Magnetars and the High-B Pulsars Connection

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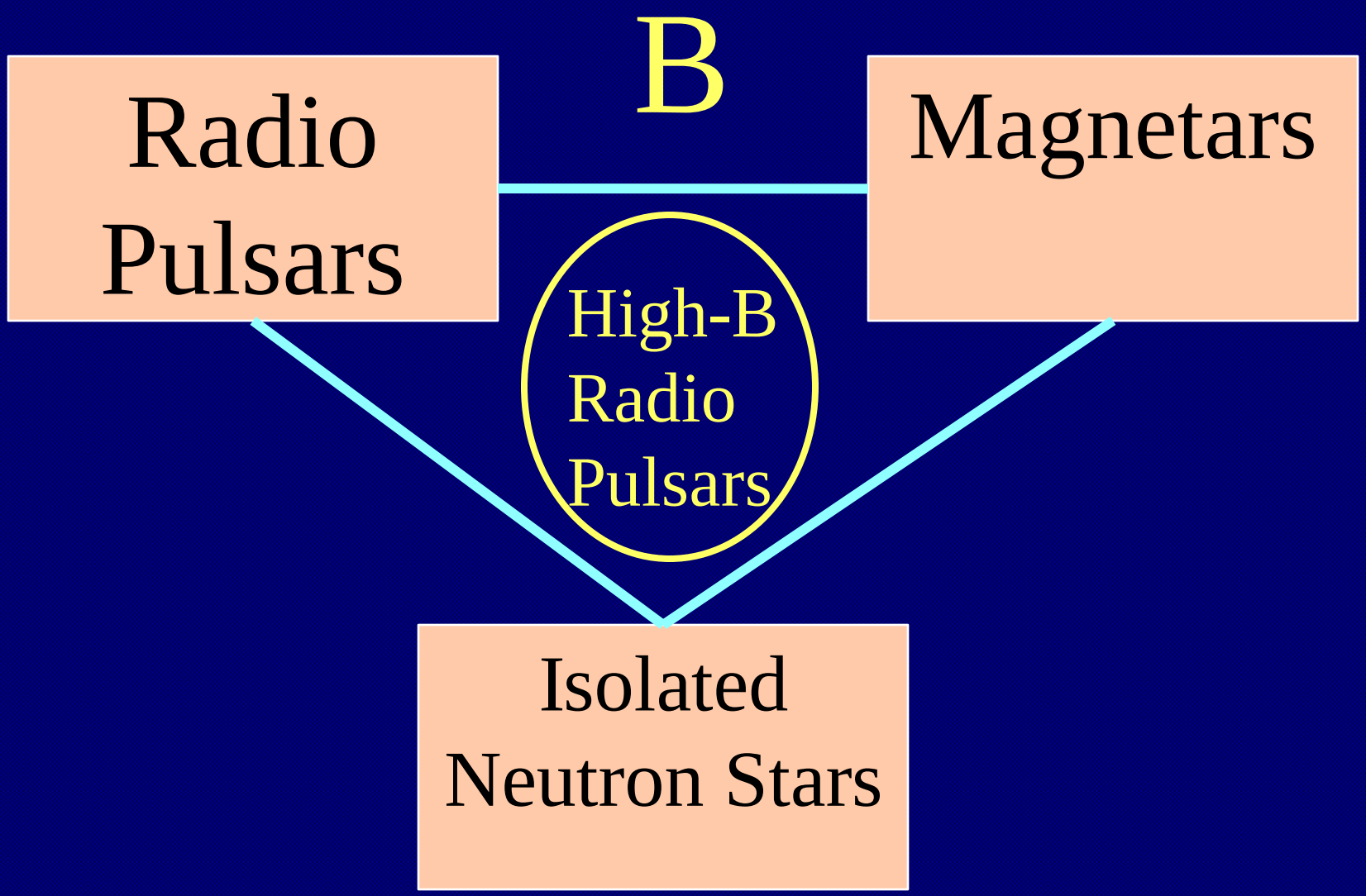
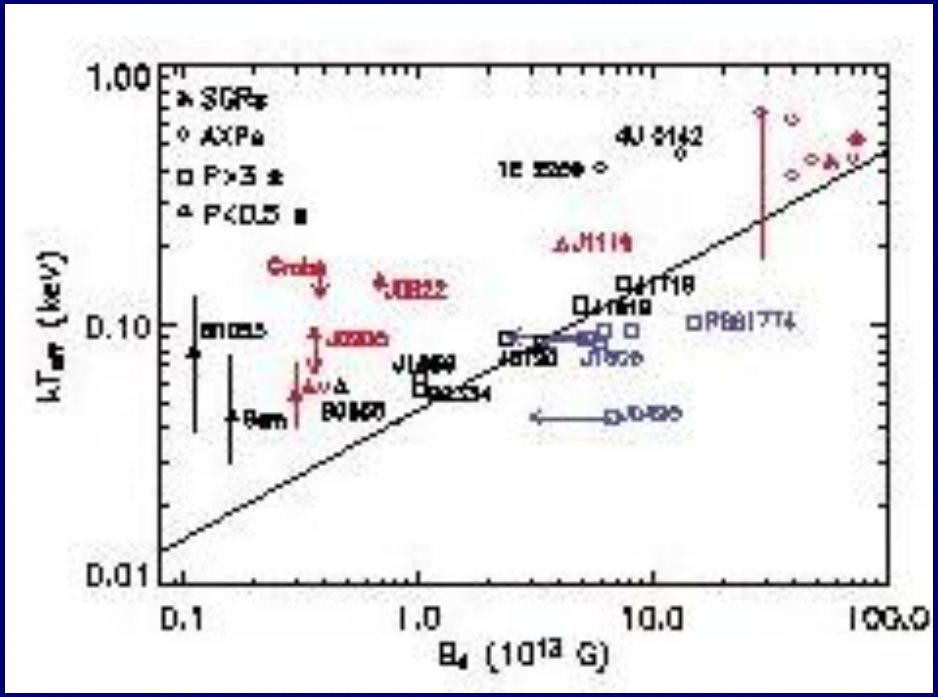
others…

GRAND UNIFICATION THEORY

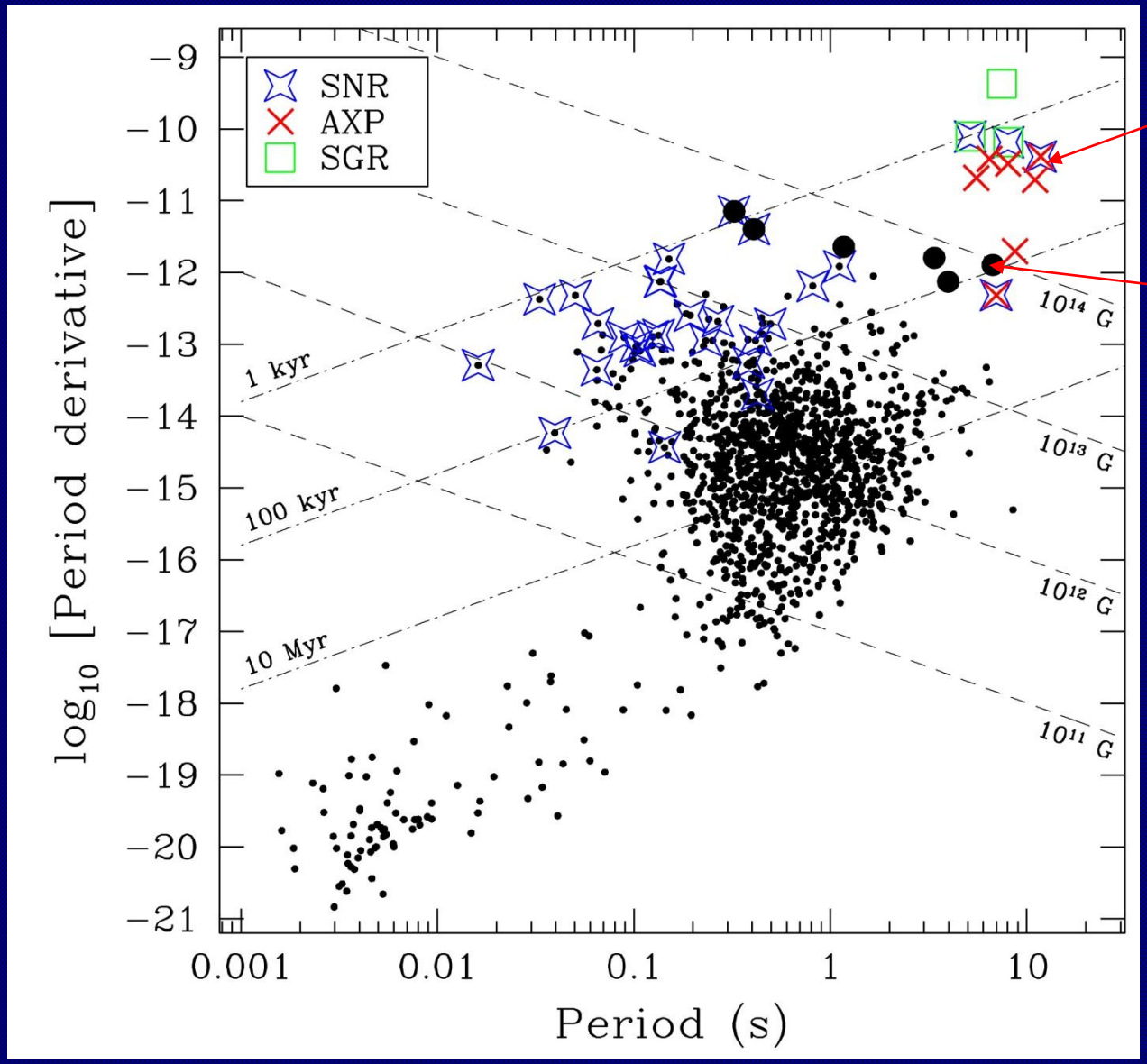


Unification?



Pons et al. 2007

P-Pdot Diagram



SGRs, AXPs

Radio Pulsars

Progress in a Decade

- Parkes MB survey discovers PSR J1814-1744 (B = 5.5e13 G), J1119-6127 (B=4.1e13G) by Camilo et al. 1999
- Pivovaroff, Kaspi & Camilo (2000): PSR J1814-1744: no X-ray emission, >10x fainter than other known AXPs
  - Paper originally rejected from ApJ!

Anonymous ApJ Review: Aug 12, 1999

"I believe this paper contains neither substantive new observational nor theoretical results for publication in the Astrophysical Journal… It is not clear if the analogy between PSR J1814-1744 and 1E 2259+586 is valid. Because, first of all, PSR J1814-1744 is a radio pulsar, while 1E 2259+586 is radio-quiet pulsar, without considering their X-ray properties. … There is no solid evidence that this object is similar to that of AXP…"

We have come very far.

High-B Radio Pulsars

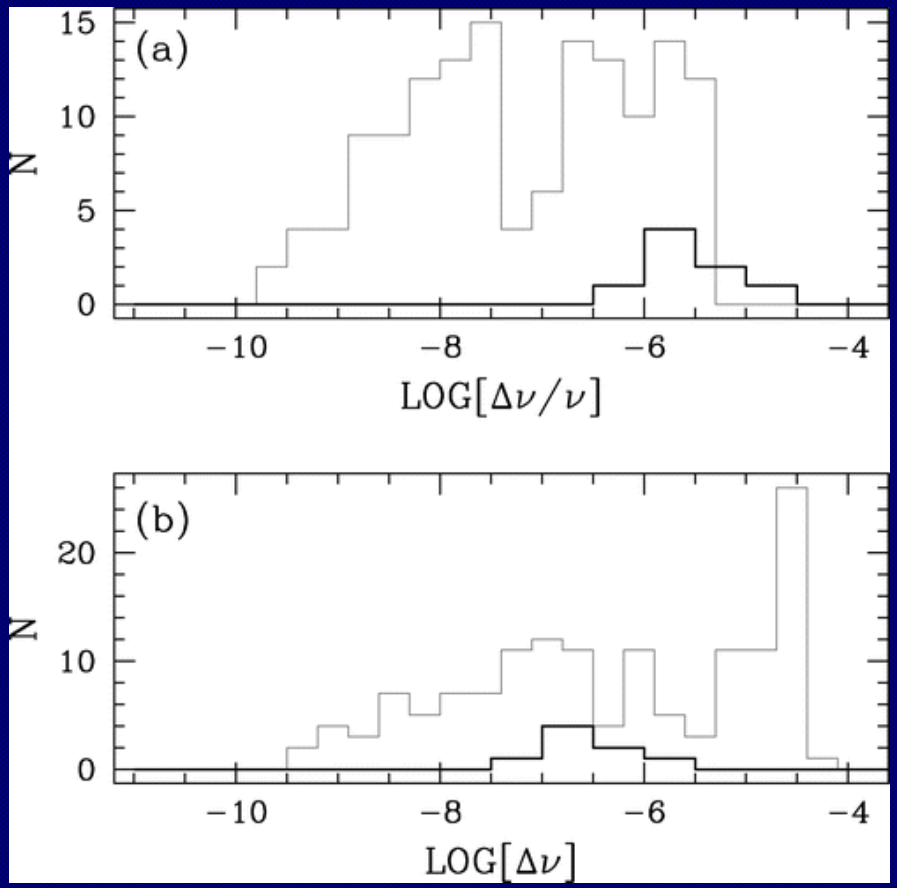
- My language:
  * “radio pulsar” = “rotation-powered pulsar”
  * “high B” = B > 4e13 G (Bqed=4.4e13G)
- B estimated from P, Pdot: uncertain
  - Spitkovsky (2006) suggests at worst factor of ~2 (at least for stable sources)
  - Thompson, Lyutikov & Kulkarni (2002) suggest could be overestimated due to global field twist

High-B Psrs vs Magnetars

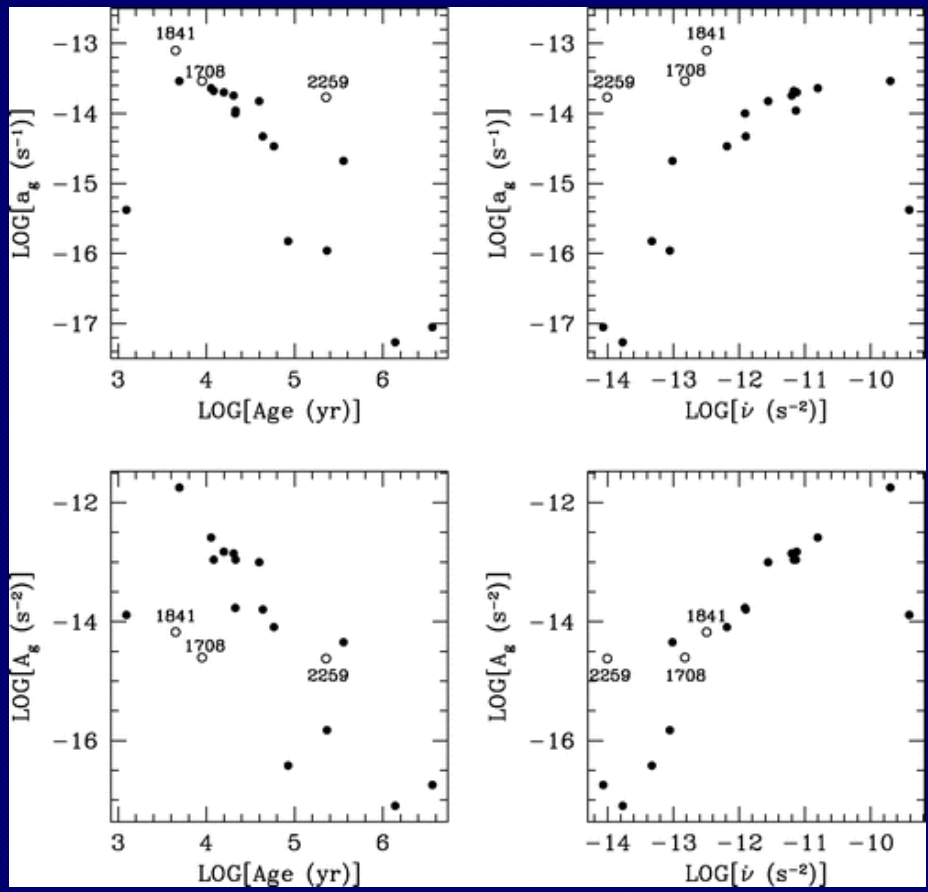
- Overlap in spin properties?
  - YES! Overlap in P, Pdot, glitches, timing noise

Glitches: AXP vs Radio Pulsar

Glitch amplitude



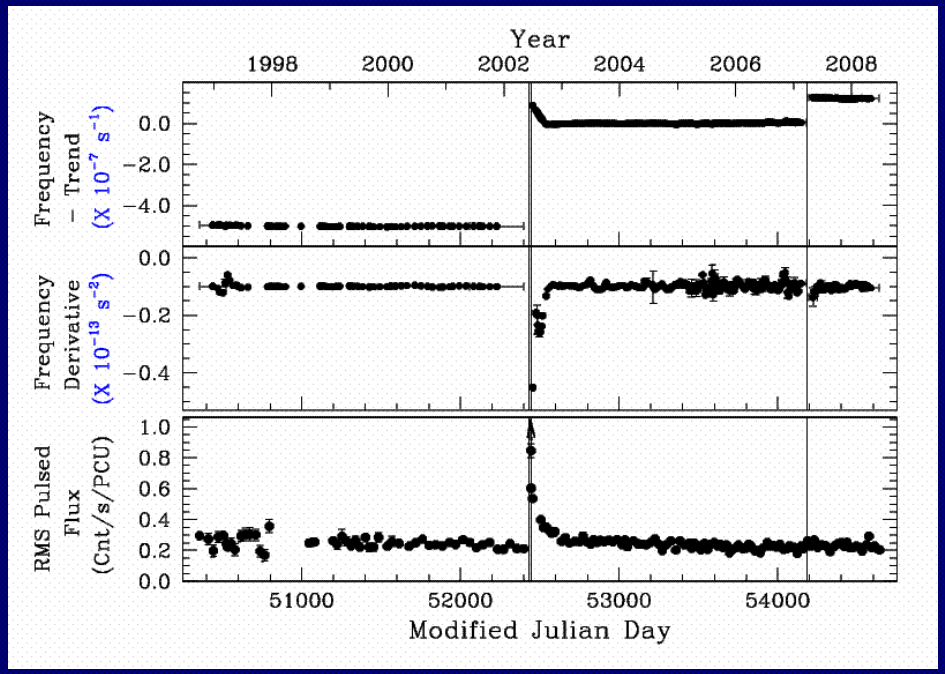
Glitch activity



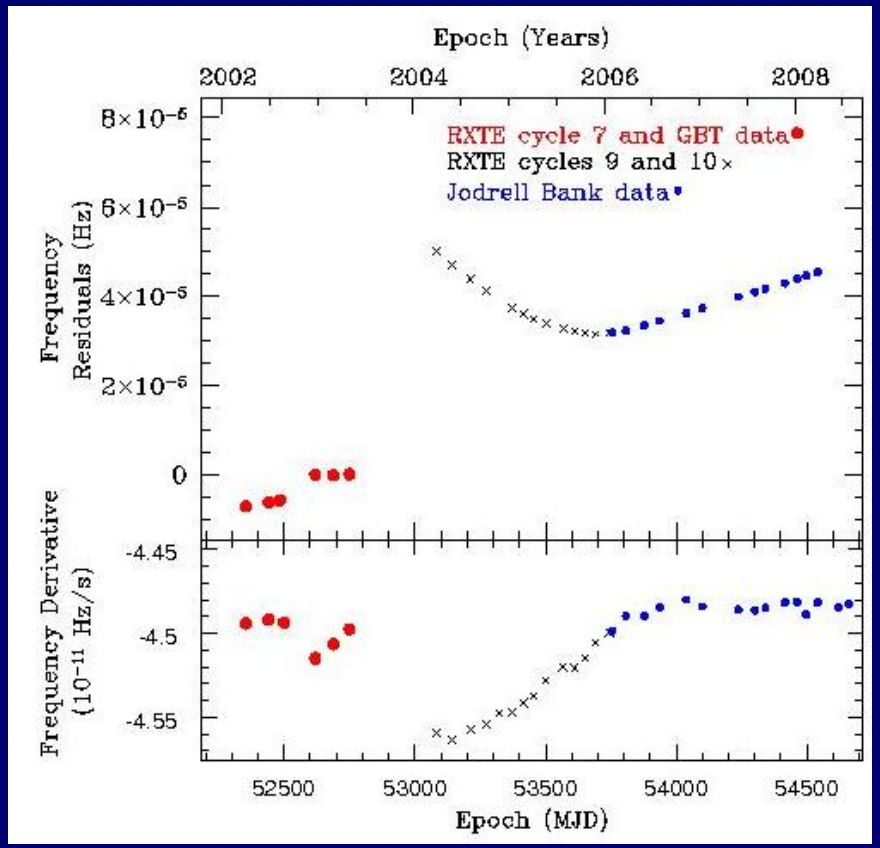
Dib, VK, Gavriil 2008

Timing Noise: AXPs vs Radio Pulsar

AXP 1E 2259+586



Radio Pulsar J0205+6449



Livingstone et al. 2009

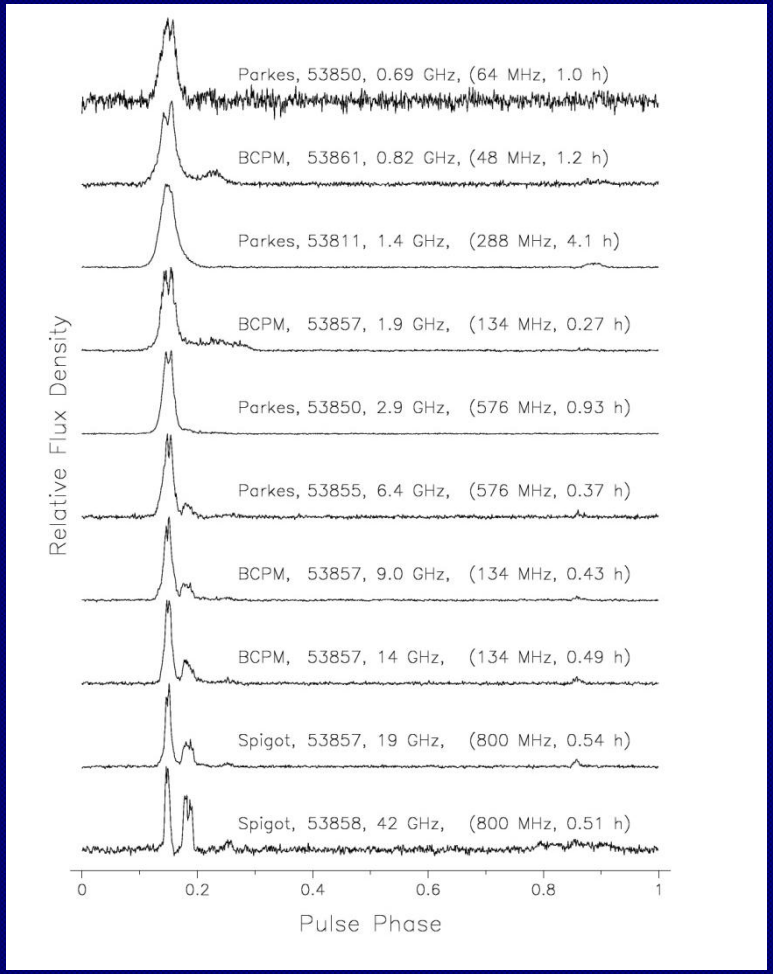
High-B Psrs vs Magnetars

- Overlap in spin properties?
  - YES! Overlap in P, Pdot, glitches, timing noise
- Can magnetars produce radio emission?
  - YES! but intermittent, variable, broad pulses, very flat spectrum, only from transient sources so far (see Thompson 2008)

Radio Pulsations from an AXP!

XTE J1810-197

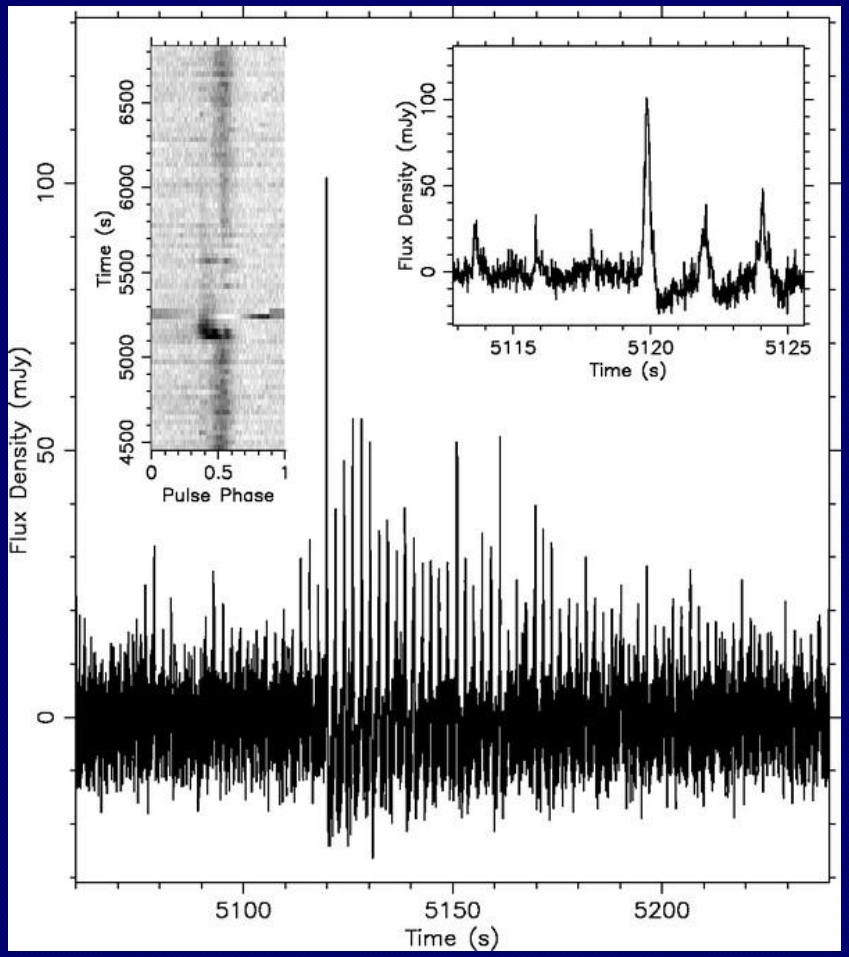
- Very flat spectrum
- Brightest “radio pulsar” at 22 GHz…why?
- Detected up to 44 GHz
- Very variable radio emission, fading…why?
- Related to transient nature?



Camilo et al Nature, 2006

More Radio Pulsations from Magnetars!

- 1E 1547.0-5408
- Transient, variabile, flat spectrum, broad pulses
- Reappeared after Jan 22 outburst (Burgay et al. 2009)



Camilo et al. 2007

High-B Psrs vs Magnetars

- Overlap in spin properties?
  - YES! Overlap in P, Pdot, glitches, timing noise
- Can magnetars produce radio emission?
  - YES! but intermittent, variable, broad pulses, very flat spectrum, only from transient sources so far (see Thompson 2008)
  - Search for radio pulsations/bursts from persistent magnetars (Burgay et al. 07; Crawford et. al. 07; P. Lazarus, work in prep.)

High-B Psrs vs Magnetars

- Can radio pulsars produce “anomalous” X-rays?
  - YES! One unambiguous event from Kes 75 pulsar
  - Other possible “hints”

Moderate B Radio Pulsars

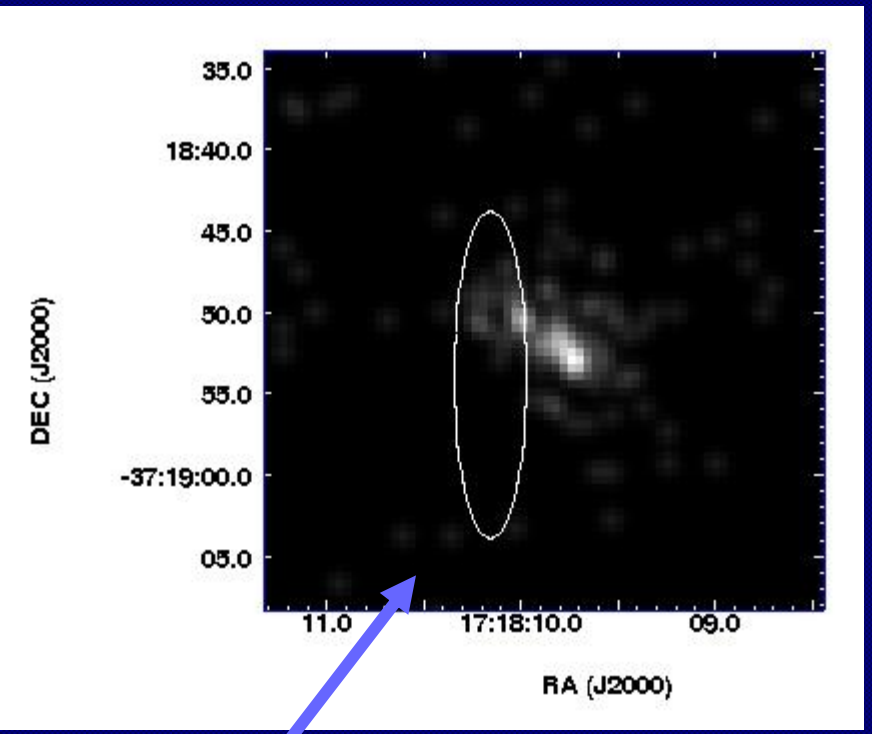
- 1e13 G < B < 4e13 G
- Experiment: for long-P, low Edot, nearby sources, look at thermal X-ray emission
- PSR B0154+61 (Gonzalez et al. 2004):
  - P=2s, B=2.1e13 G, 2.2kpc; no XMM detection (31ks)
- PSR B1916+14 (Zhu et al. in prep.):
  - P=1.2s, B=1.6e13 G, 1.9kpc; PRELIM. kT~0.17 keV in XMM ~10 ks; more XMM obs soon(?)

High-B Radio Pulsars

	Name	P (s)	Pdot	B (G)	D (kpc)
x	J1119-6127	0.4	4.1e-12	4.1e13	8.4
x	J1718-3718	3.4	1.6e-12	7.4e13	4.9
?	J1734-3333	1.2	2.3e-12	5.2e13	7.4
n	J1814-1744	4.0	7.4e-13	5.5e13	9.8
x	J1819-1458	4.3	5.7e-13	5.0e13	3.6
x	J1846-0258	0.3	7.1e-12	4.8e13	6
n	J1847-0130	6.7	1.3e-12	9.3e13	8.4

PSR J1718-3718

- P=3.4 s, B=7.4e13G, D=4.9 kpc
- 50 ks archival Chandra/ACIS obs
- Pulsar 7’ off axis



- formal positional offset: 0.2σ in DEC, 1.6σ in RA
- does not account for CXO pointing offset or timing noise
- Chandra log N-log S (0.5-2 keV Grindlay et al. 2003) says probability of chance < 1%
- NEW: upcoming 130 ks Chandra observation

VK & McLaughlin 2005

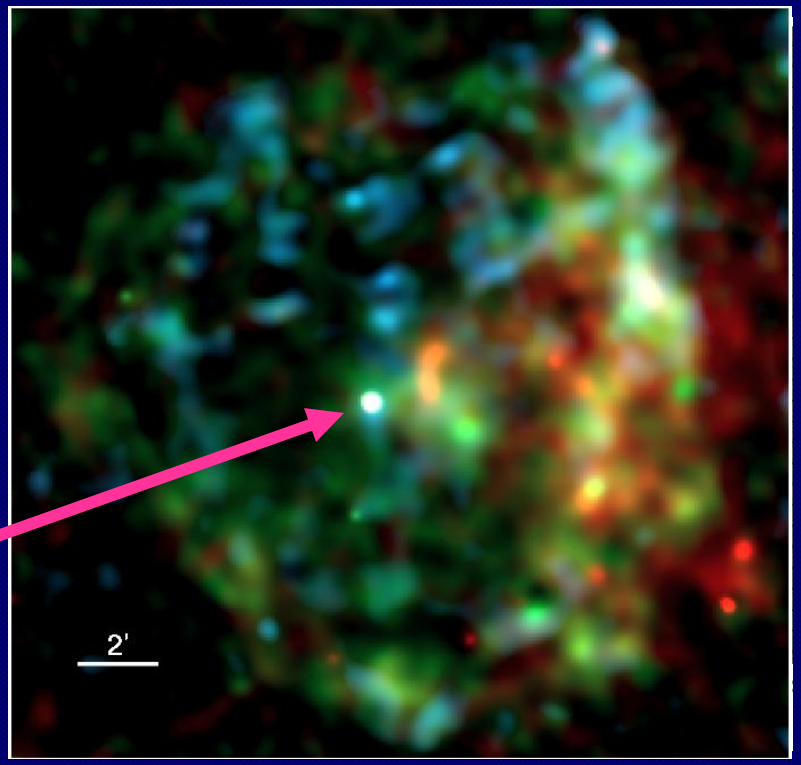
PSR J1718-3718

- Spectrum, flux:
  - Consistent with initial cooling
  - Lx > 3 orders of magnitude fainter than for any known persistent AXP
  - …**but** consistent with transient AXP in quiescence…

"This raises the interesting possibility that PSR J1718-3718, and other high-B radio pulsars, may one day emit transient magnetar-like emission, and conversely that the transient AXPs might be more likely to exhibit radio pulsations." (VK & McLaughlin 05)

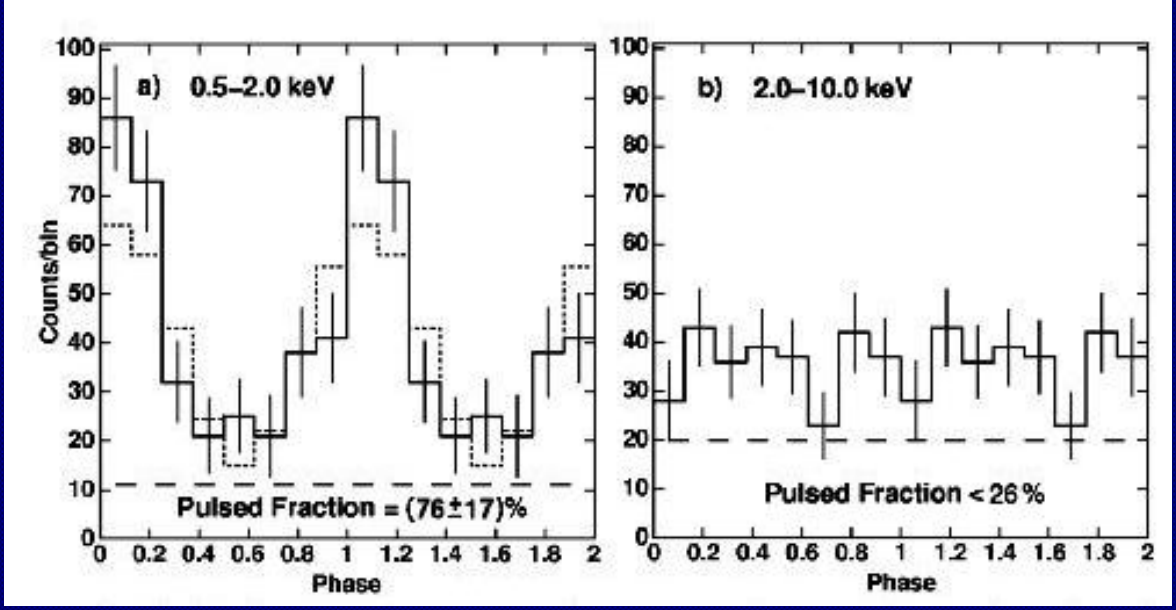
PSR J1119-6127:

- P=0.4 s, $\dot{P}$=4.1e13 G, n=2.9 (Camilo et al. ‘99)
- P/2$\dot{P}$=1.7 kyr
- At center of SNR G292.2-0.5
- SNR X-ray detected by XMM (Gonzalez et al, 2005)



PSR J1119-6127:

- 50 ks XMM-Newton observation of pulsar
- X-ray pulsations detected at radio period
- Pulsations only seen for E<2.0 keV: **thermal emission** (youngest!)

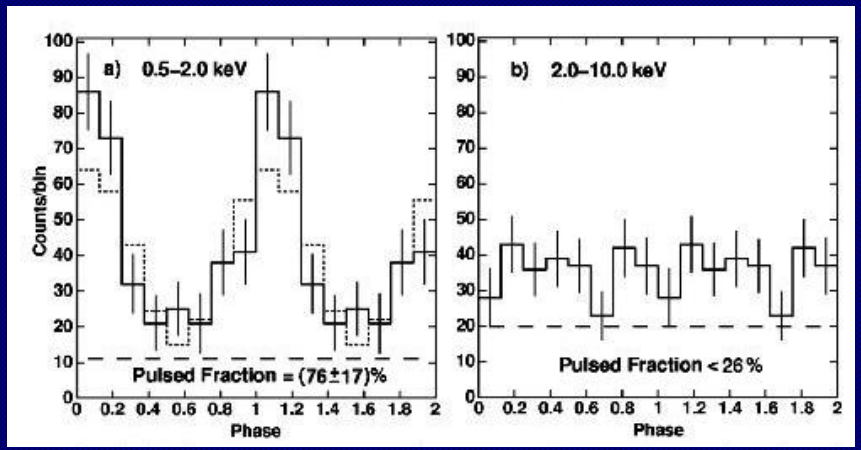


Pulsed Fraction: (74+/- 14)%

Gonzalez et al. 2005

PSR J1119-6127:

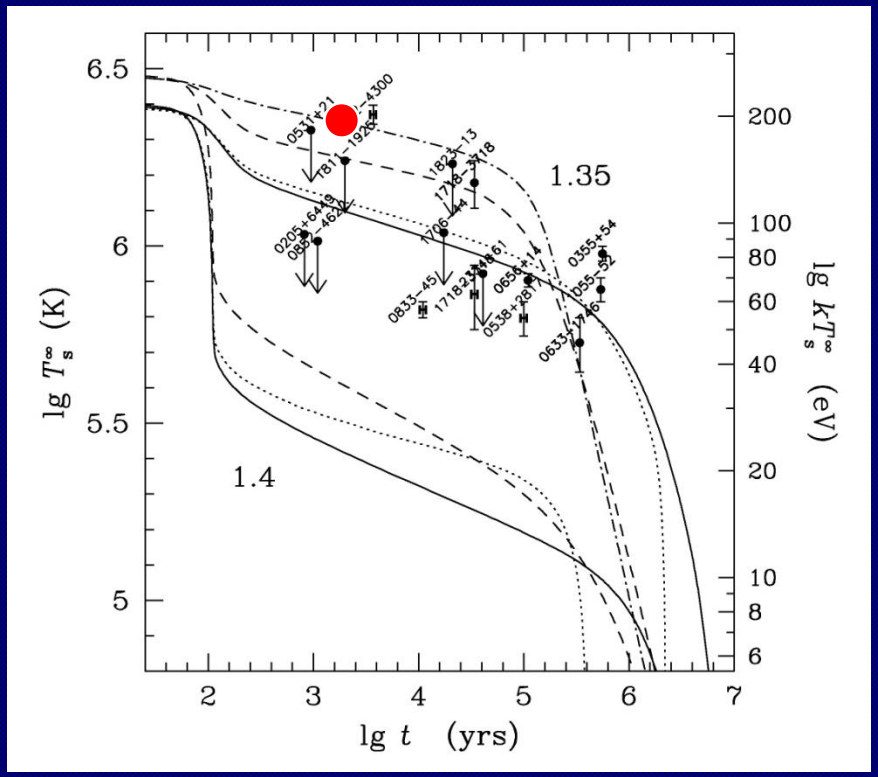
- Surface thermal emission, from initial cooling, should have:
  - Sinusoidal pulse profile from GR light bending
  - Low pulsed fraction, <37% for passively cooling neutron star with high B, no hot spots (Dedeo & Psaltis 2004)
- Here, pf=74+/-14%, profile non-sinusoidal
- AXPs have high pulsed fractions, non-sinusoidal profiles…
- But see Zavlin (2007); Safi-Harb & Kumar (2008)
- Need more data!!



PSR J1119-6127:

- Blackbody temperature is high!

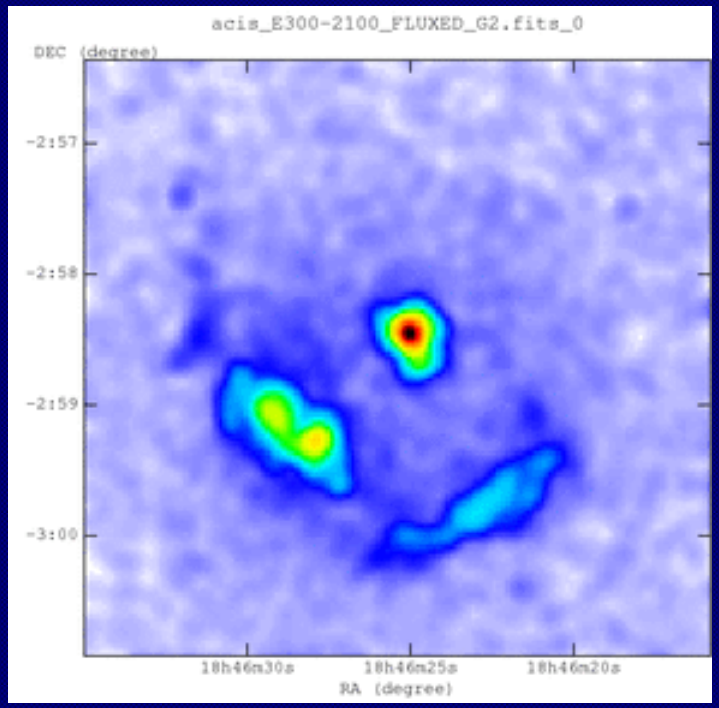
$$T = 2.4^{+0.3}_{-0.2} \times 10^6\ K$$



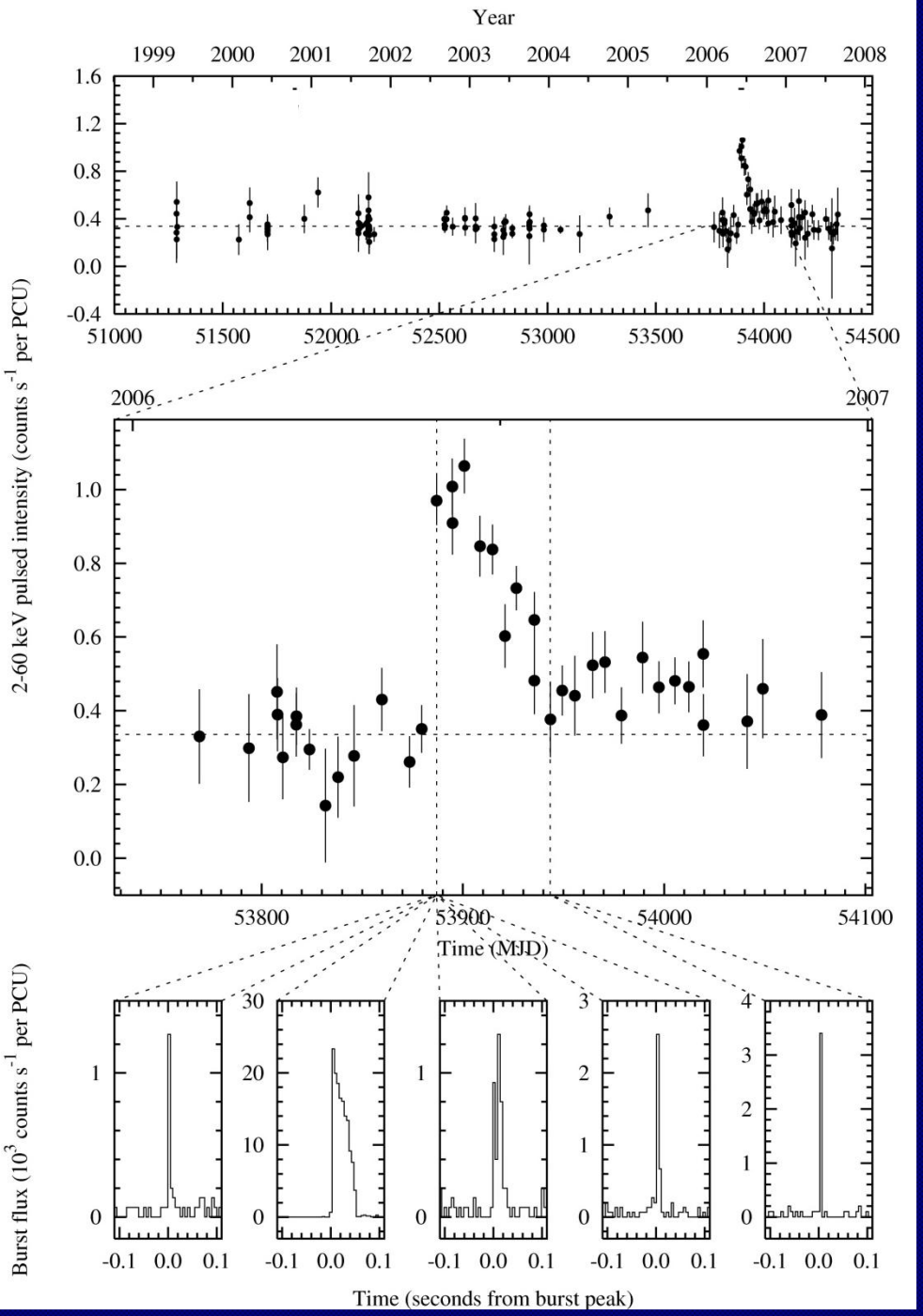
Of known young (<2 kyr) rotation-powered pulsars, this is the hottest, by far.

Quiescent Magnetar??

PSR J1846-0258



- 0.3 s pulsar in SNR Kes 75
- Youngest known: 884 yr
- *Bona fide* **rotation-powered**:
  - $L_X << \dot{E}$
  - Power-law X-ray spectrum
  - Pulsar wind nebula
  - Normal timing properties, including n=2.65, as measured by RXTE monitoring (Livingstone et al. 2006)
- Interestingly, not detected in radio with 4.9 uJ upper limit at 1.9 GHz, among faintest 1% of known radio pulsars (Archibald et al. 2008)



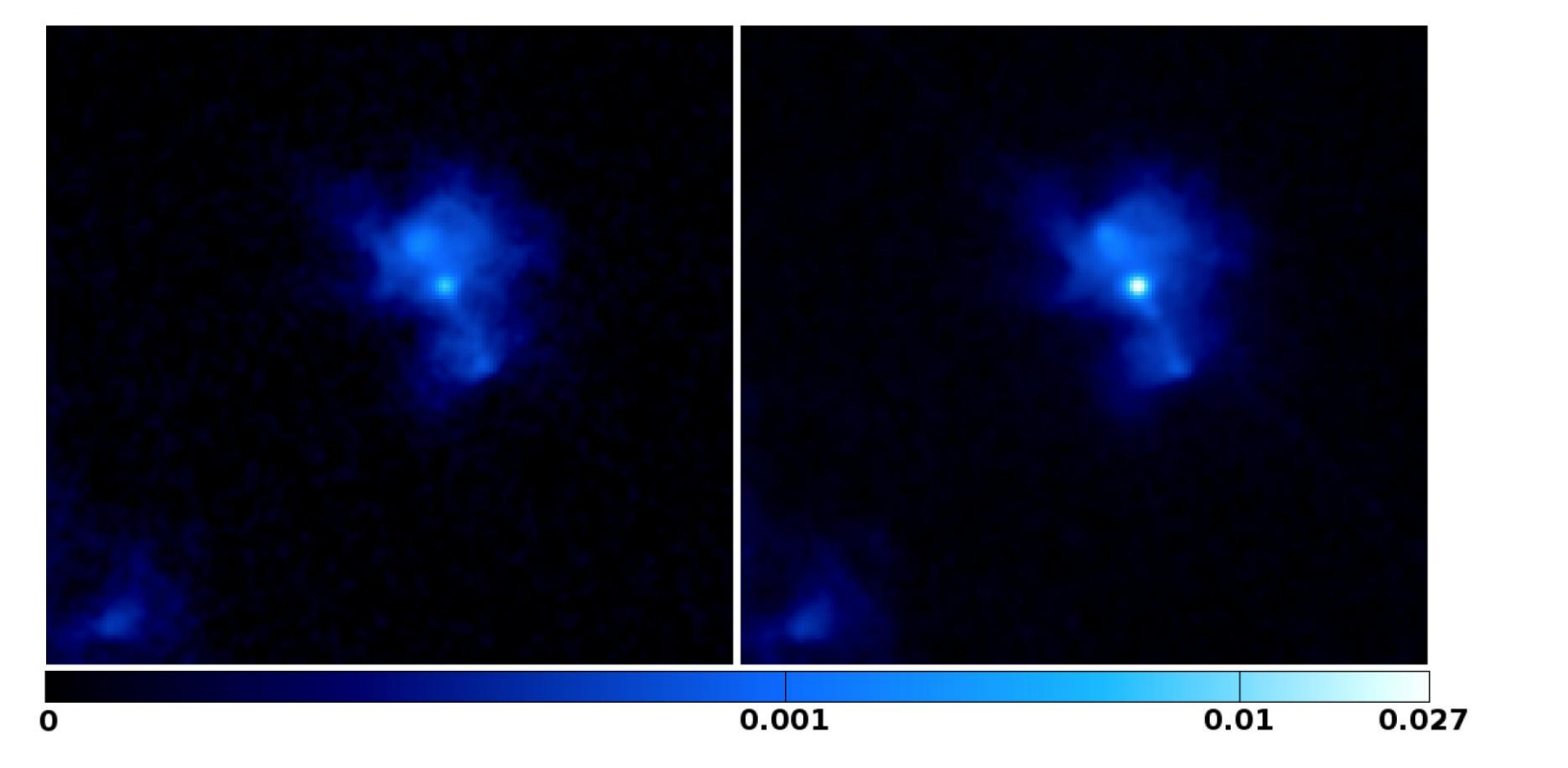
Magnetar-like Behavior in a Rotation-Powered Pulsar

Very fortuitously, Chandra X-ray Observatory observed Kes 75 during the outburst.

Gavriil et al., Science, 2008

Chandra Observations of Kes 75

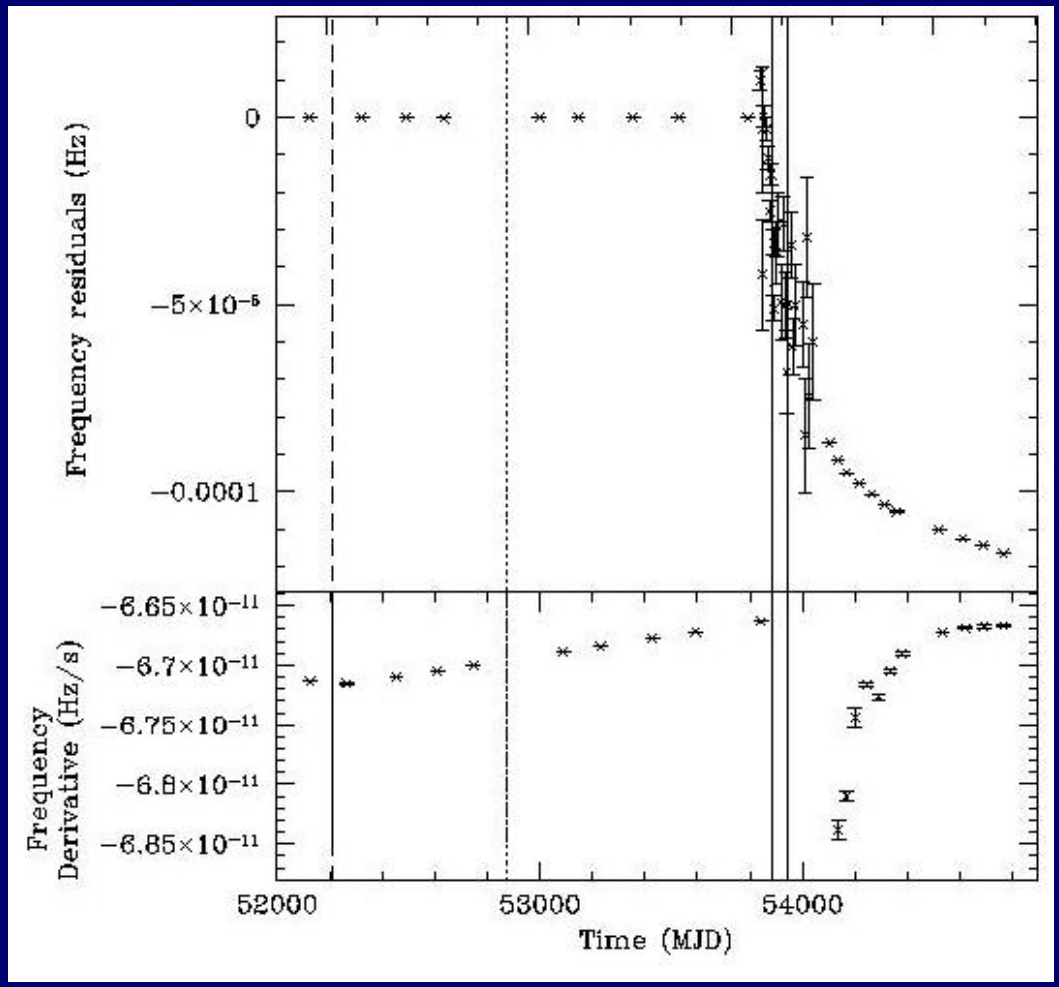
Images by M. Gonzalez



Gavriil et al., 2008;
see also Kumar & Safi-Harb 2008; Ng et al. 2008.

Timing Anomaly in PSR J1846-0258

- Pulsar had spin-up glitch (df/f~4e-6) followed by strong spin-down
- Net effect: large spin-down df/f = 5e-5
- Similar to that in SGR 1900+14 (Thompson et al. 2000); also in AXP 0142+61 (Gavriil et al. in prep.)
- Interesting glitch behavior in magnetars!
- New n soon…



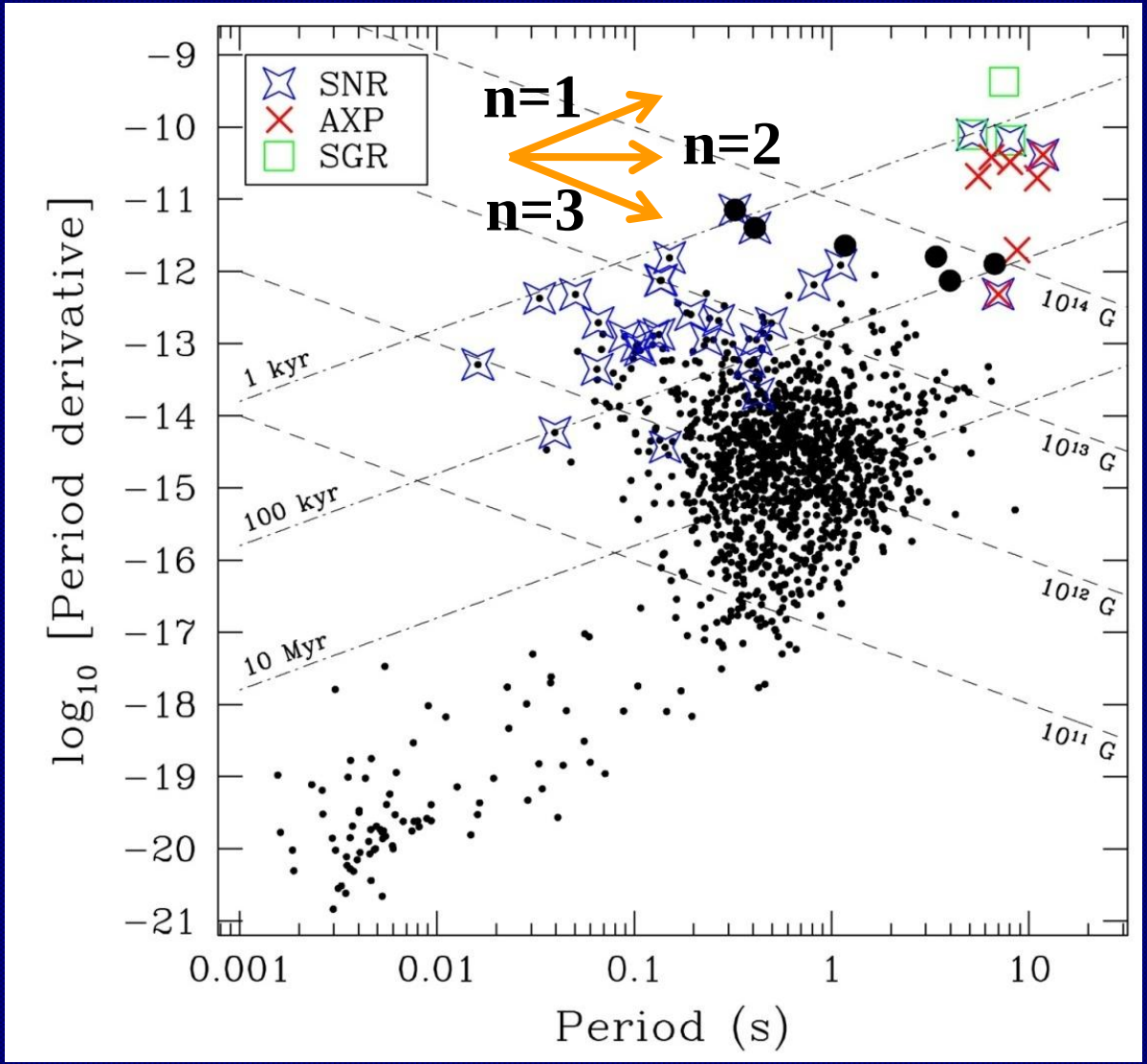
Livingstone et al. (in prep.)

Radio Pulsars Become Magnetars?

Braking index

$$n = 2 - \frac{P\ddot{P}}{\dot{P}^2}$$

- Vela: n=1.4(2)
- new pulsar has n=1.3715(77) (Kramer, Lyne)



Summary

- Natural magnetar model predictions have been verified:
  - Periodicities, spin-down in SGRs
  - Bursts in AXPs
  - Radio emission from some magnetars
  - Magnetar-like emission from some high-B radio pulsars
- Important open questions:
  - Is B the "grand unification parameter" for radio pulsars, magnetars, INS?
  - Are there evolutionary relationships?
  - Do high-B radio pulsars evolve into magnetars?
  - Are INSs older high-B radio pulsars?
  - Do all high-B radio pulsars show occasional magnetar activity?
  - Why do only transient magnetars show radio emission?
  - Why is magnetar radio emission different from low-B radio emission?