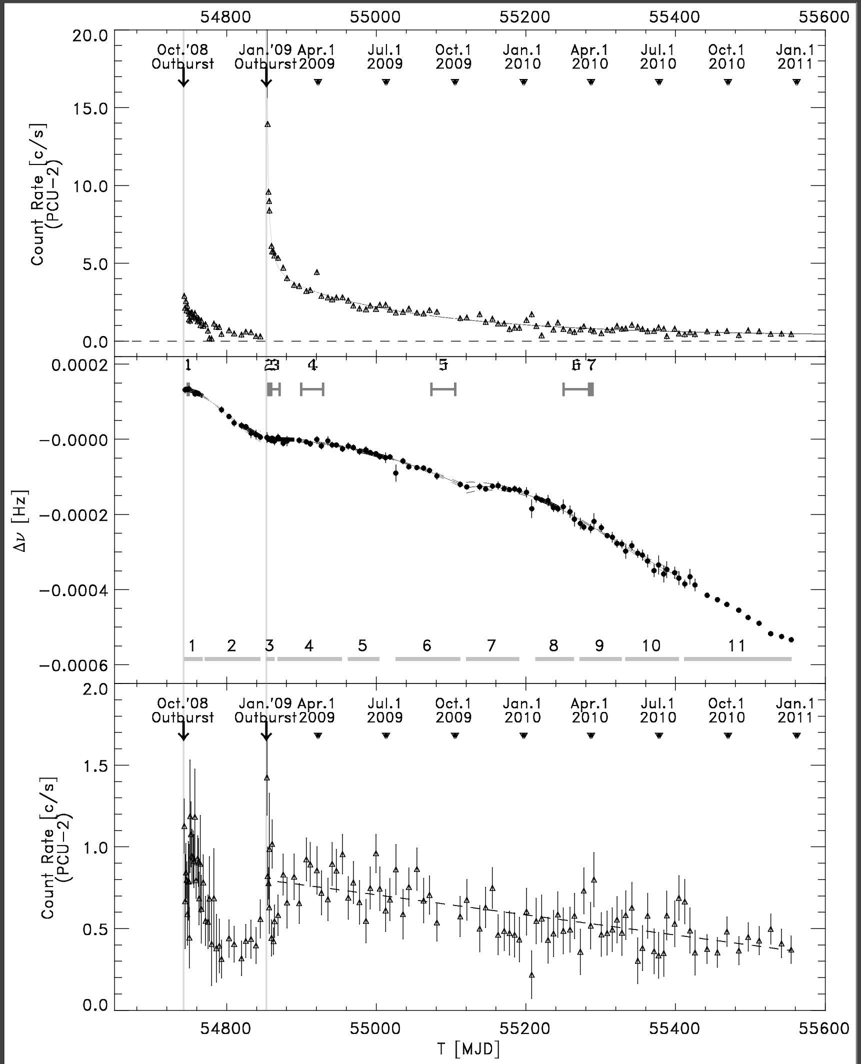
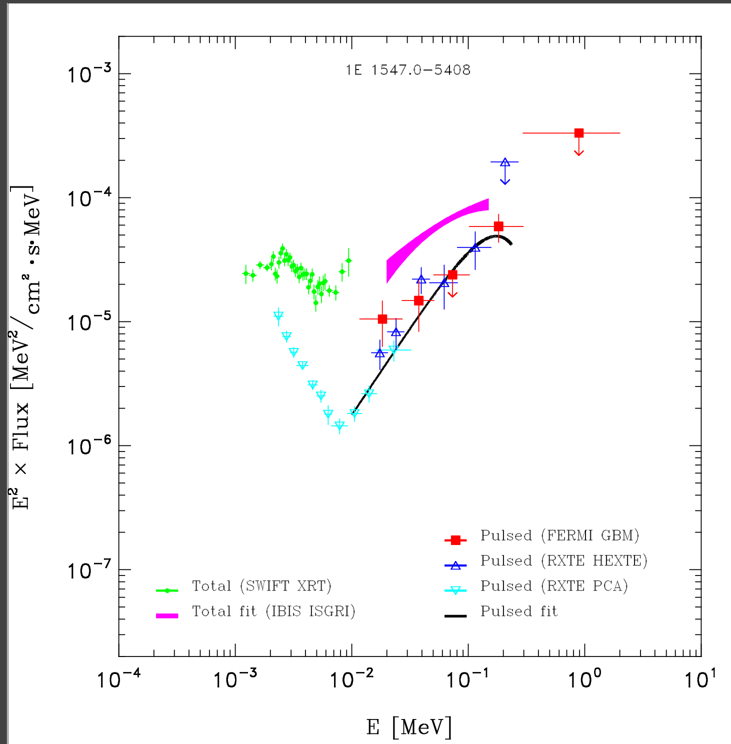
Transient "magnetar" 1E1547.0-5408





Break required at 207^{+64}_{-53} keV

Kuiper, Hermsen, den Hartog
and Urama et al. 2011 (submitted)

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Summary & Conclusions

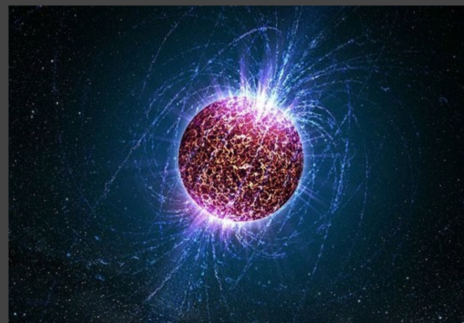
- Updated timing data for RXTE HEXTE and INTEGRAL ISGRI combined with (newly derived) Fermi GBM timing information yielded a significantly improved picture of the pulsed AXP spectrum at hard X-rays/soft γ-rays:

  1) 4U0142+614 $E_c = 231^{+64}_{-52}$ keV

  2) 1E1841-045 $E_c = 125^{+26}_{-20}$ keV

  3) 1E1547.0-5408 $E_c = 207^{+64}_{-53}$ keV

  4) 1RXS J1708-4009 $E_c > 429$ keV



  Pulsed fraction near 100 keV high, but not 100%!

- In future, instruments are required that are 10-50 x more sensitive than current generation detectors to map in detail the spectral shape in the break region → underlying emission process?

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