AXP & SGR: “magnetars” or “Quactar”?

Do “magnetars” really exist?

1、 ***Basic observations***:

AXP(Anomalous X-ray Pulsars)

SGR: Soft Gamma-ray Repeaters

2. Magnetar: Challenge from

---Energy Budget

---Edot < LX

---B: radio & X-ray

---τc & τhost

3、 *“Magnetar” or* “Quarcstar”

Basic observations: **AXP**

- spin periods **P**: 2-- 12 s , 10 Know
- $P_{dot} \approx 10^{-13}$ **to** 10^{-11} s/s, spinning down
- Large timing noise
- $E_{dot} < L_X$
- spin down **time scales**: 10^3—10^5 yr
- very **soft** X--ray spectra
- **lack** of bright optical counter parts
- SNR

Mereghetti, et al. astroph/0205122

Basic observations: **SGR**

- ***super-outbursts → 10^{44} reg/s***
  (low-energy gamma-ray and X-ray bursts)
- **Observations for AXP:**
  - **spin periods P: 5-- 8 s**
  - P_{dot} ≈ 10^−13 to 10^{-11} s/s
  - **Large timing noise**
  - $E_{dot} < L_X$
  - **soft X--ray spectra**
  - **secular spin down on time scales: 10^3—10^5 yr**
  - **lack of bright optical counter parts**
  - **SNR**

Mereghetti, et al. astroph/0205122

AXPs

- ~10 known
- X-ray pulsars, P=2-12 s
- Spinning down
- Timing noise, glitches
- 3 in SNRs
- Thermal+power-law spectra with sharp upturn >10 keV
- Large variability
- Bursts

SGRs

- ~6 known
- X-ray pulsars, P=5-8 s
- Spinning down
- Timing noise
- 1(?) in SNR
- Thermal+power-law spectra with moderate upturn > 10 keV
- Large variability
- Bursts
- Giant flares

Kaspi， 2009

AXP and SGR					
CXOU J010043.1−721134	8.02	$1.9\ 10^{-11}$	60	SMC	AXP [85, 96, 148]
4U 0142+61	8.69	$2\ 10^{-12}$	3.6	-	B, G? [73, 26]
1E 1048.1−5937	6.45	$(1–10)\ 10^{-11}$	8	-	B, G [139, 152, 46, 28]
1E 1547.0−5408	2.07	$2.3\ 10^{-11}$	5	G327.2–0.1	T, B, R [12, 64, 33, 106]
PSR J1622–4950	4.33	$1.7\ 10^{-11}$	9	-	R [88]
CXOU J164710.2−455216	10.6	$9.2\ 10^{-13}$	3.9	Westerlund 1	T, B, G [114, 71]
1RXS J170849.0−400910	11.0	$2.4\ 10^{-11}$	5	-	G [141, 72, 18, 27]
XTE J1810−197	5.54	$(0.8–2.2)\ 10^{-11}$	3.1	-	T, B, R [70, 13, 163, 9]
1E 1841−045	11.77	$4.1\ 10^{-11}$	8.5	Kes 73	G [159, 49, 111, 27]
1E 2259+586	6.98	$4.8\ 10^{-13}$	4	CTB 109	B, G [39, 80]
AX J1844.8–0256	6.97	-	8.5	G29.6+0.1	candidate, T [160, 142]
SGR 0418+5729	9.1	$<1.1\ 10^{-13}$	2	-	T, B [155, 34]
SGR 0501+4516	5.76	$7.1\ 10^{-12}$	1.5	-	T, B [131, 4, 30]
SGR 0526−66	8.05	$6.5\ 10^{-11}$	55	LMC, N49	B, GF [95, 93, 149]
SGR 1627−41	2.59	$1.9\ 10^{-11}$	11	-	T, B [165, 103, 37, 32]
SGR 1806−20	7.6	$(8–80)\ 10^{-11}$	8.7	star cluster	B, GF [82, 120, 109, 162]
SGR 1833–0832	7.6	$7.4\ 10^{-12}$	10	-	T, B [55, 38]
SGR 1900+14	5.2	$(5–14)\ 10^{-11}$	15	star cluster	B, GF, G? [94, 164, 104]

Models

$E_{dot} < L_X$

==➔

1) **Accretion => energy**
2) **B => energy: Magnetar**
3) **Glitch NS => energy**
4) **Quark star => energy**

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Energy Budget: persistent X-ray radiation

$$E_x > 3 \times 10^{47} erg\left(\frac{\tau_c}{10^5 yr}\right)\left(\frac{L_x}{10^{35} ergs^{-1}}\right)$$

$$E_B \approx \left(\frac{B^2}{8\pi}\right)\left(\frac{4\pi R^3}{3}\right)$$

$$E_x = \xi E_B$$

$$\xi \ll 1$$

as $\xi = 1$, when $B = 10^{15} G$,
then $E_x = 1.7 \times 10^{47} ergs$.
Take Neutrino & giant flares:
$\Rightarrow B > 10^{16} G$.
How about $\xi \ll 1$?

SGR 0418+5729

$B_{dip} \leqslant 7.5 \times 10^{12} G.$

D=2kpc, $L_x = 6.2 \times 10^{31} erg/s$,

$\tau_c = 24 Myr$, from

$$B^2 \simeq 6 L_x \tau_c / R^3$$

$B_{tor} = 5 \times 10^{14} G.$

How about $\xi \ll 1$?

B_{tor} can be as large as you like?

Challenge to magnetar

- Radio pulsar J1847-0130

  PSR J1718-3718

  B～**9.4 × 10^13 G** ;

  B～7**.4 × 10^13 G**

- Anti-Magnetar:

  PSR J1852+0040

  Lx = 18 E_dot

  Lx > E_dot

  Bs = 3.1×10^10 G

----

strong B ≠》 X-ray radiation

E_{dot} < L_x ≠》 strong B

==============================

Radio: XTE J1810–197, AXP 1E 1547.05408

radio radiation ⇐/⇒ low B

Radio pulsar, magnetar, anti-magnetar

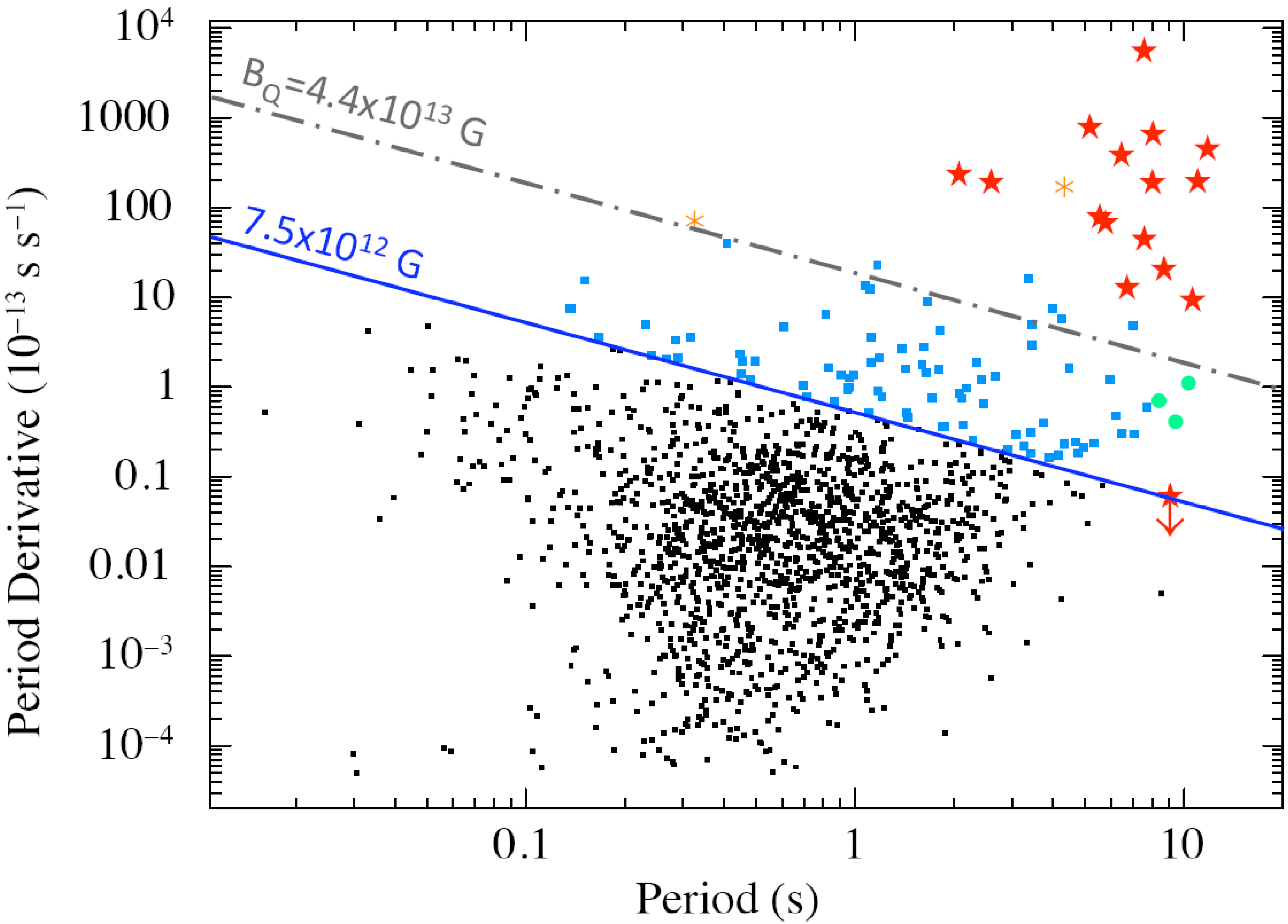
Name	P (s)	$\dot{P}$ (s·s^{-1})	τ_c (yr)	B_s (G)	Note
PSR J1847-0130	6.7	1.3e-12	8.2e4	9.4e13	High-B Radio PSR(a)
PSR J1718-3718	3.3	1.5e-12	3.5e4	7.4e13	High-B Radio PSR(b)
PSR J1814-1733	4.0	7.4e-13	8.6e4	5.5e13	High B Radio PSR(c)
SGR 0418+5729	9.1	1.1e-13	4.1e6	3.0e13	Magnetar, no radio (d)
1E2255+586	7.0	4.9e-13	2.3e5	5.9e13	Magnetar, no radio(e)
XTEJ1810-197	2.1	2.3e-11	1.4e3	2.4e14	Magnetar, radio(f)
1E 1547.0-5408	5.54	1.2e-11	7.6e3	2.6e14	Magnetar, radio(g)
PSR J1622-4950	4.3	1.7e-11	4e3	2.8e14	Magnetar? , radio(h)
PSR J1846-0258	0.324	7.1e-12	7.2e2	4.9e13	$L_X/\dot{E}_{\rm rot} = 0.05$,no radio(i)
PSR J1852+0040	0.105	8.7e-18	1.9e8	3.1e10	Anti-mag.$L_X/\dot{E} = 17.7$,no radio(j)

Qiao,Xu,Du, 2010, astro-ph: 0044740

Table 3 Rotation Powered Pulsars with B>4 10^{13} G.

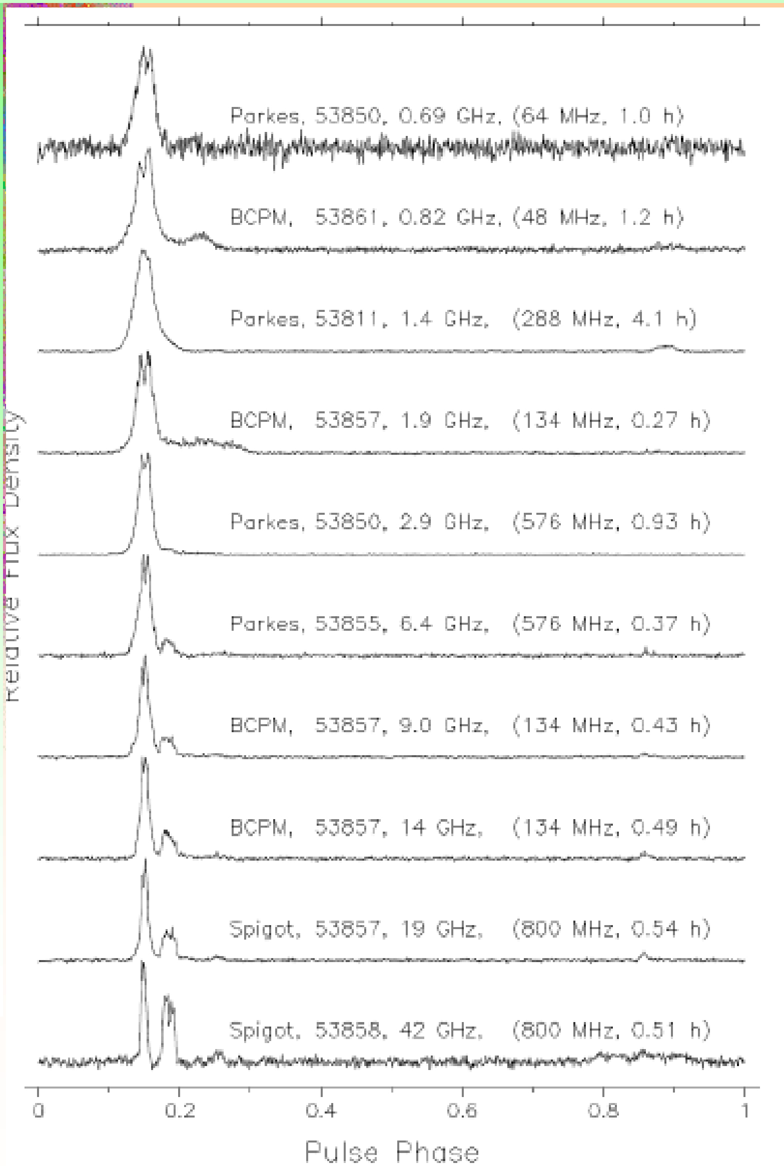
Name	Period (s)	$\dot{P}$ ($s\ s^{-1}$)	B (G)	L_x (erg s^{-1})	
J1847–0130	6.7	1.3 10^{-12}	9.4 10^{13}	<5 10^{33}	
J1718–3718	3.4	1.6 10^{-12}	7.4 10^{13}	6 10^{33}	
J1814–1744	4.0	7.5 10^{-13}	5.5 10^{13}	<2 10^{33}	
J1734–3333	1.2	2.3 10^{-12}	5.2 10^{13}	–	
J1846–0258	0.3	7.1 10^{-12}	4.9 10^{13}	4 10^{34}	in SNR Kes 75
J1119–6127	0.4	4.0 10^{-12}	4.1 10^{13}	3 10^{33}	in SNR G292.2–0.5

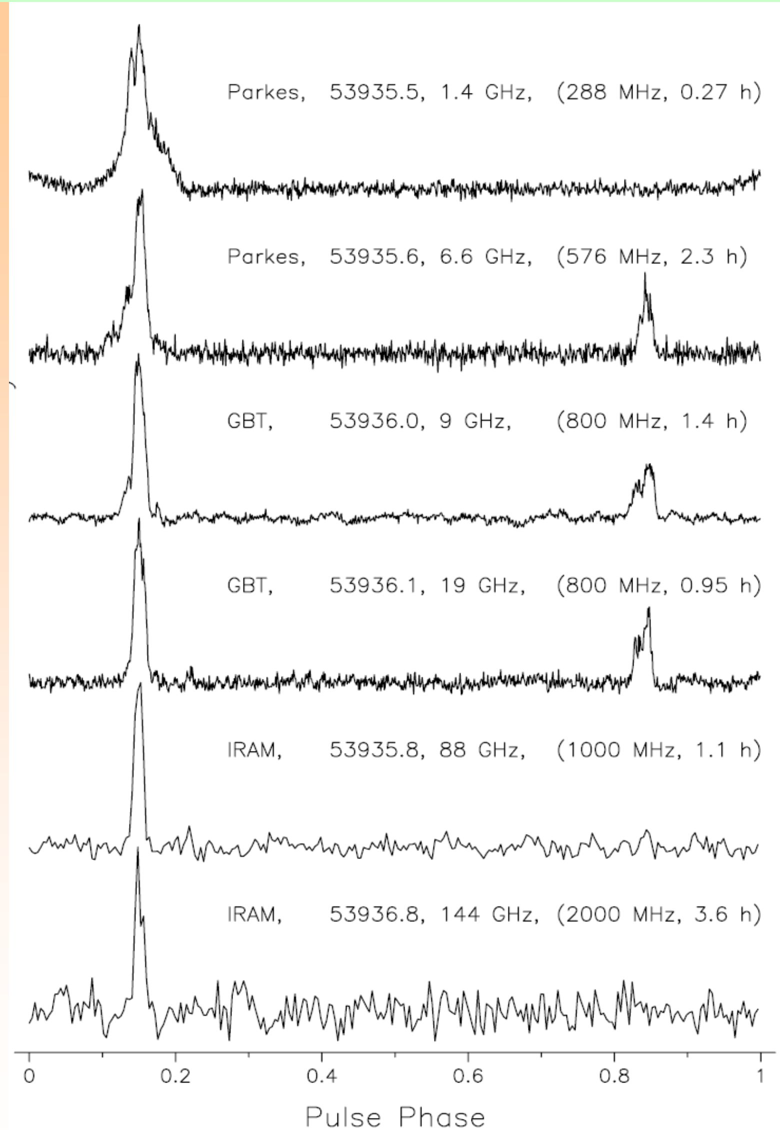
Mereghetti,S. Astro-ph:1008.2891



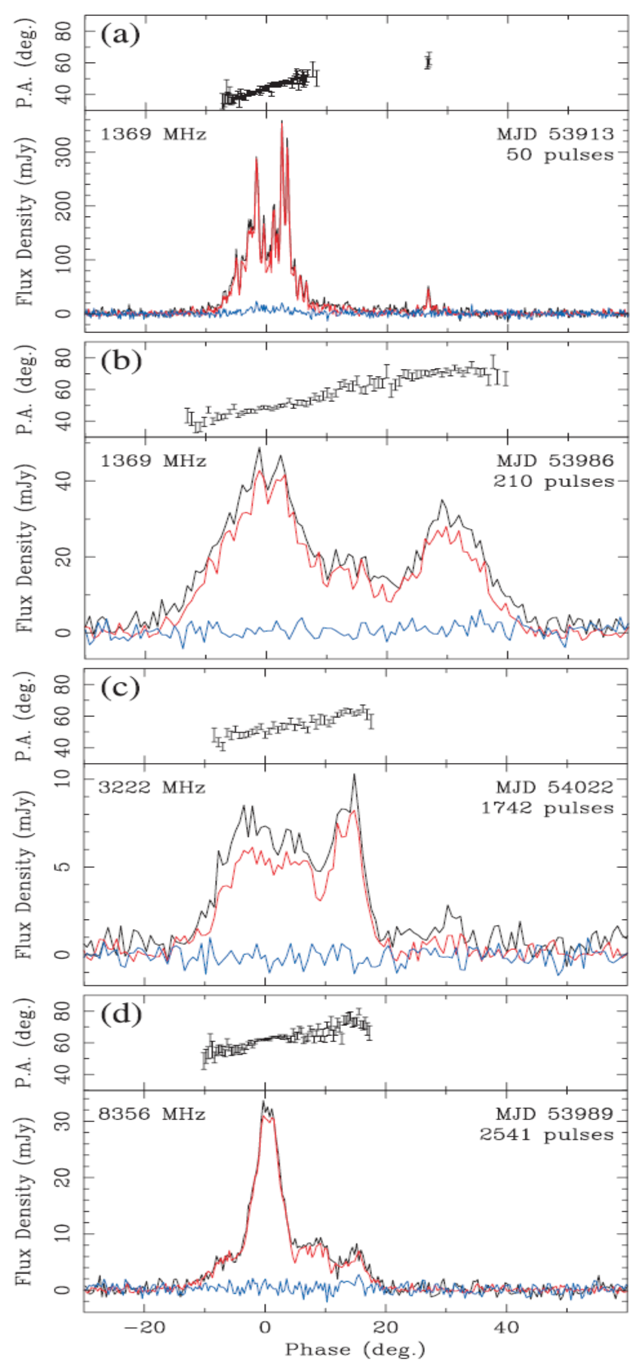
Rea et al. ,arXiv:1010.2781

AXP XTE J1810–197 :p=5.54 s, B=1.7x10^14 G

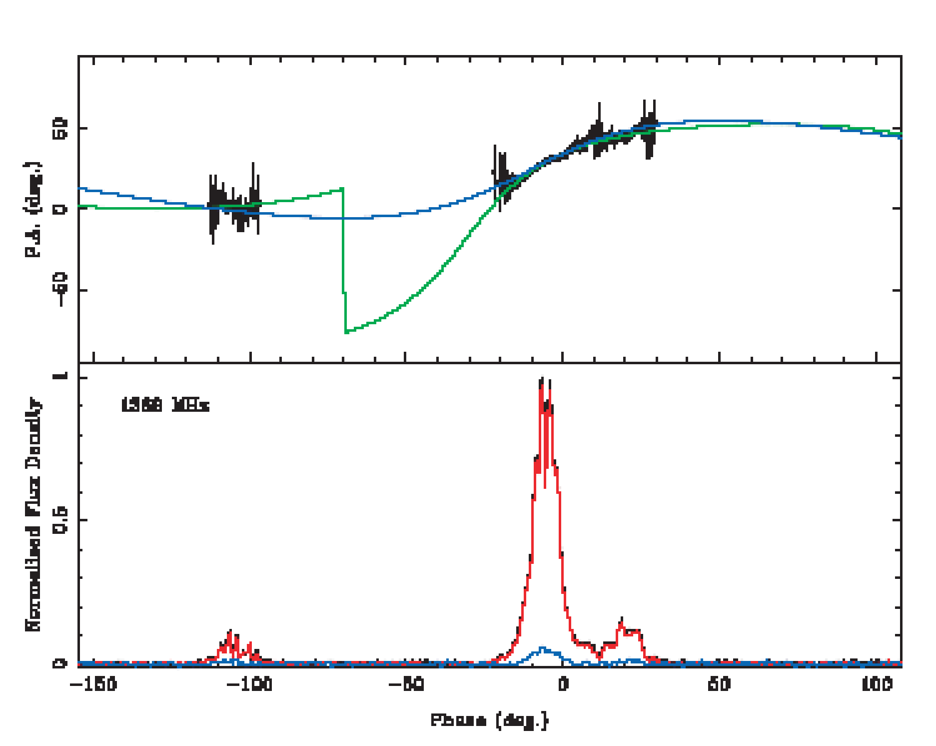




Camilo at al. ApJ. 2007,669,561



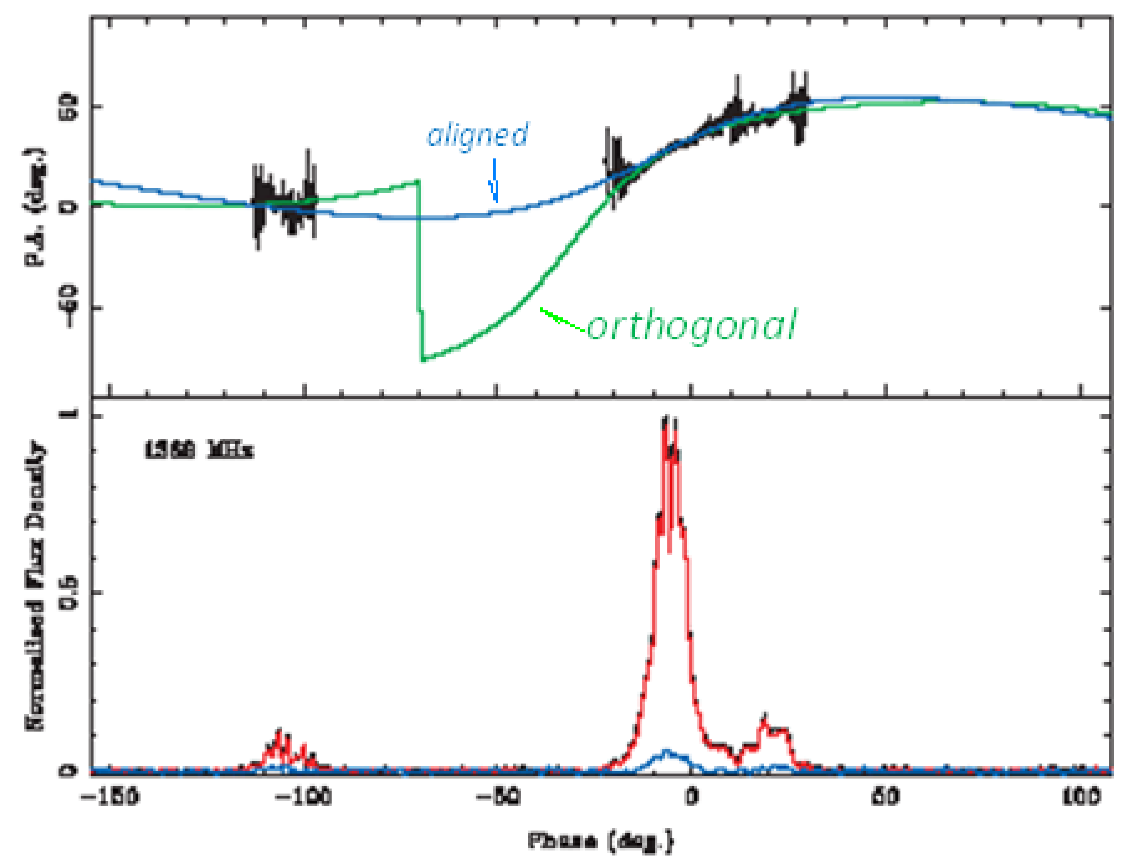
AXP XTE J1810–197



the profiles over time and frequency.

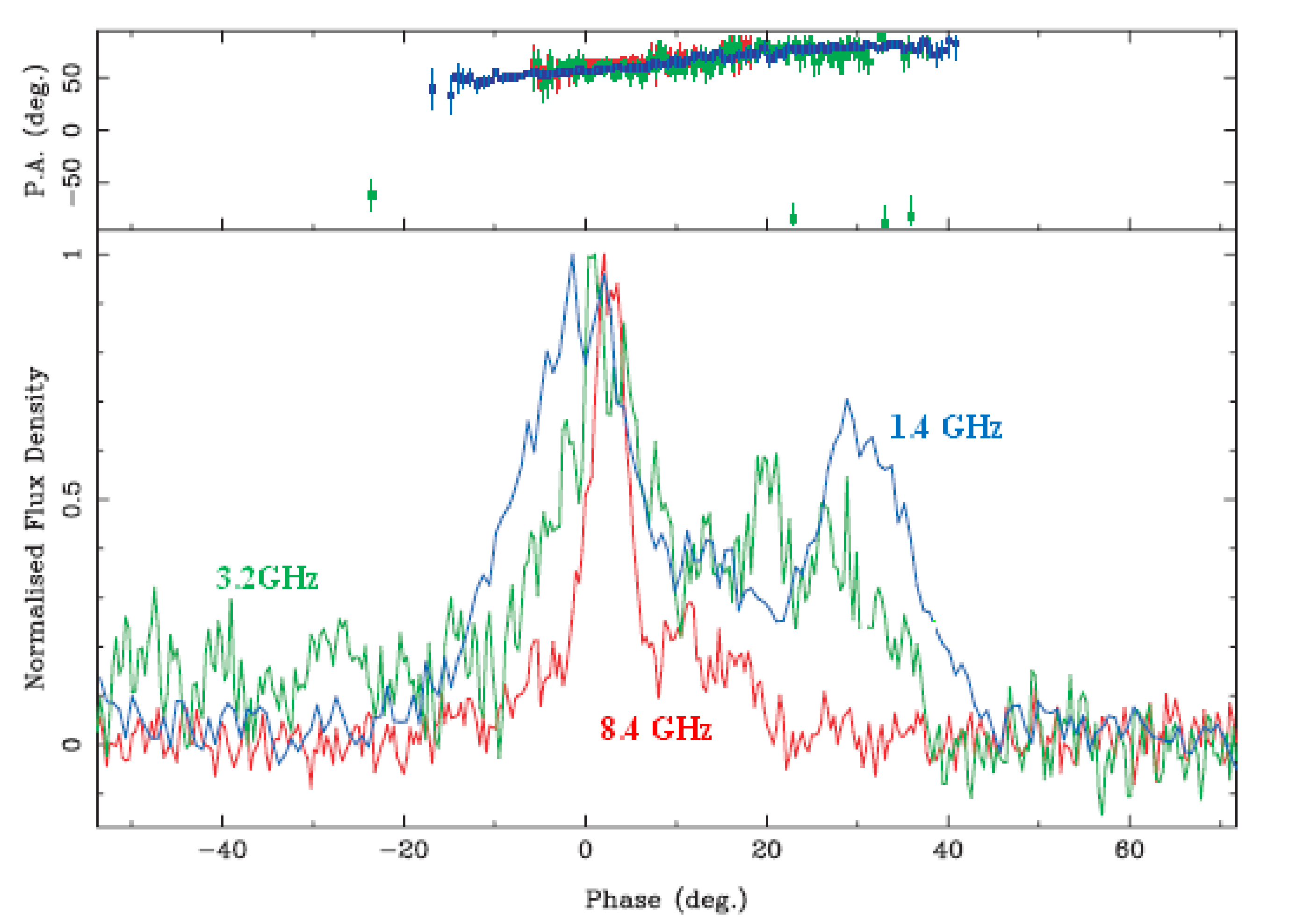
Camilo et al.2007,ApJ.659，L37

1810-197:   rotating vector model curves (RVM)



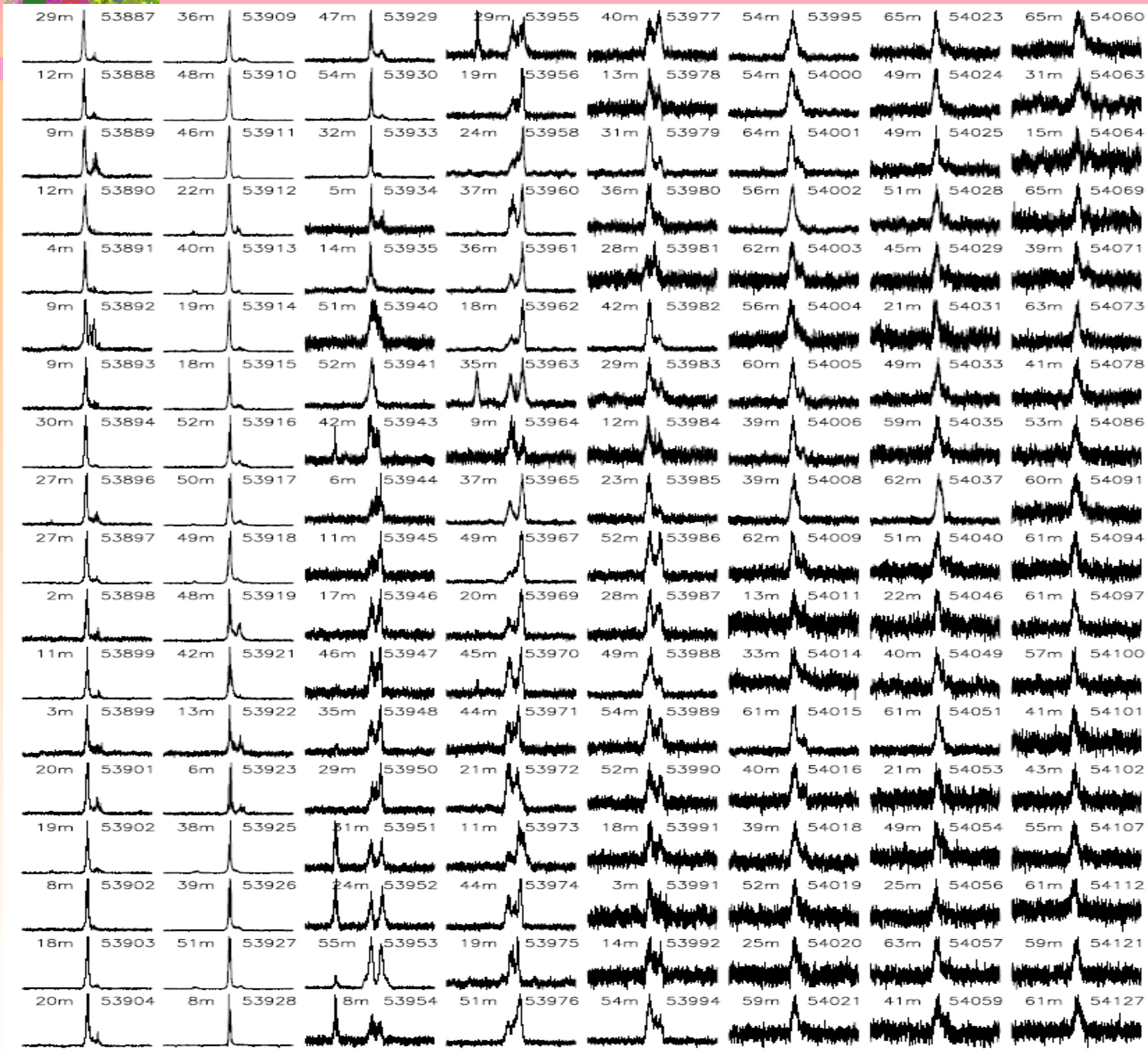
Camilo et al.2007,ApJ.659，L37

AXP XTE J1810–197



Camilo et al.2007,ApJ.659，L37

- In what case have not radio emission?
- In what case have radio emission?
- In what case have pulsed radio emission?



Radio emission:

J1810-197 :

Obs. June 1 2006

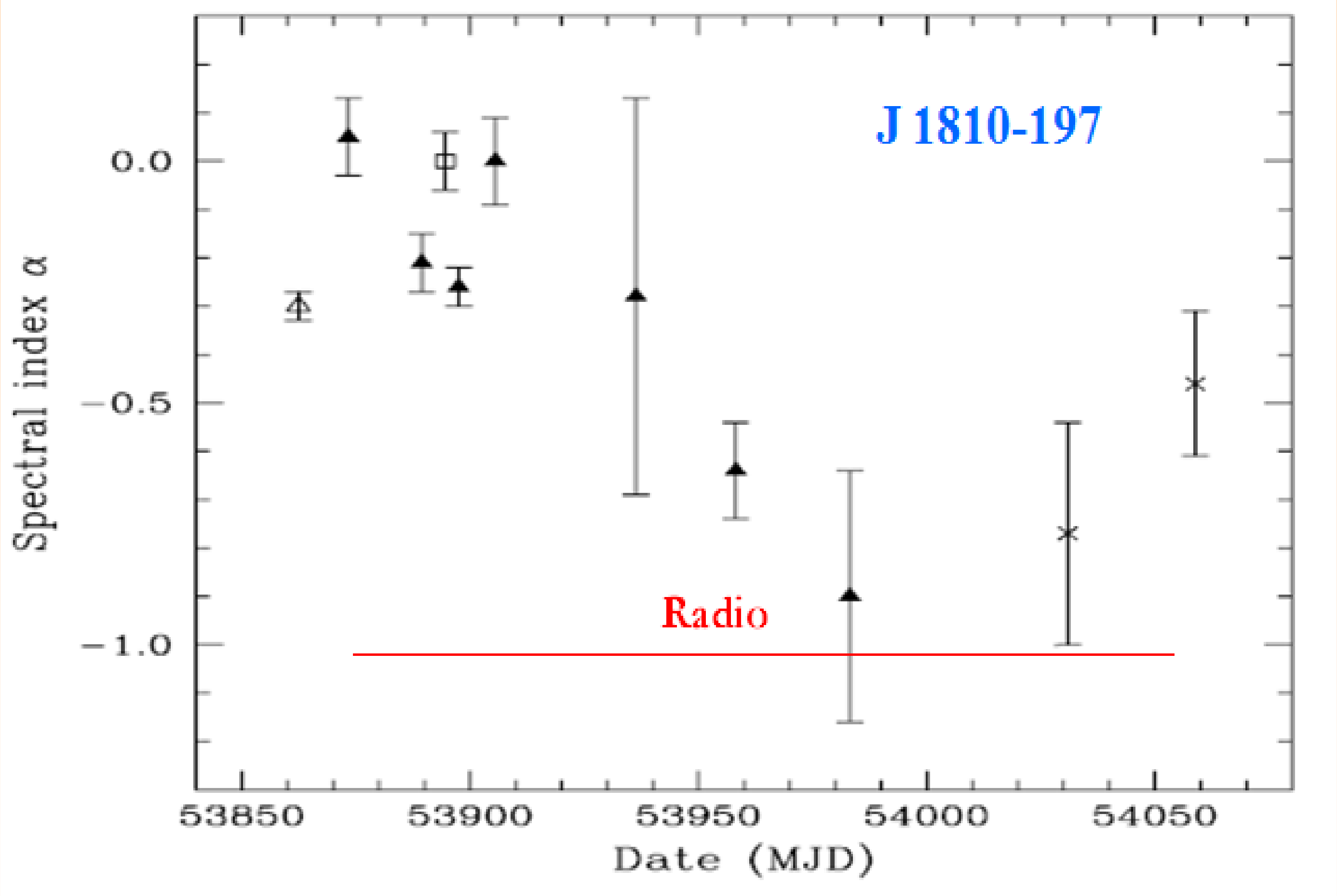
To Jan. 27 2007

Feq.1.4GHz

JD:53887--54091

Camilo at al. ApJ. 2007, 663:497

J 1810-197: Spectral Indeces (1.4 GHz—8.5 GHz)



F. Camilo….ApJ., 669:561–569, 2007

AXP XTE J1810–197: X-ray Obs.

XTE J1810–197 :

---first transient AXP.

---highly variable X–ray flux

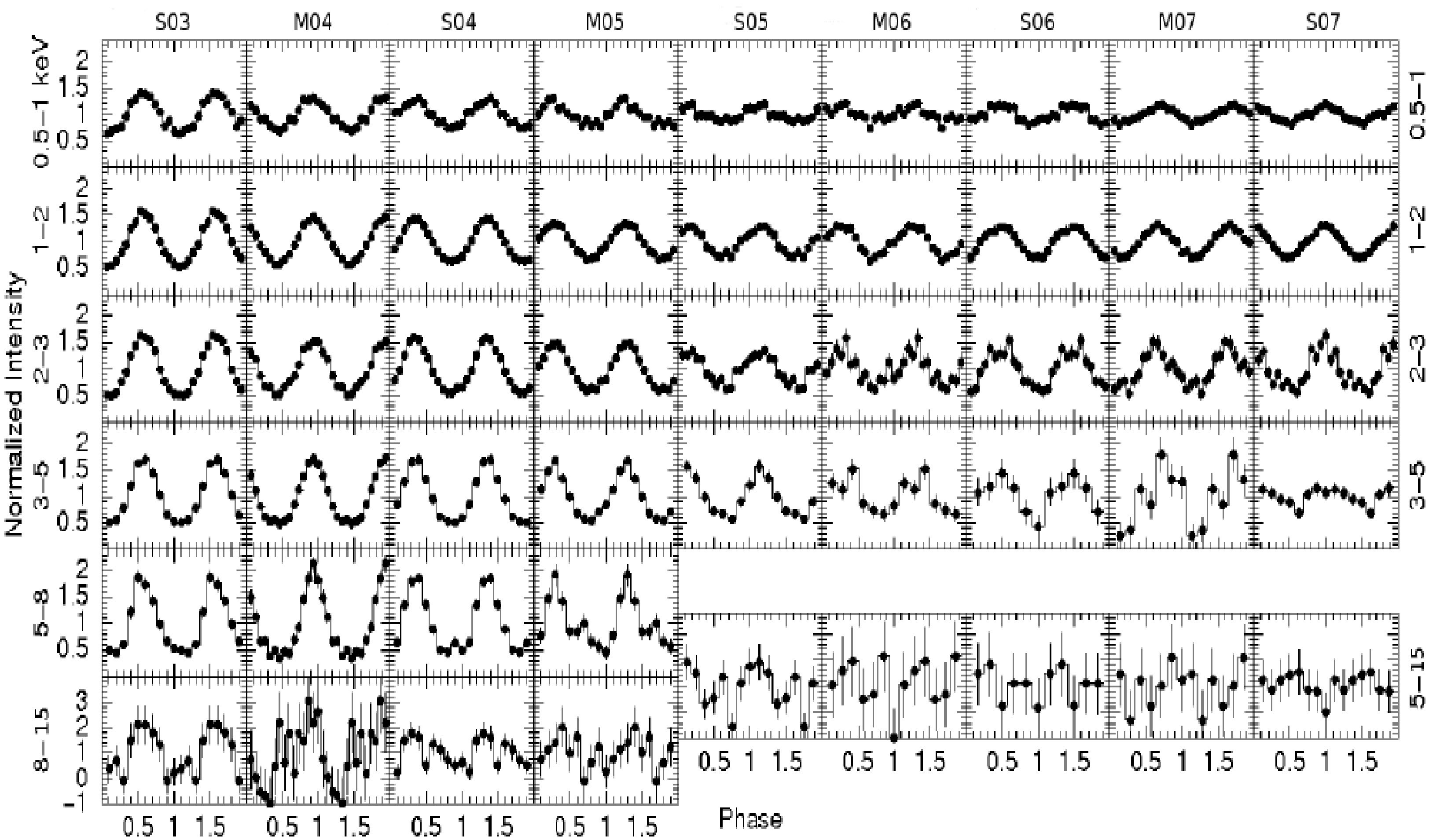
---timing and spectral variation

XMM–Newton obs. four yrs

September 2003 – September 2007

Bernardini et al. 2009

1810-197: X-ray obs. Sep. 2003 – Sep. 2007



Radio: JD:53887- -54091, Feq.1.4GHz
Obs. June 1, 2006 To Jan. 27, 2007.

Bernardini et al. 2009

AXP XTE J1810–197: X-ray Obs.

PF = (Amax − Amin)/(Amax + Amin)

Sep. 2003 to Sep. 2007

---PF **decreased** in the 0.5 – 10 keV:

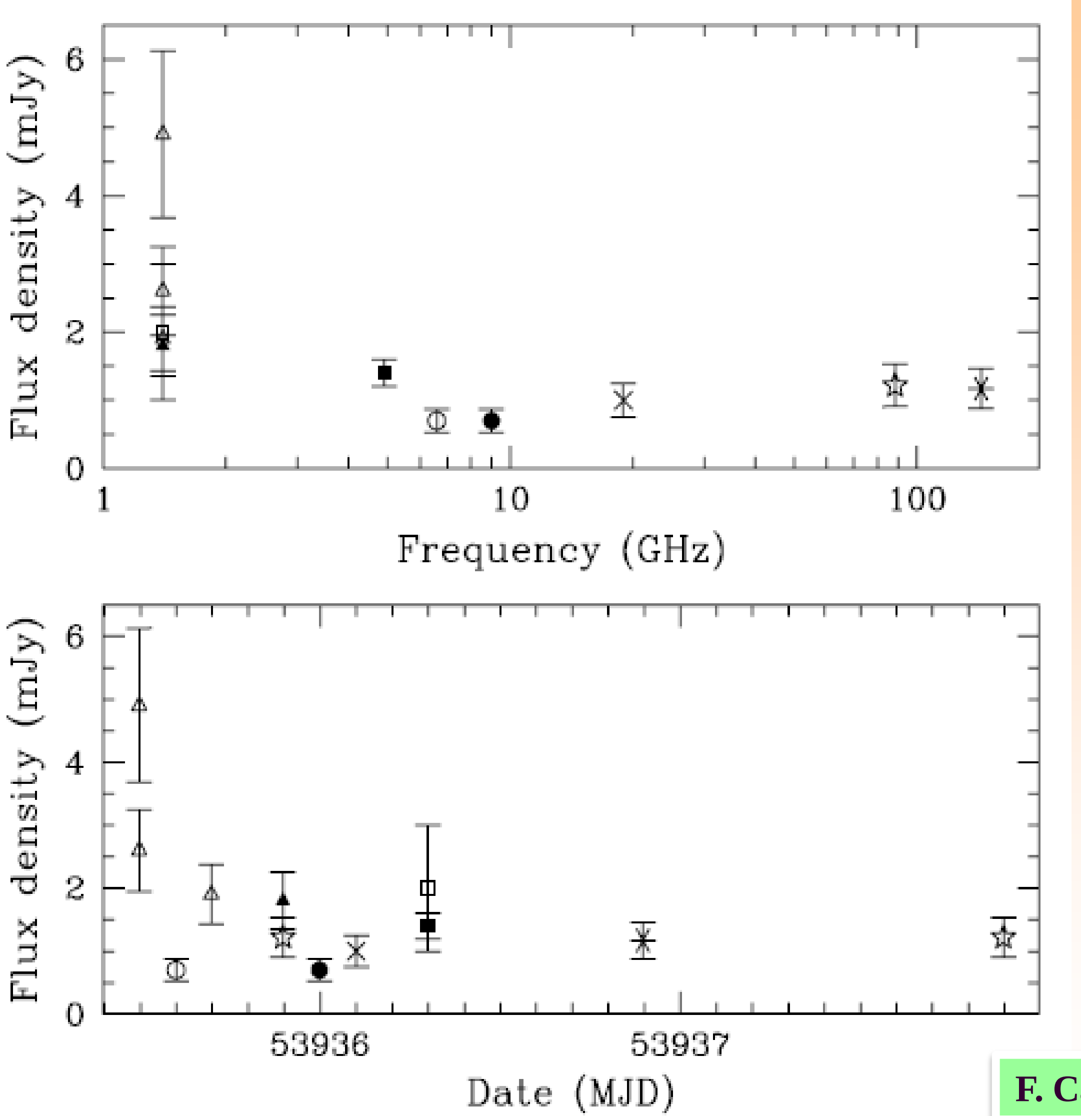
~ **50% and ~ 25%**

---PF **decreases** as a function of **time (**same energy band)

increases as a function of **energy** (same obs.)

Bernardini et al. 2009

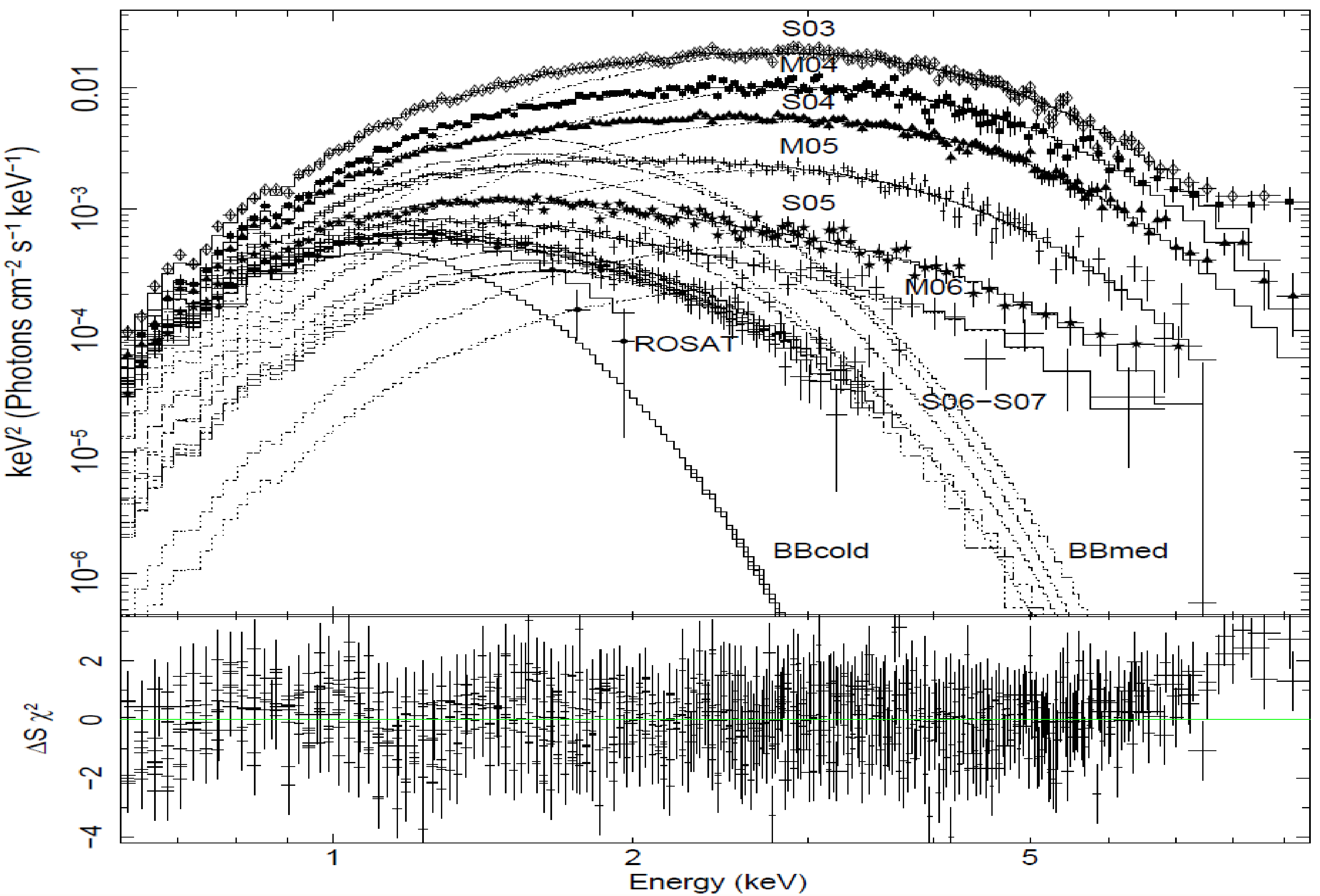
J 1810-197



1.4–144 GHz
Obs. 2.5days

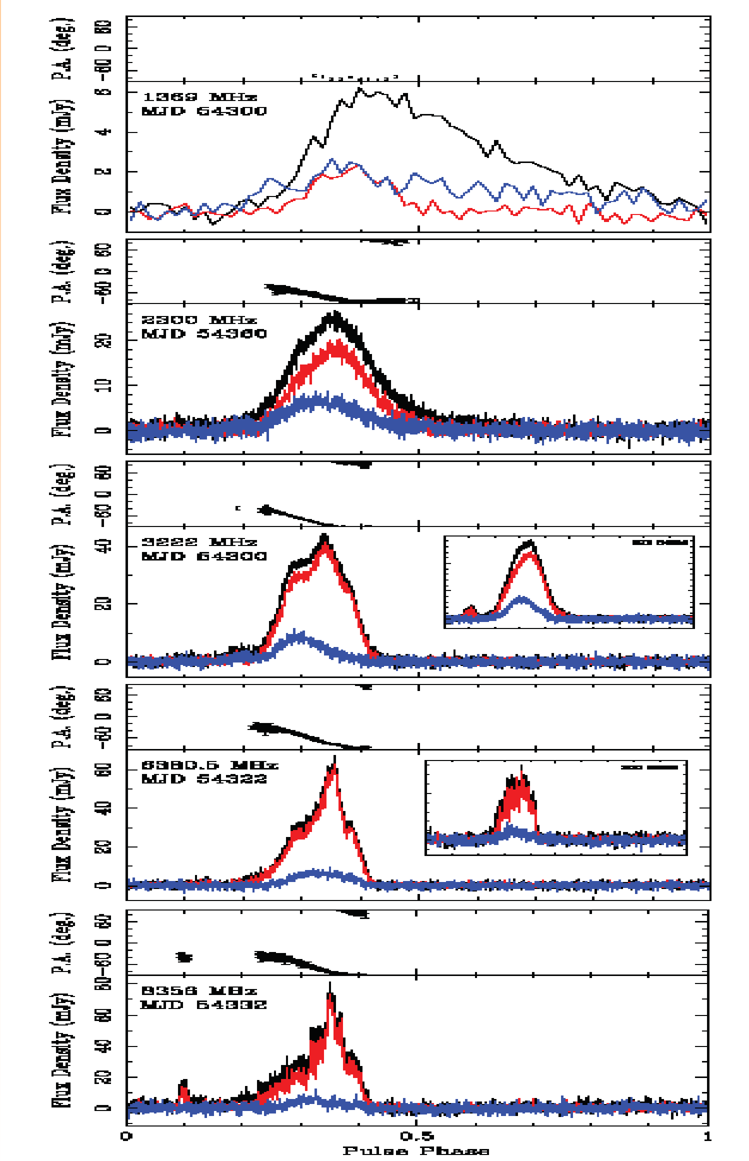
F. Camilo….ApJ., 669:561–569, 2007

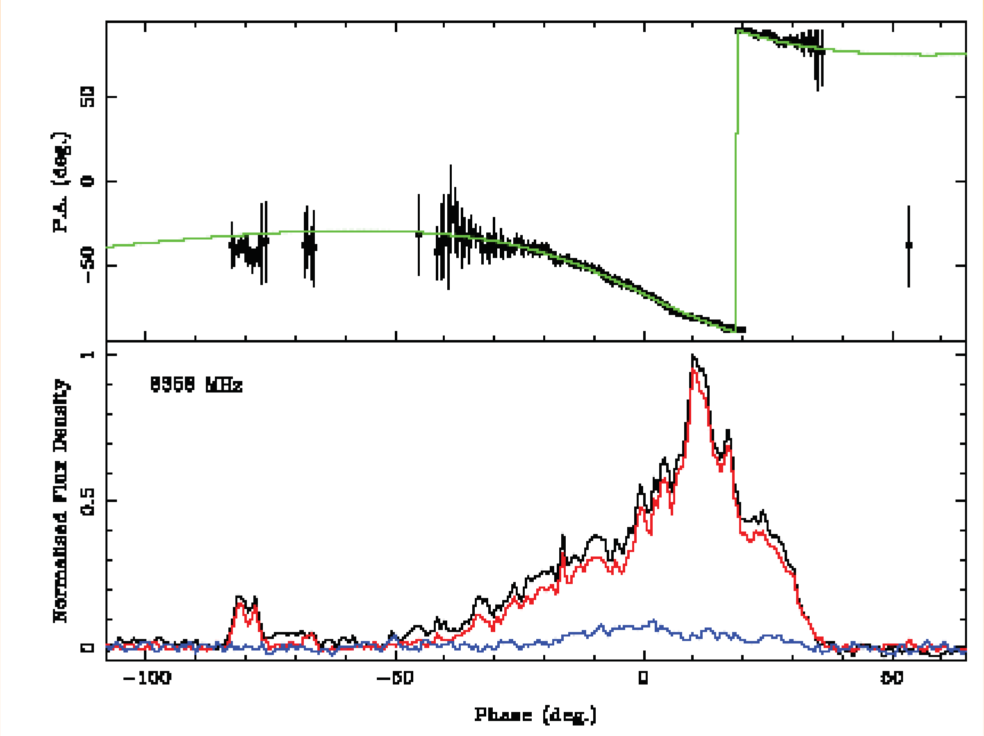
1810-197: X-ray obs. Sep. 2003 – Sep. 2007



Bernardini et al. 2009

Transient AXP 1E 1547.05408(PSR J15505418)



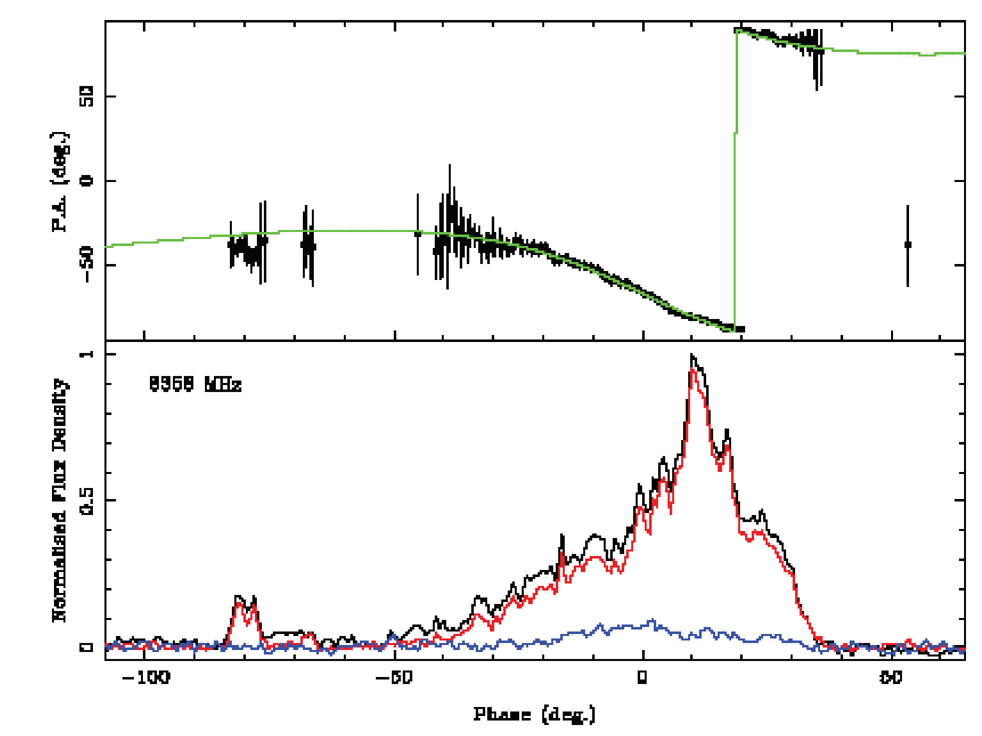


1.4–8.4 GHz.

8.4 GHz.

nearly 100% linearly polarized

AXP 1E 1547.05408



No X-ray pulsations have been detected from it before.

8.4 GHz

PA: in RVM

$\alpha = 160^0$, $\beta = 14^0$

Discorved radio from 2007 June 8, Jun. 27, 2007

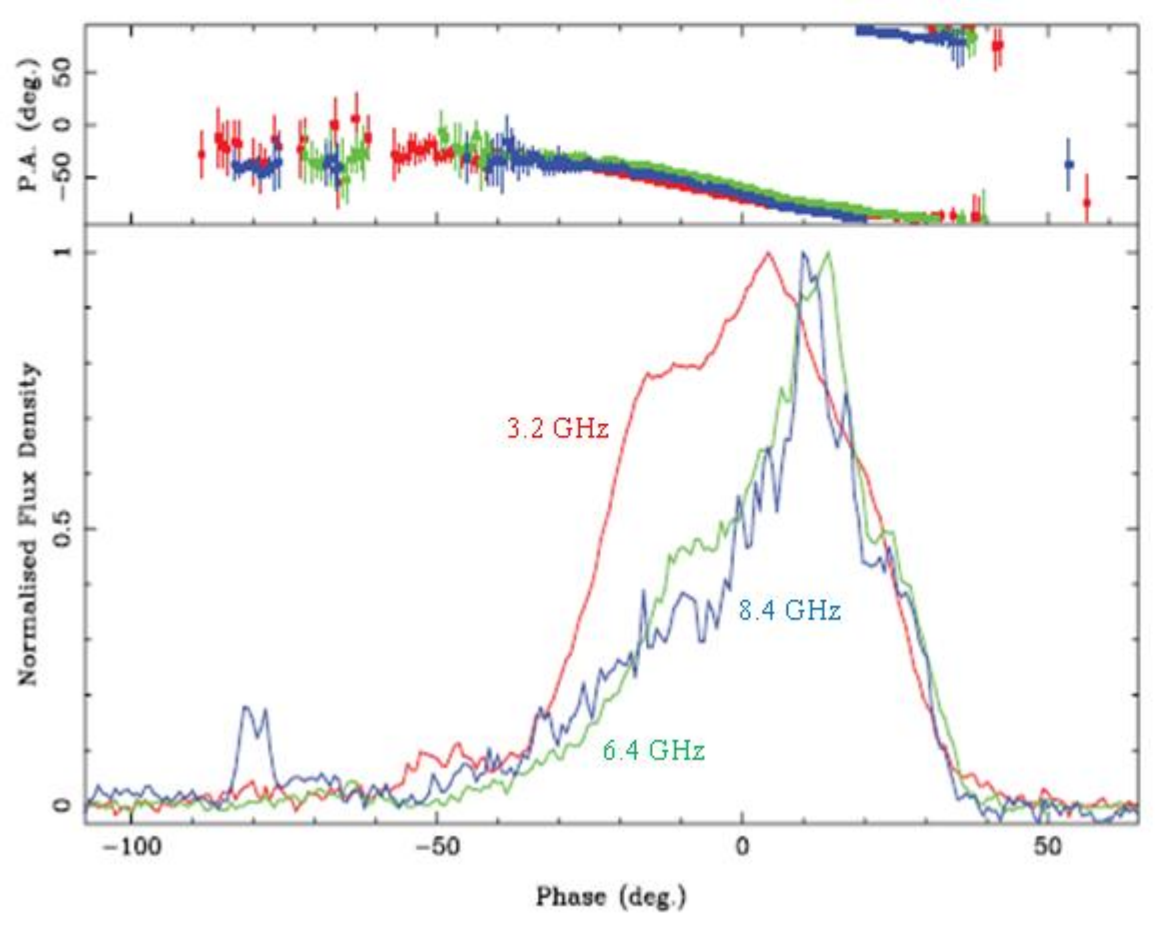
JD 54091

P = 2.069 s, B = 2.2 × 10^14 G,

100% linearly polarized

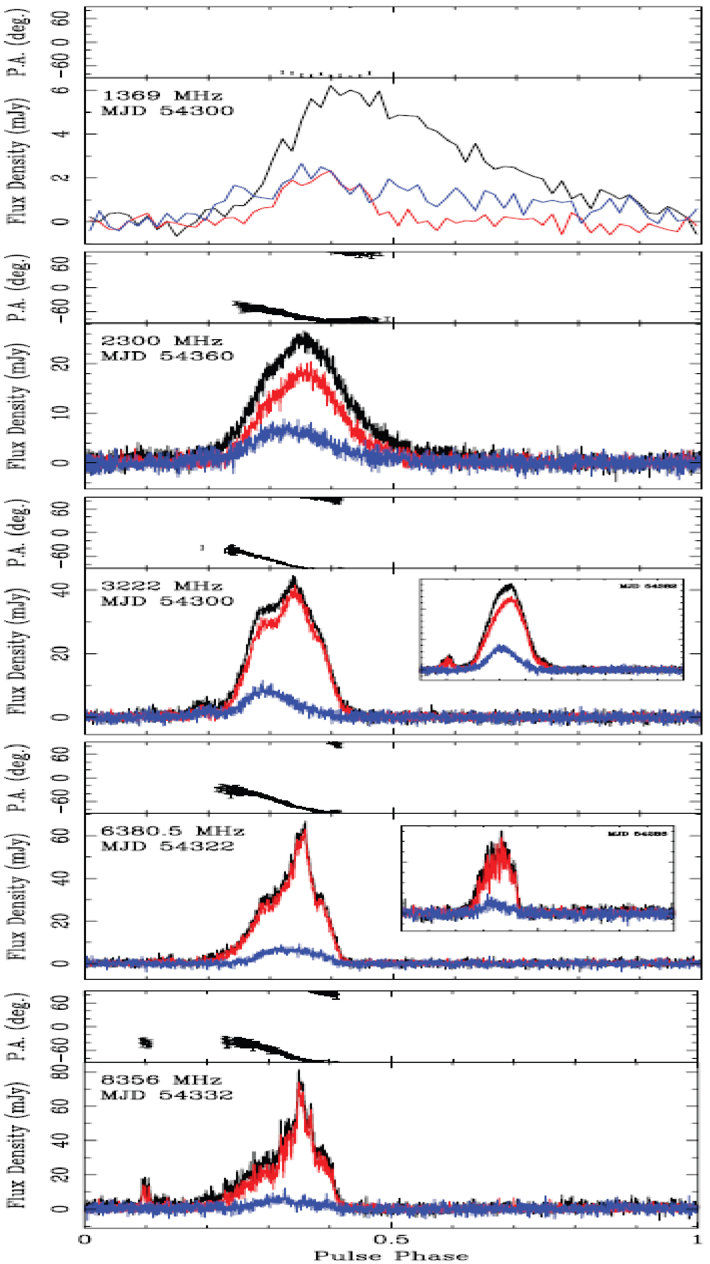
Camilo et al. 2007,2008,ApJ.

AXP 1E 1547.05408



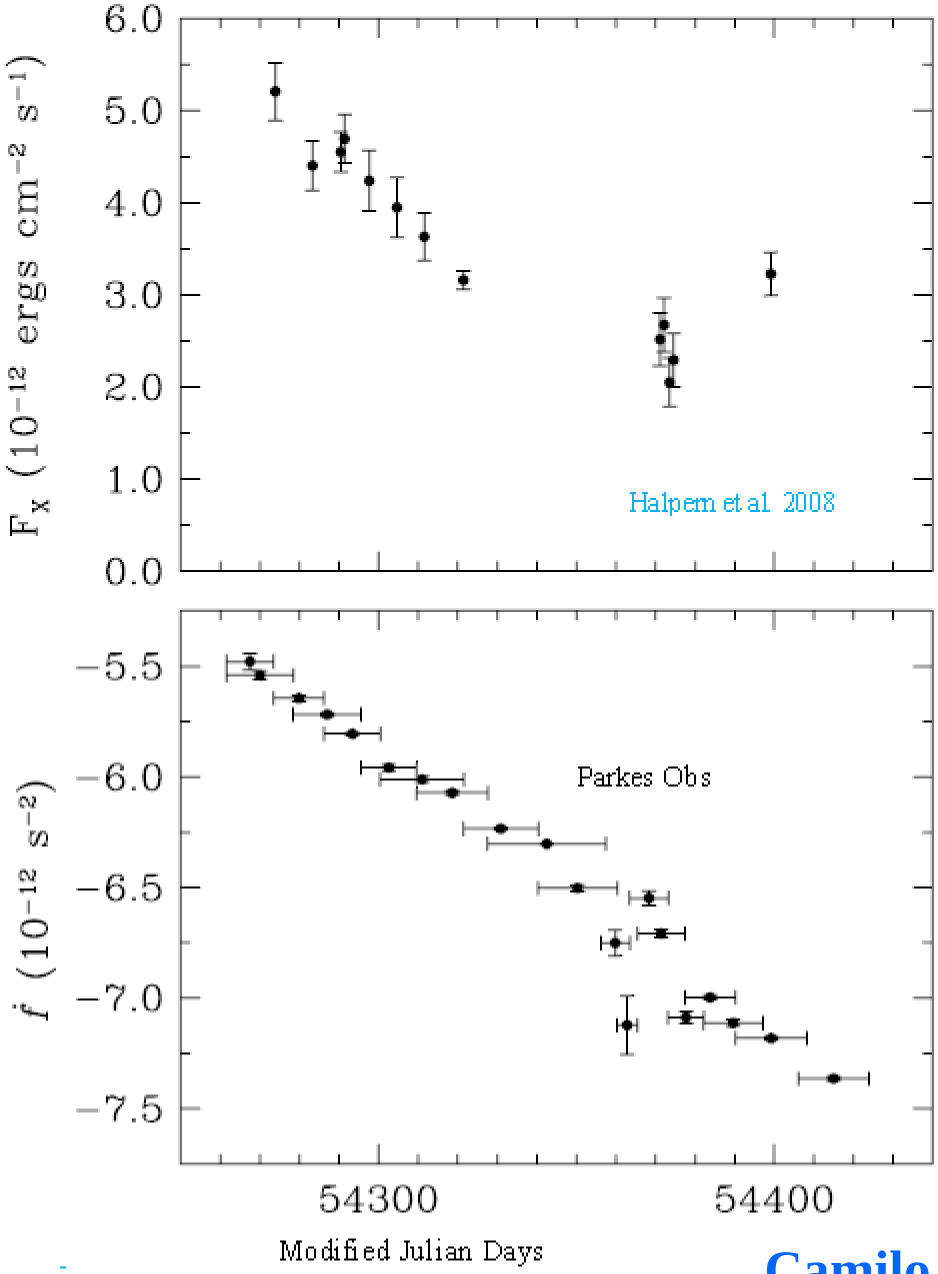
Camilo et al. ApJ.679,681,2008

AXP 1E 1547.05408



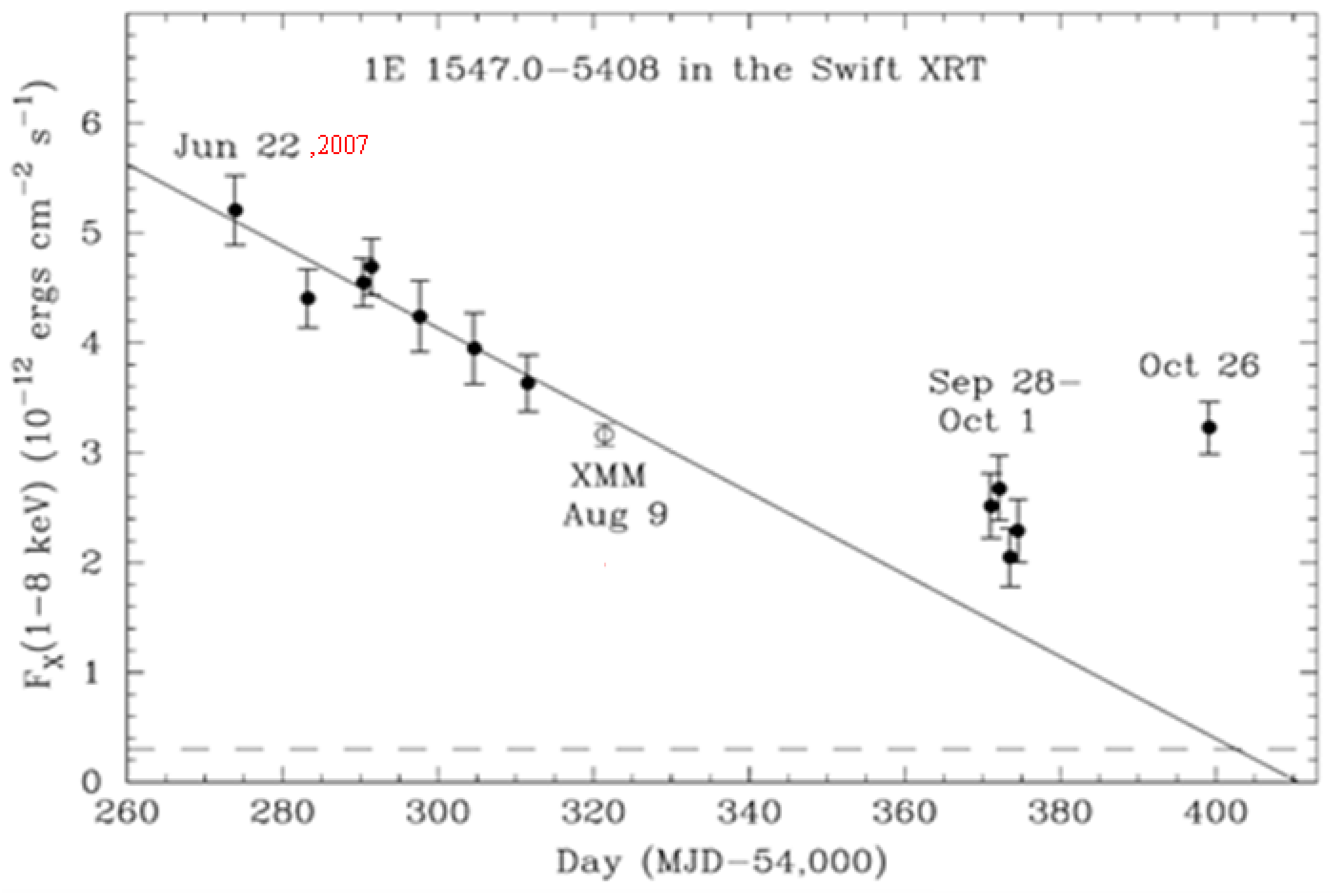
Camilo et al. ApJ.679,681,2008

AXP 1E 1547.05408



Camilo et al. ApJ.679,681,2008

1E 1547: X-ray Obs. Halpern et al. (2008)



Radio: detected from 2007 June 8

Xray obs. Beween 2007 June 22 and 2007 August 9

1E 1547.0–5408

X-ray historic minimum flux: 3×10^{-13} ergs cm^{-2} s^{-1}

Now high state, f_X(1-8 keV): 5×10^{-12} ergs cm^{-2} s^{-1}

➔ $L_X = 1.7 \times 10^{35} (d/9\ \mathrm{kpc})^2$ ergs s^{-1}

declining by 25% in 1 month.

From the decay: this outburst to 10^{42} ergs < E < 10^{43} ergs.

---increase in the **temperature** and **area** of a hot region, to 0.5 keV and ---16% of the surface of NS,

➔ its **increase in luminosity**.

---The **energy**, **spectrum**, and **timescale** of decay

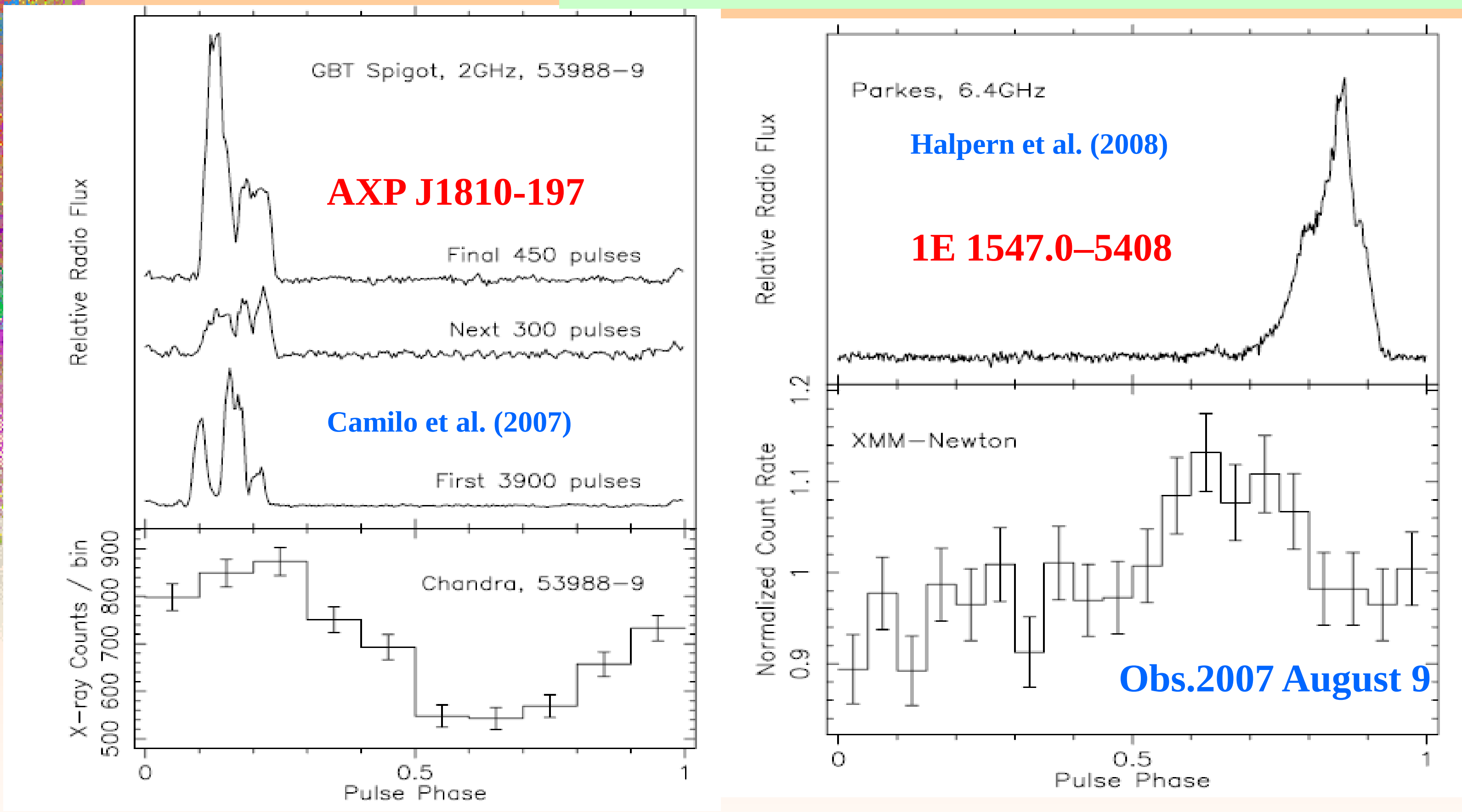
➔ a deep **crustal heating** event

similar to an interpretation of the X-ray turn-on of the transient AXP **XTE J1810_197.**

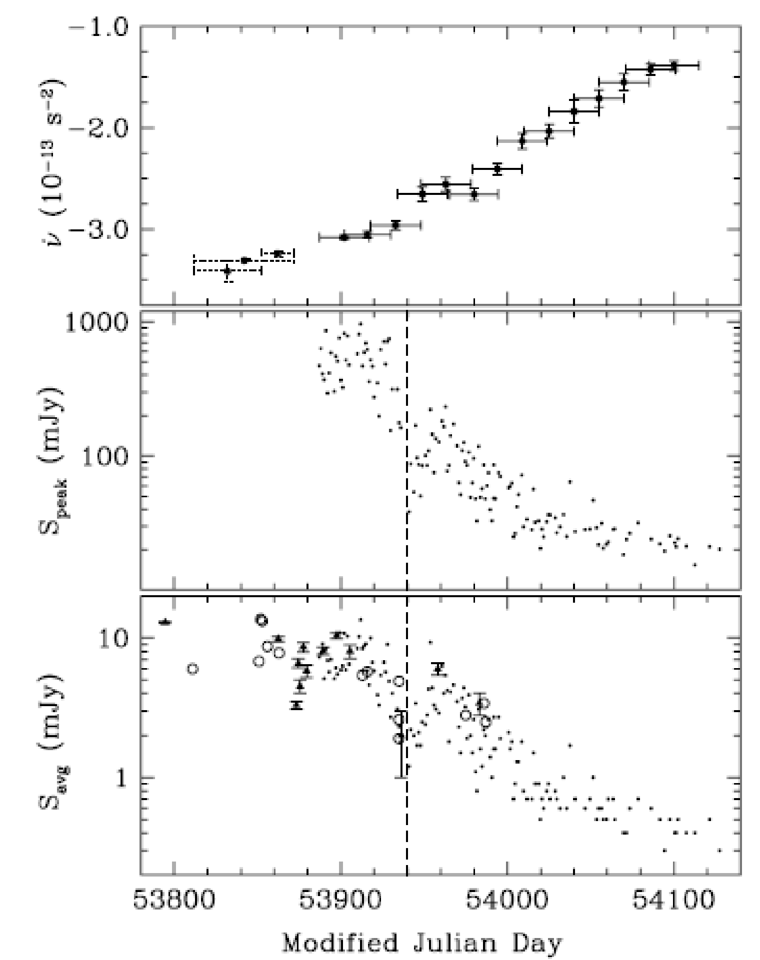
Halpern et al. (2008)

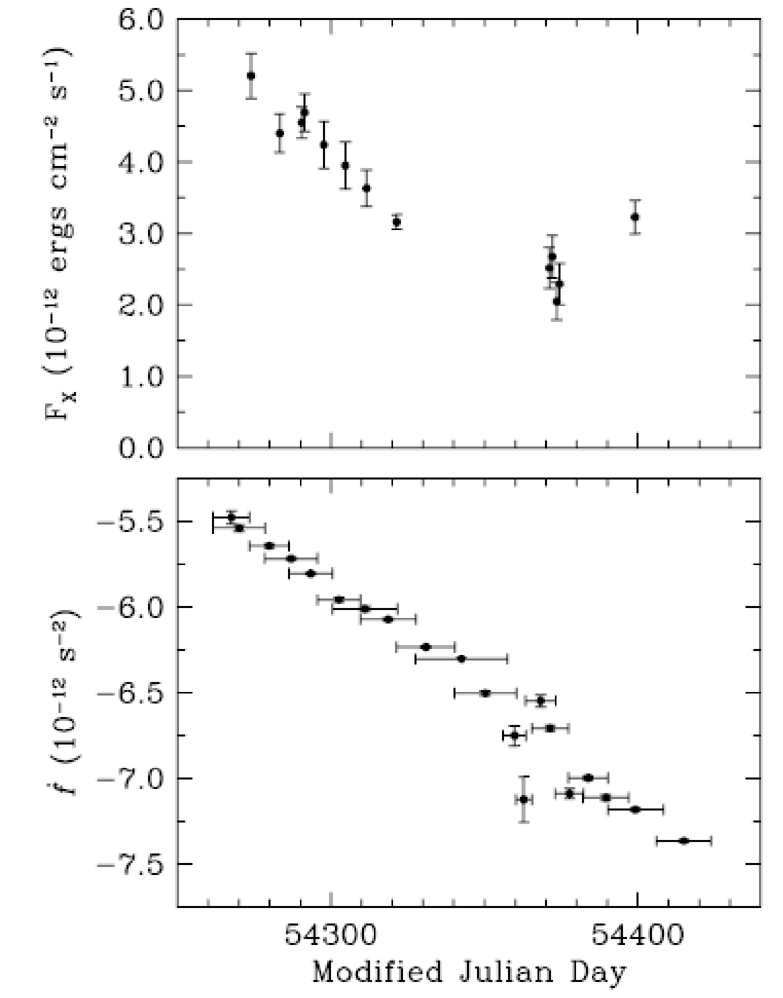
Rough alignment between radio and X-ray arrival times

- which is unusual for pulsars!



1547, Radio: detected from 2007 June 8 ,
Xray obs. Beween 2007 June 22 and July 30,
pulsed fraction –only 7%





AXP J1810-197:

1E 1547.0–5408 :

Camilo et al. (2008)

--Flat and changing flux density and spectrum

--Large degree of timing noise (correlated with flux density?)

=>correlation would be unusual for pulsars!

--Both detected radio-loud magnetars had previous X-ray burst

Pre-burst radio-observations did not find a source

--BUT, also examples for failed radio detection of AXPs after burst

(e.g. SGR 1627-41. Camilo & Sarkissian 2008),

--Magnetic field rearrangement may be responsible for radio switch on, hence(X-ray Burst) rearrangement may be necessary but not sufficient

(cf. Halpern et al. 2008)

PSR J 1622-4950

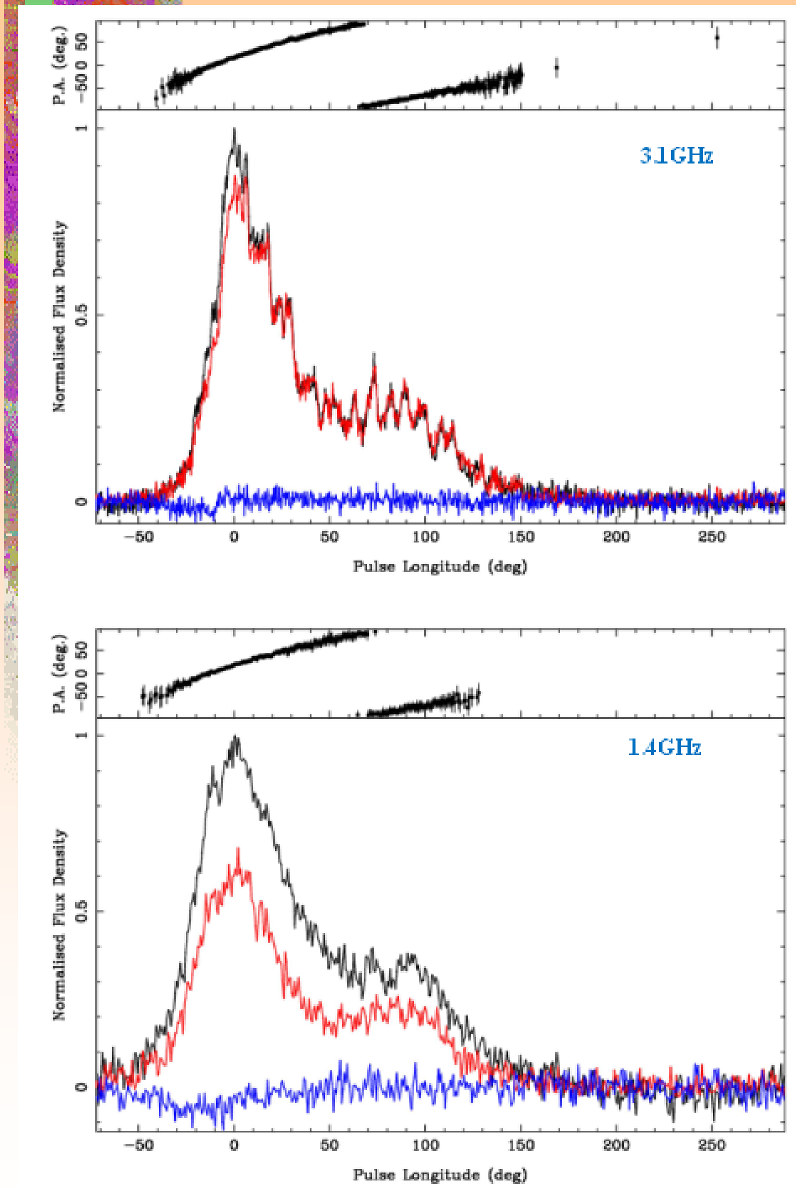


TABLE 1
PARAMETER SUMMARY OF PSR J1622-4950.

	Parameter	Value
Observed		
	Right ascension (J2000) [a]	$16^h22^m44^s.80(3)$
	Declination (J2000) [a]	$-49°50'54''.4(5)$
	Galactic longitude [a]	333.85
	Galactic latitude [a]	−0.10
	Epoch	MJD 55080
	Spin period (P)	4.3261(1) s
	Period derivative ($\dot{P}$)	$1.7(1)\times10^{-11}$ s s^{-1}
	Dispersion measure (DM)	820(30) cm^{-3} pc
	Flux density at 1400 MHz (S_{1400})	4.8(3) mJy
	Rotation measure (RM)	−1484(1) rad m^{-2}
Derived		
	Distance [b]	≈ 9 kpc
	Surface magnetic field (B)	2.8×10^{14} G
	Characteristic age (τ_c)	4 kyr
	Spin down luminosity ($\dot{E}$)	8.5×10^{33} erg s^{-1}
	X-ray luminosity (L_X) [c]	2.5×10^{33} erg s^{-1}

Levin et al. astro-ph, 1007.1052

“Outburst” = bursts + flare (+ …)

“Activity” often associated with timing events:

Every “outburst” accompanied by timing event

Converse not true

Kaspi,2009

Magnetar?

- in such a strong B the radiation **output is highly anisotropic** but the observed …
- cannot provide a satisfactory explanation for **burst duration**, time scale between bursts, synchrotron self absorption feature, and the **persistent x-ray** emission.
- **Radio emission** ?
- Strong B ?

Magnetic field of magnetars ?

$$\dot{E} = -I\Omega\dot{\Omega} = \dot{E}_\mu$$

$$\Rightarrow \text{Bs} \approx 10^{14} - 10^{15} \text{ G}$$

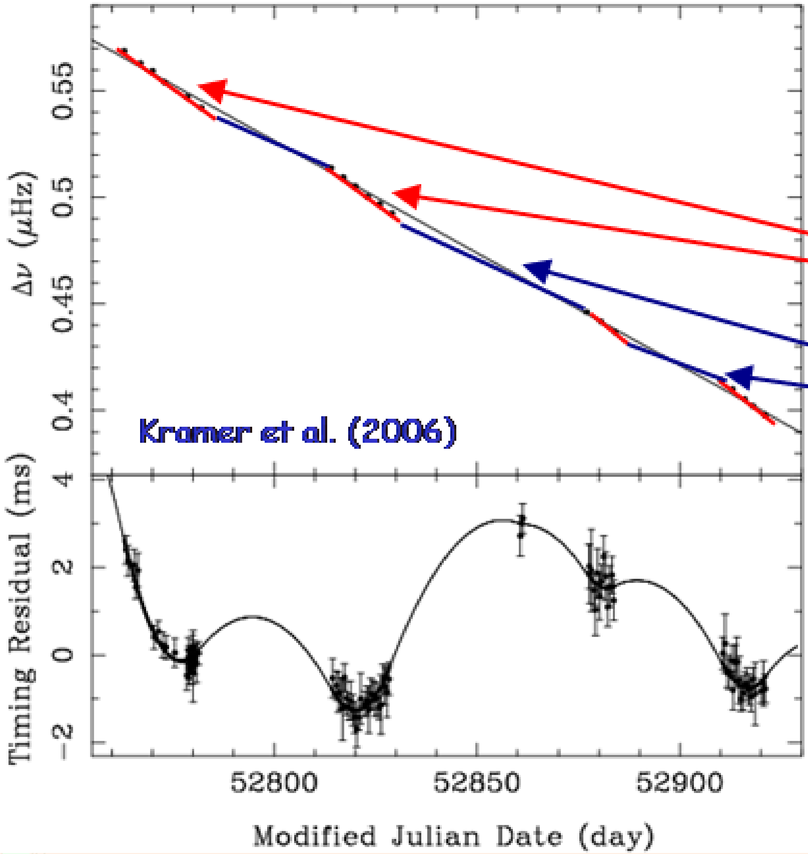
$$\dot{E}_{rot} = 4\pi^2 I\dot{P}P^{-3} \ll L_X$$

$$-I\Omega\dot{\Omega} = \dot{E}_{p,r} + \dot{E}_\mu$$

$$\dot{E}_{p,r} \gg \dot{E}_\mu .$$

$$\not\Rightarrow \text{Bs} \approx 10^{14} - 10^{15} \text{ G}$$

Xu & Qiao, 2001, AA



- When on, pulsar spins down faster: additional torque!

dv/dt =-16.3(4)x10^{-15} Hz/s

dv/dt =-10.8(2)x10^{-15} Hz/s

$$\frac{\dot{\nu}_{on}}{\dot{\nu}_{off}} = 1.51 \pm 0.05$$

When on, spins down faster: additional torque!

Significant fraction of spin-down torque is also provided by particle wind and its current!

Magnetic field overestimated by (at least) √1.5 or ~22%.

Do "magnetars" really exist?

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2. Magnetar: Challenge from

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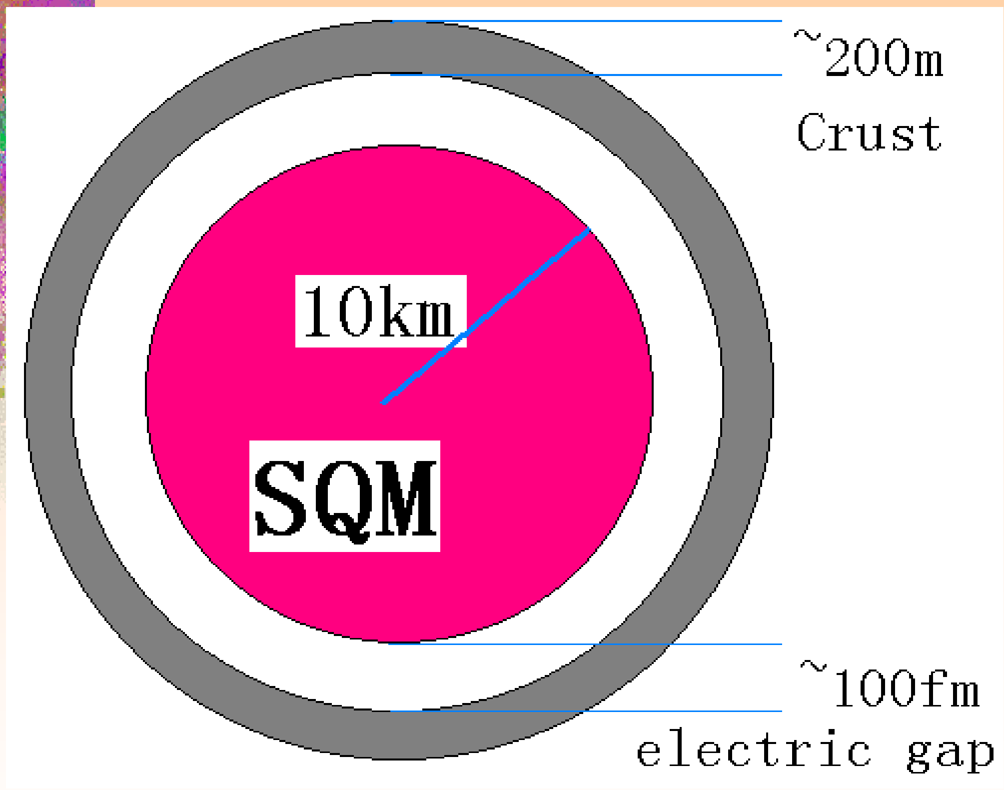
---τc & τhost

3、 *"Magnetar" or* "Quarcstar"

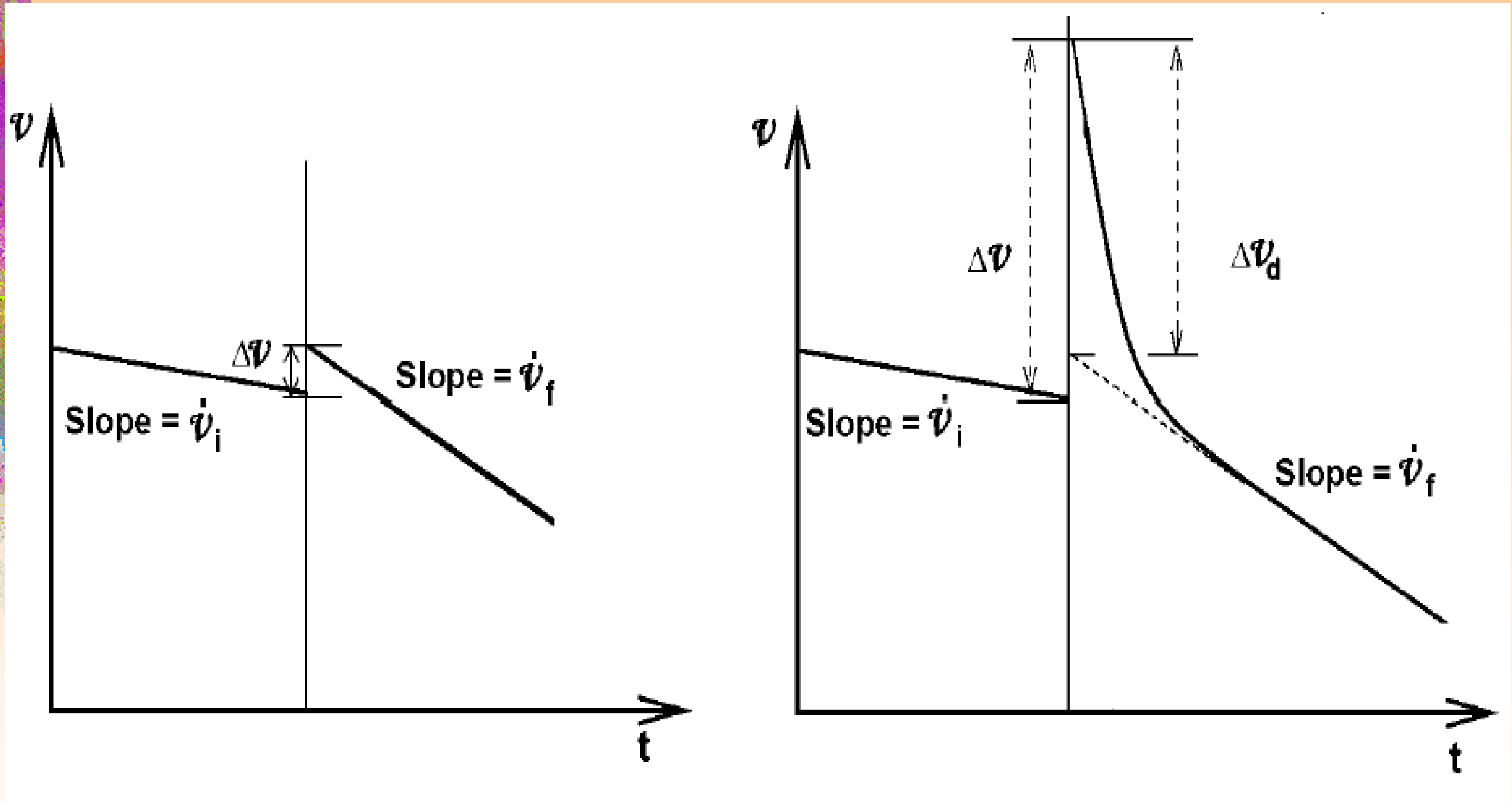
SGR & AXP : Magnetars or Quark Stars?



M_{crust} 10^-6 M_{sun} ---10^-5 M_{sun}

Cheng et al. 1998
Xu et al.2006

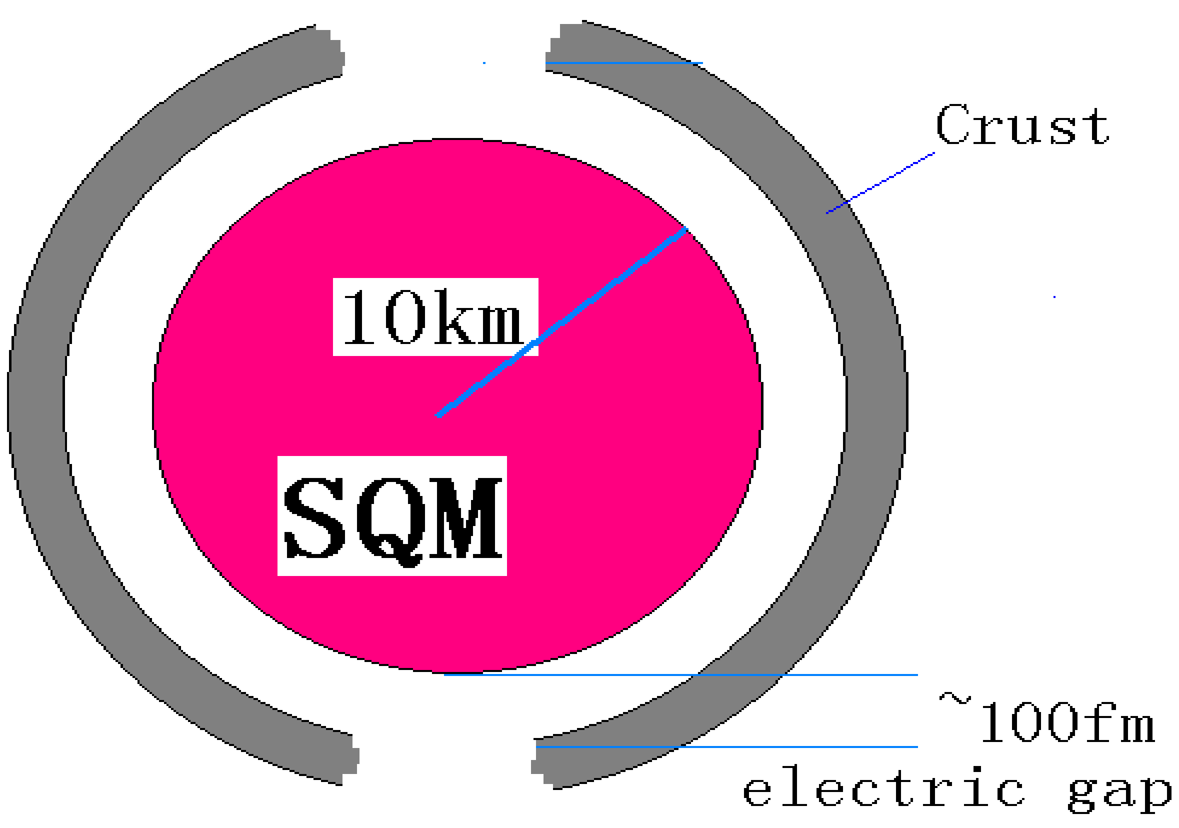
Glitches



Standard model: interior faster-spinning crustal superfluid transfers angular momentum to crust.

Kaspi,2009

SGR & AXP : Magnetars or Quark Stars?



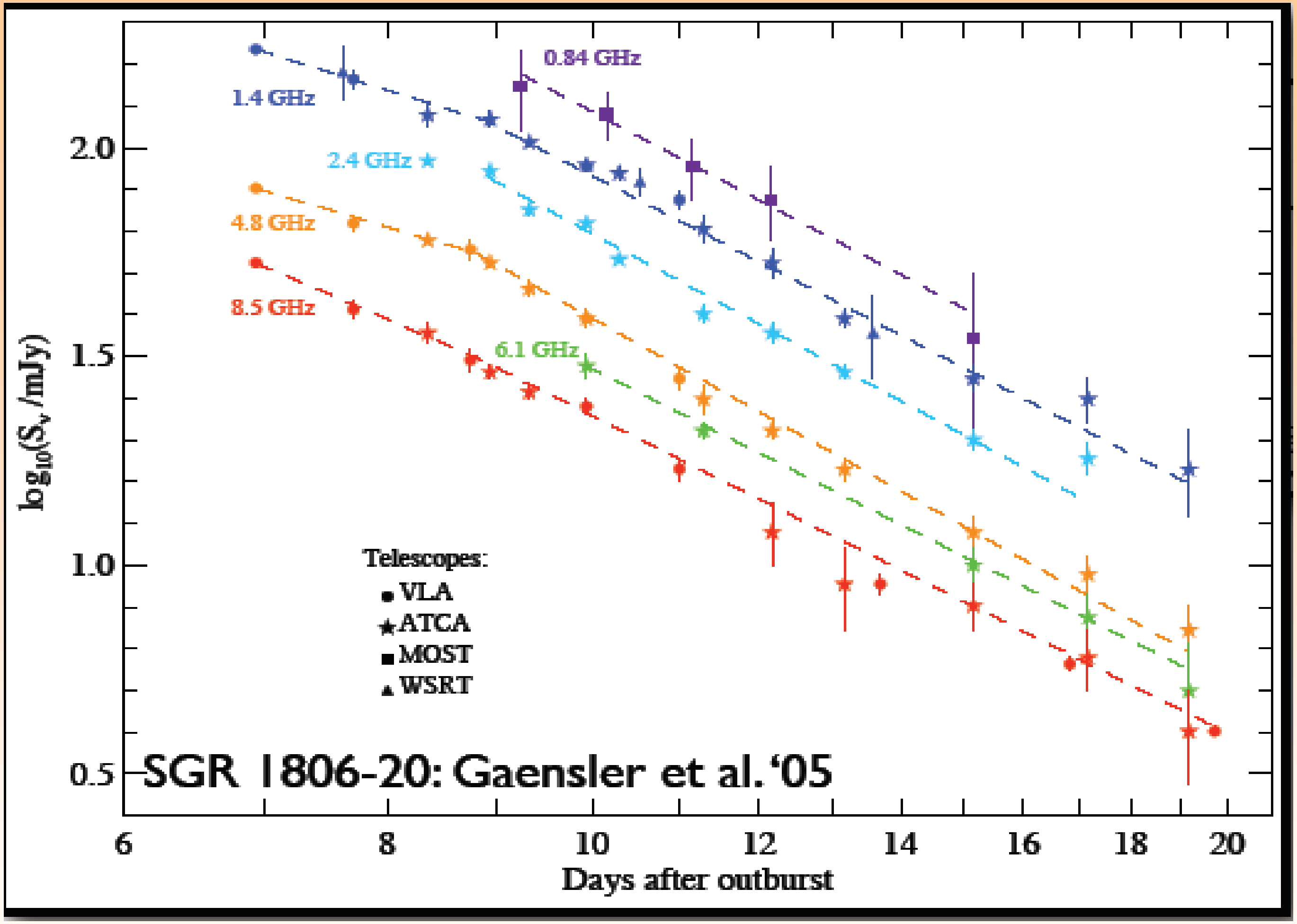
M_{crust} 10^-6 M_{sun} ---10^-5 M_{sun}

AXP&SGR

NAME	P (s)		RADIO	IR	OPTICAL	X SOFT	X HARD
CXO J0110-72	8.0	SMC				P	
4U 0142+61	8.7			D	P	P	P
1E 1048-59	6.4			D	P	P	D
1E 1547-54	2.1	G327.24-0.13	P	D NEW		P T	
CXO J647-45	10.6	Westerlund 1				P T	
RXS 1708-40	11.0			D?		P	P
XTE J1810-197	5.5		P	D		PT	
1E 1841-045	11.8	Kes 73		D?		P	P
AX J1845-02	7.0	G29.6+0.1				P T	
1E 2259+586	7.0	CTB 109	NEW			P	
SGR 0501+45	5.7		T	D		P T	P
SGR 0526-66	8	LMC , N49				P	
SGR 1627-41	2.6 NEW					P T	
SGR 1806-20	7.6	Star cluster	T	D		P	D
SGR 1900+14	5.2	Star cluster	T	D?		P	D

S. Mereghetti - Neutron Stars and GRBs 2009 - Cairo

AXP&SGR



Relativistic outbursts seen as radio transients from giant flares (Frail et al.' 98; Cameron et al. '05; Gaensler et al. '05)

XTE J1810-197: No pulsed radio radiotion

Imaging Observations of AXPs at 1.4 GHz

Source	F_ν (mJy)	d (kpc)	$F_\nu d^2$ (mJy kpc^2)	Ref.
4U 0142+61	<0.16	3	<1.4	1
1E 1048.1−5937	...	2.7	...	2
1RXS J170849.0−400910	<1.8	5	<45	1
XTE J1810−197[a]	4.5 ± 0.5	2.5	28	3
1E 1841−045	<0.36	7	<18	4
AX J1844.8−0256[a]	<0.5	~8	<32	3
1E 2259+586	<0.050	3	<0.45	5, 6

Halpern et al. 2005

PSR 1259-63

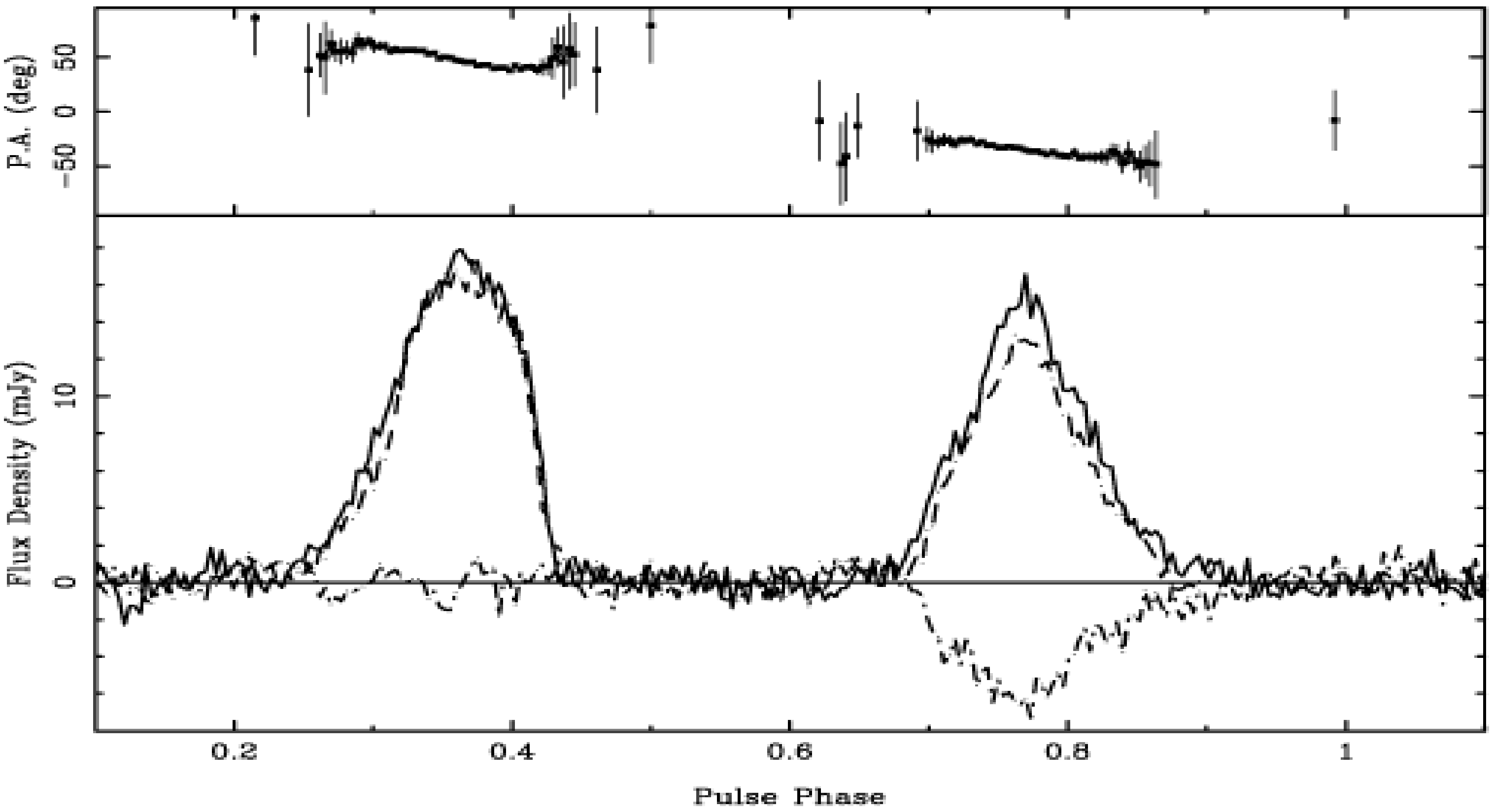
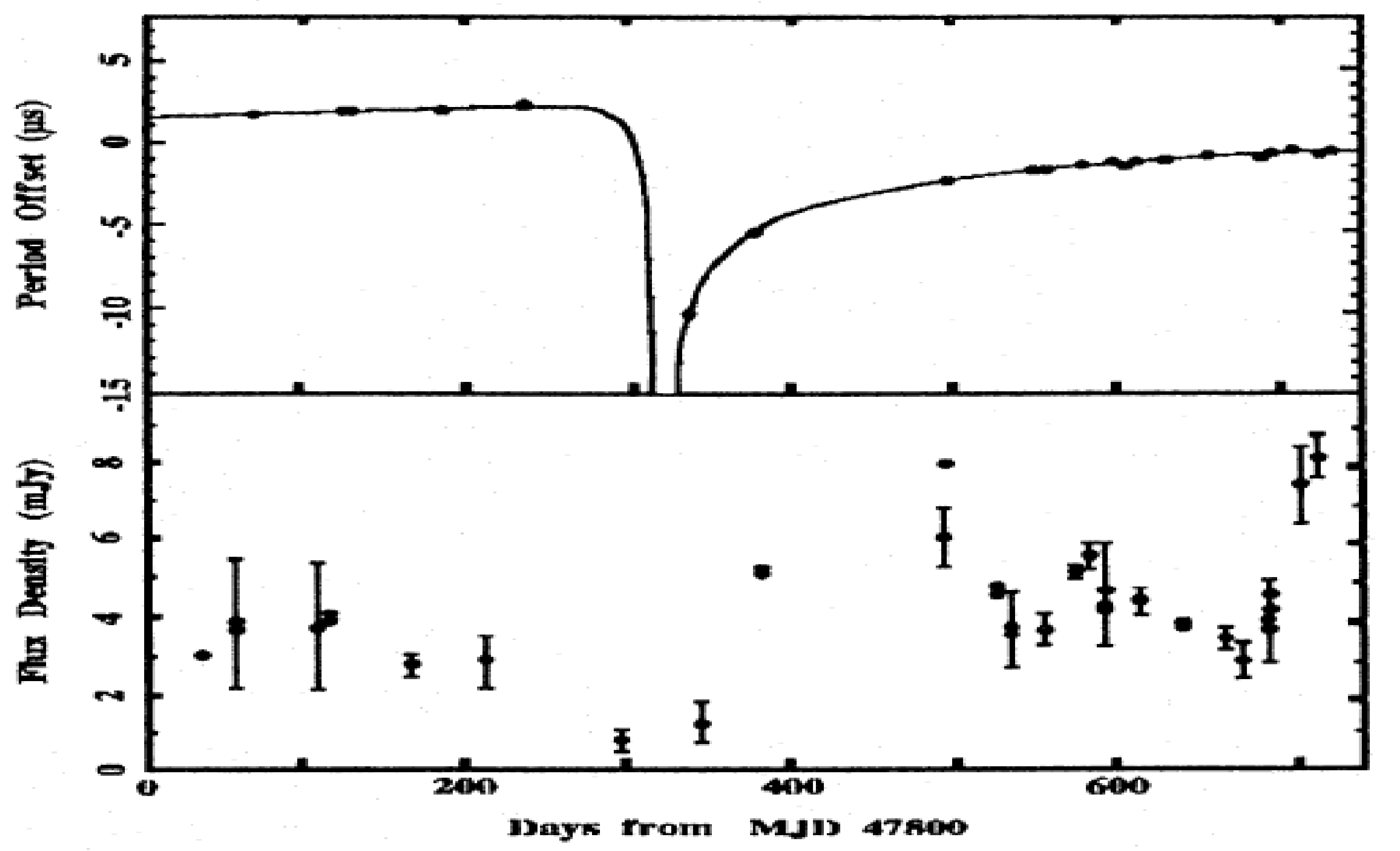


Figure 1. Mean pulse profile at 1.4 GHz. Position angle is shown on top, and the total intensity (solid line), linear (dashed line) and circular (dash–dot line) polarizations are shown in the bottom panel.

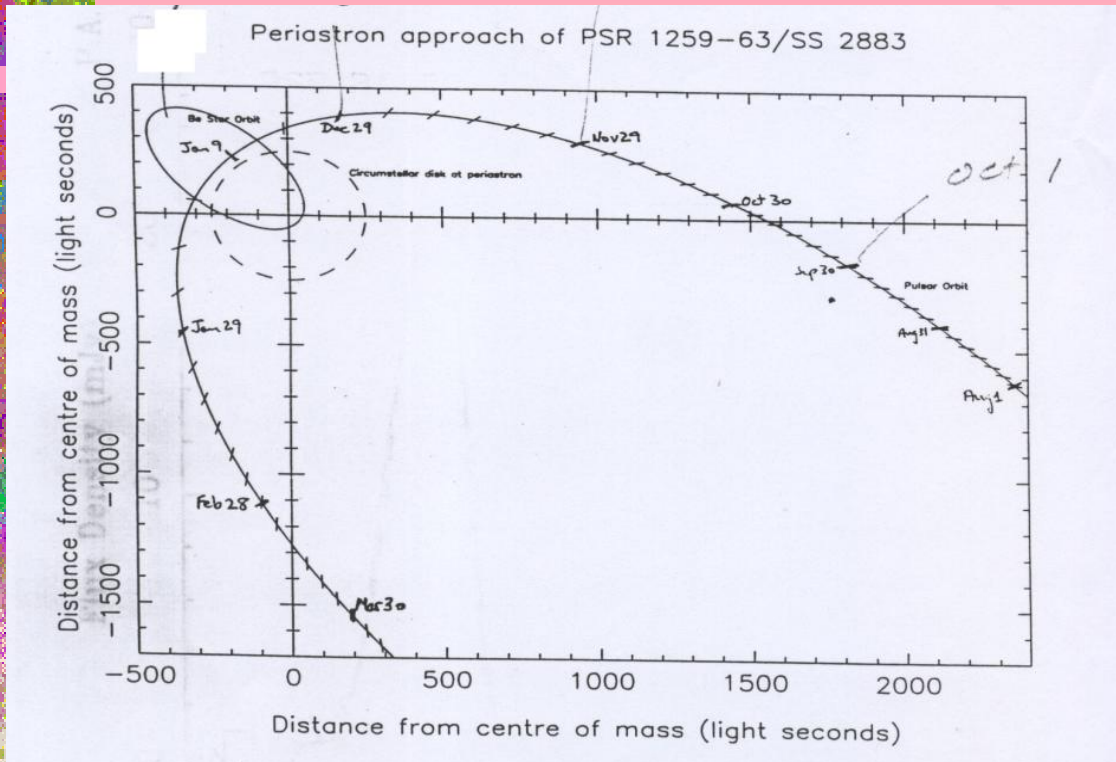
Connors…MN. 336,2002

PSR 1259-63

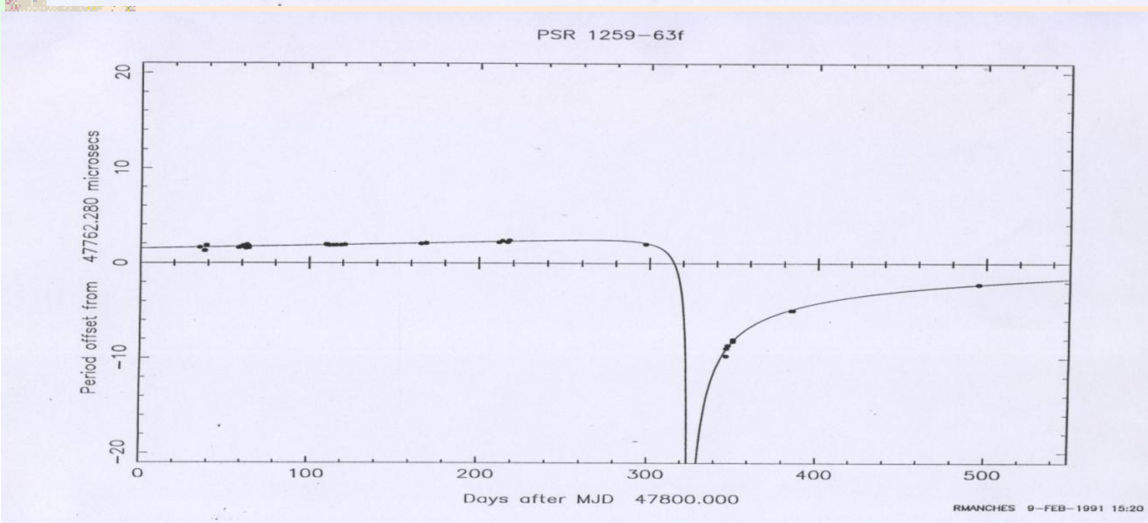


Period Offset (μs)
5
0
-5
-10
-15
Flux Density (mJy)
8
6
4
2
0
0
200
400
600
Days from MJD 47800

PSR 1259-63

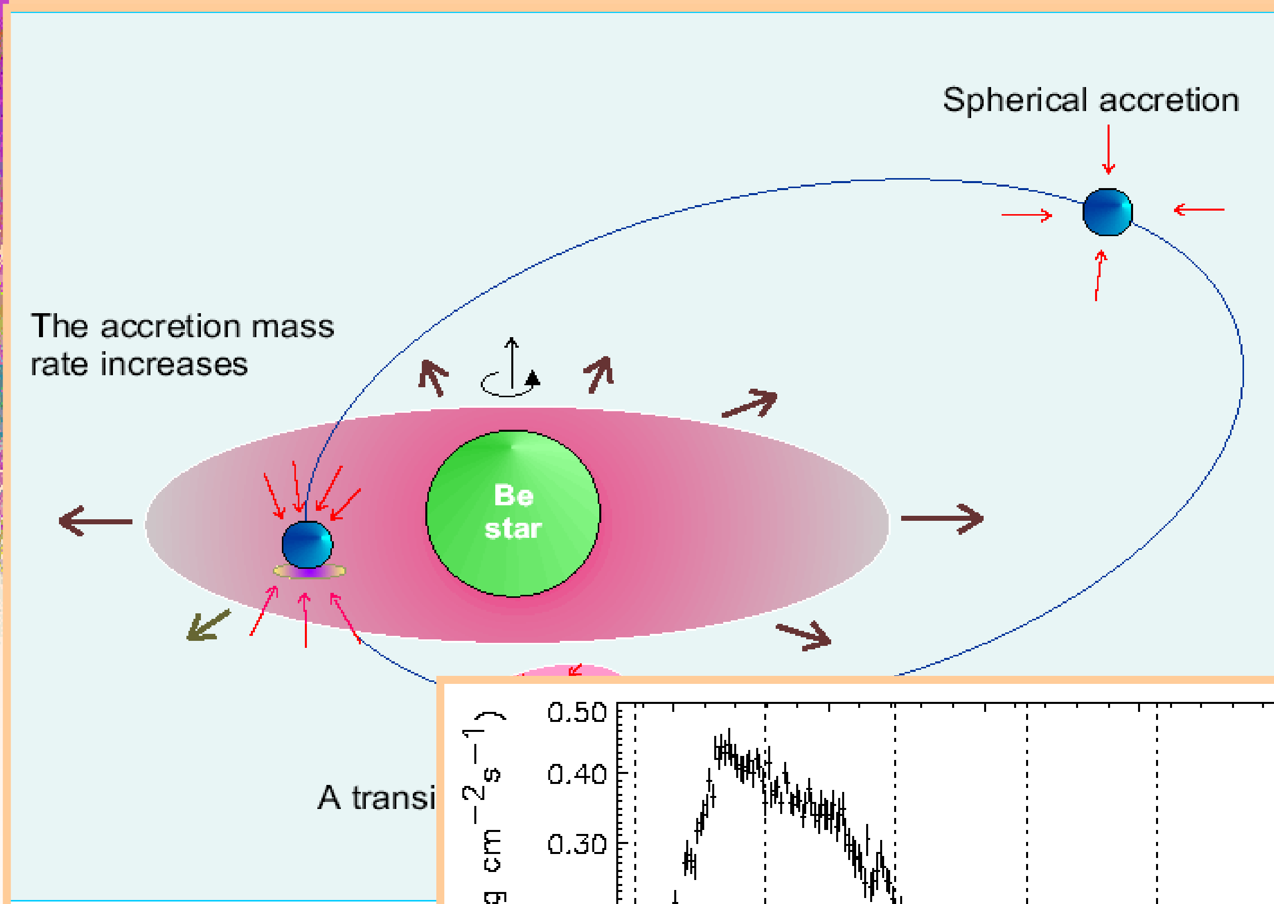


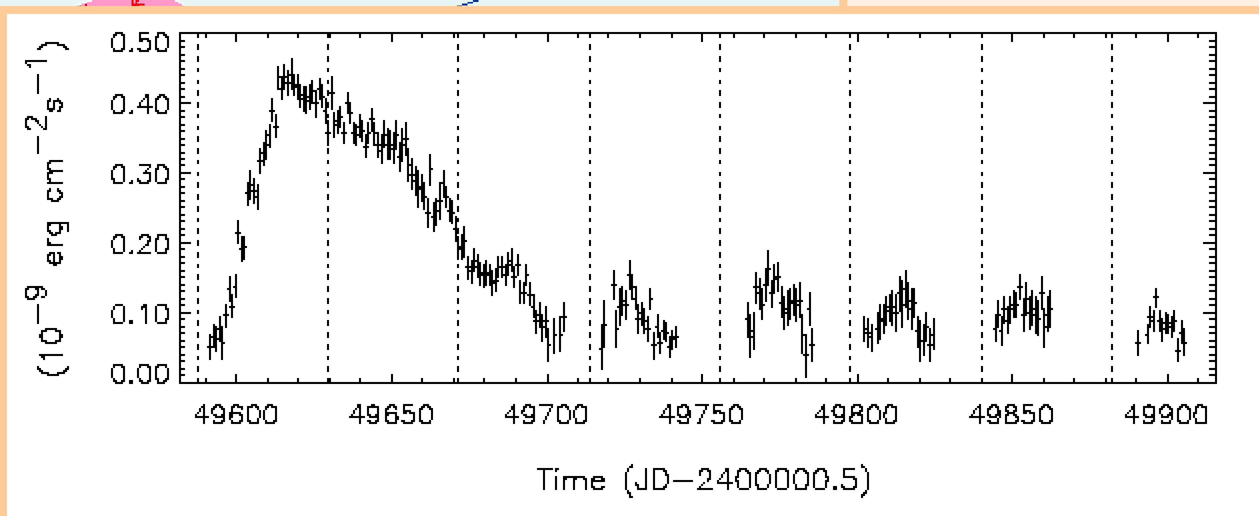
Periastron approach of PSR 1259−63/SS 2883
Be Star Orbit
Circumstellar disk at periastron
Pulsar Orbit
Dec 29
Nov29
Oct 30
Jan 29
Feb 28
Mar30
Distance from centre of mass (light seconds)
Distance from centre of mass (light seconds)



PSR 1259−63f
Period offset from 47762.280 microsecs
Days after MJD 47800.000
RMANCHES 9−FEB−1991 15:20

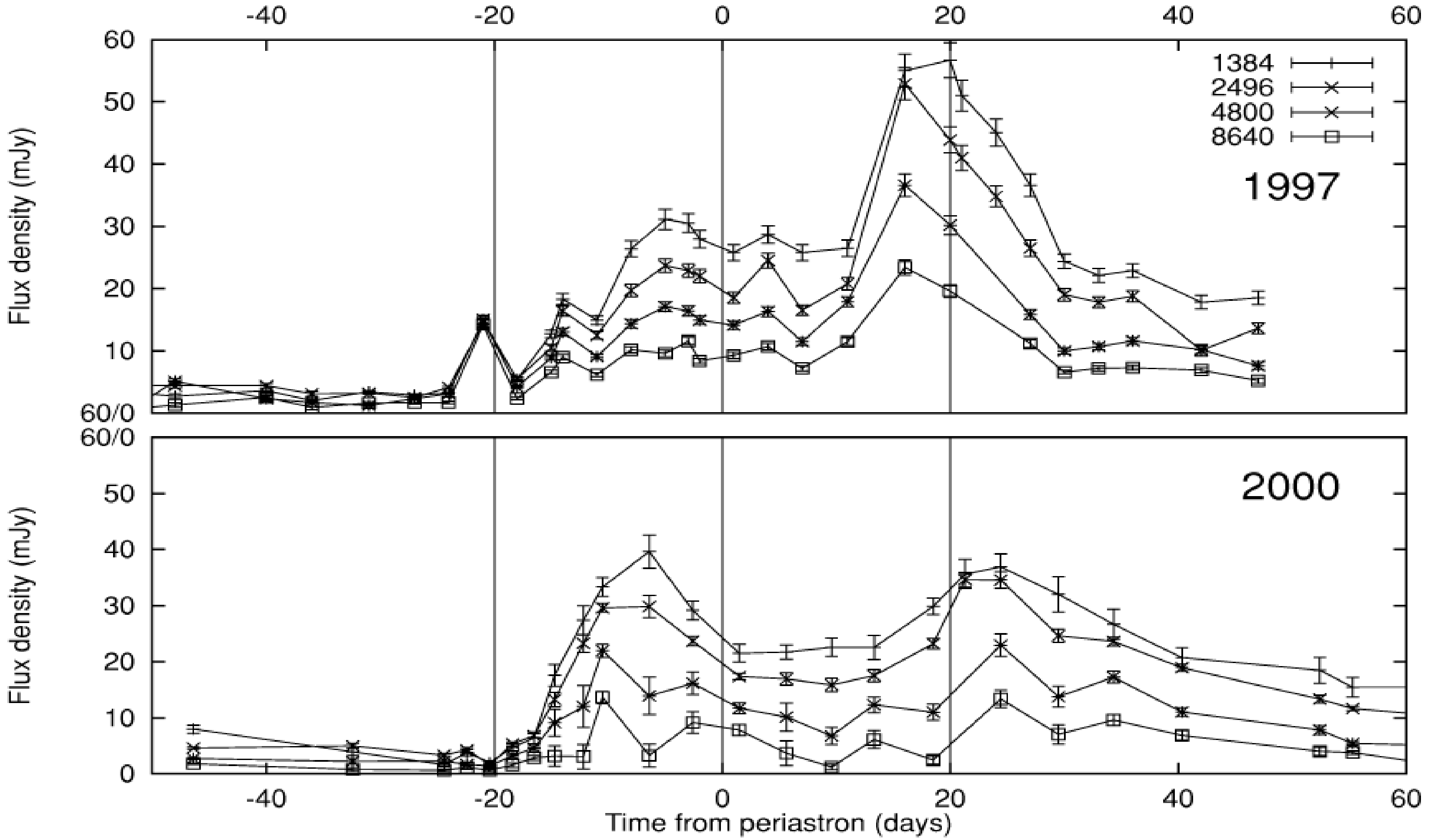
Sketch of a Be/X-ray binary





System 2S1417-624

PSR 1259-63



Pulsed + Unpulsed

Connors…MN. 336,2002

PSR 1259-63

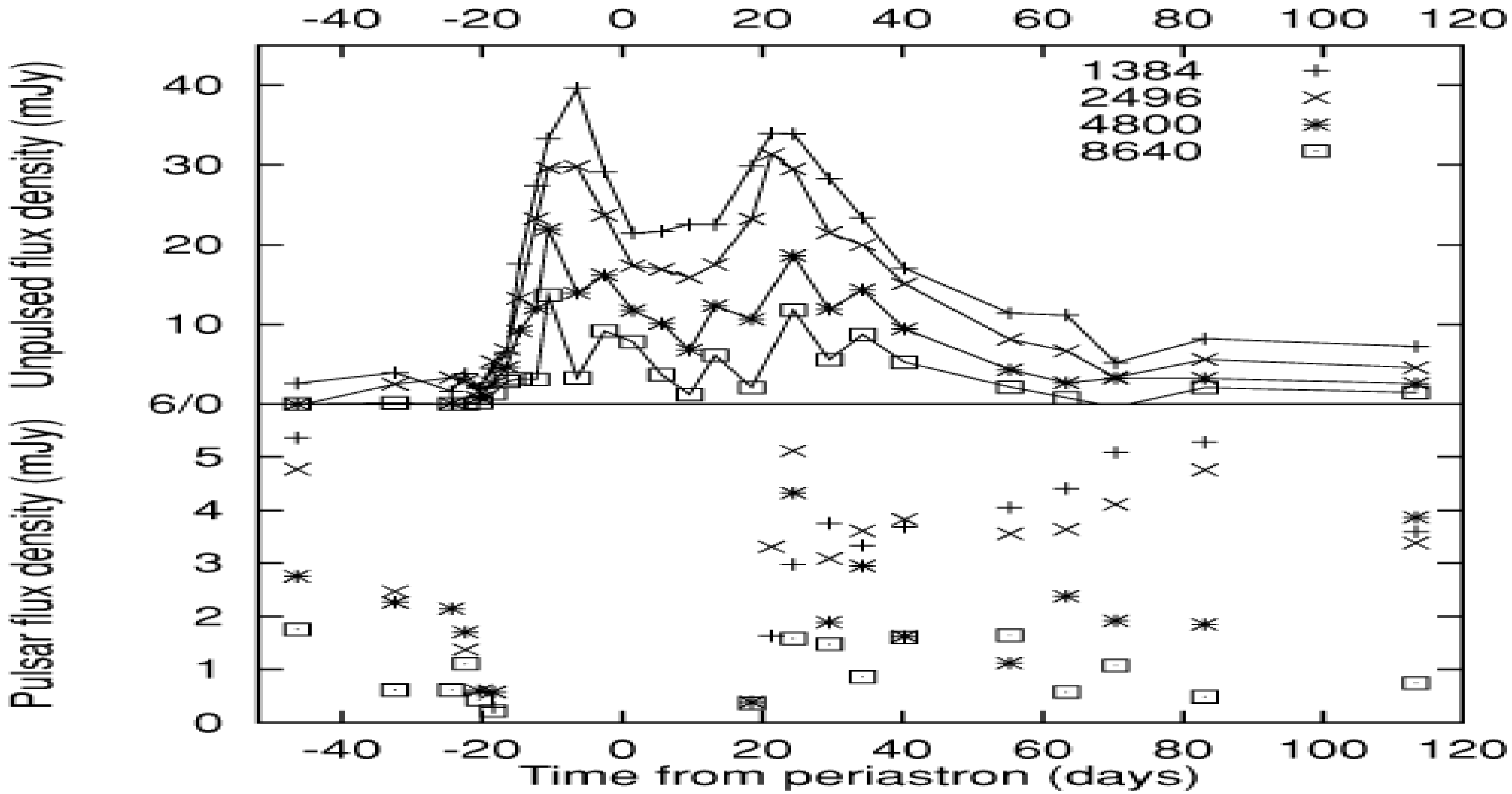
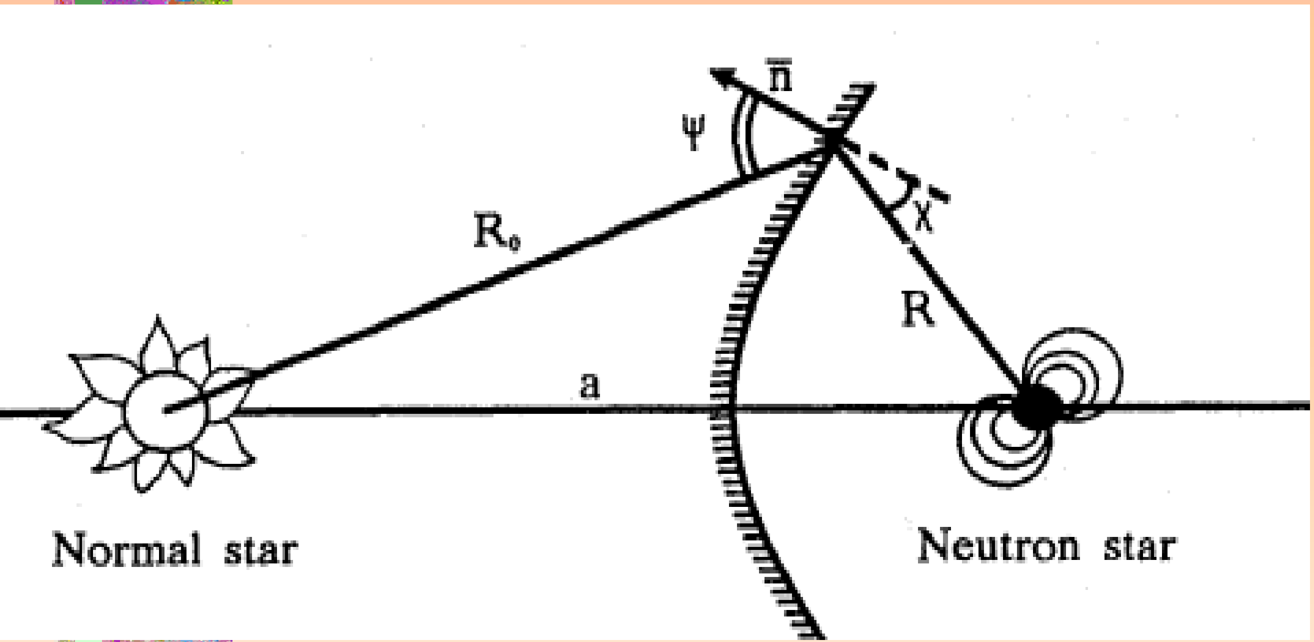


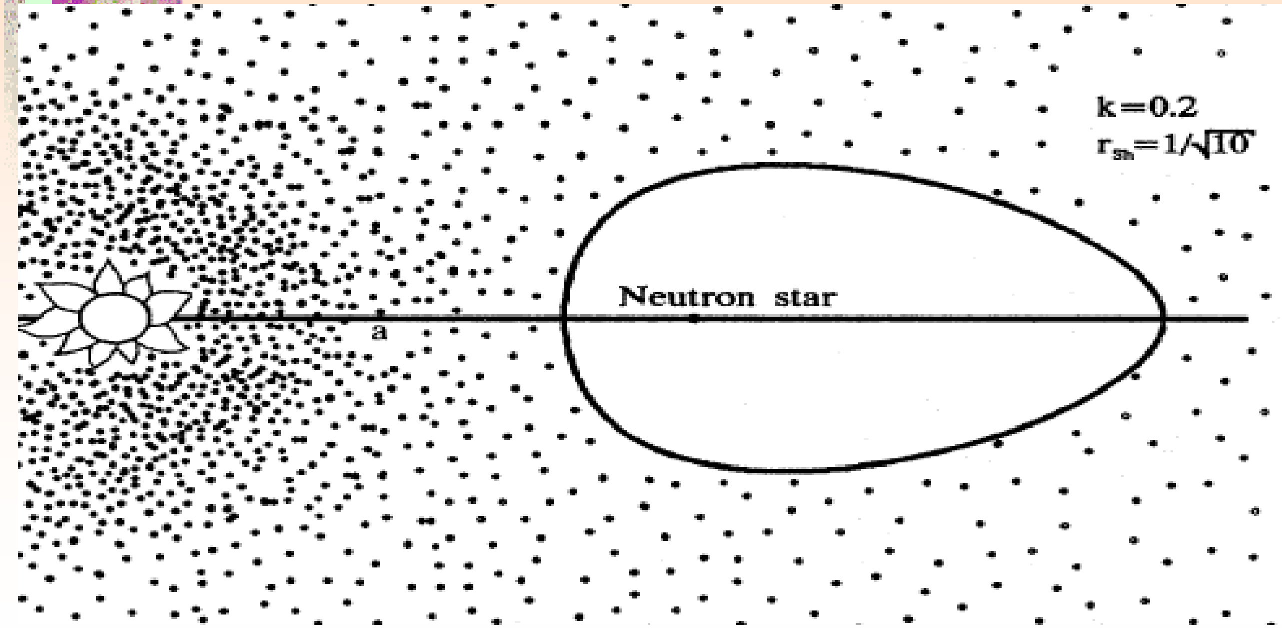
Figure 2. Light curves for the unpulsed emission (top) and the pulsar (bottom) from the 2000 periastron data. For clarity the error bars have been omitted.

Connors…MN. 336,2002

PSR 1259-63

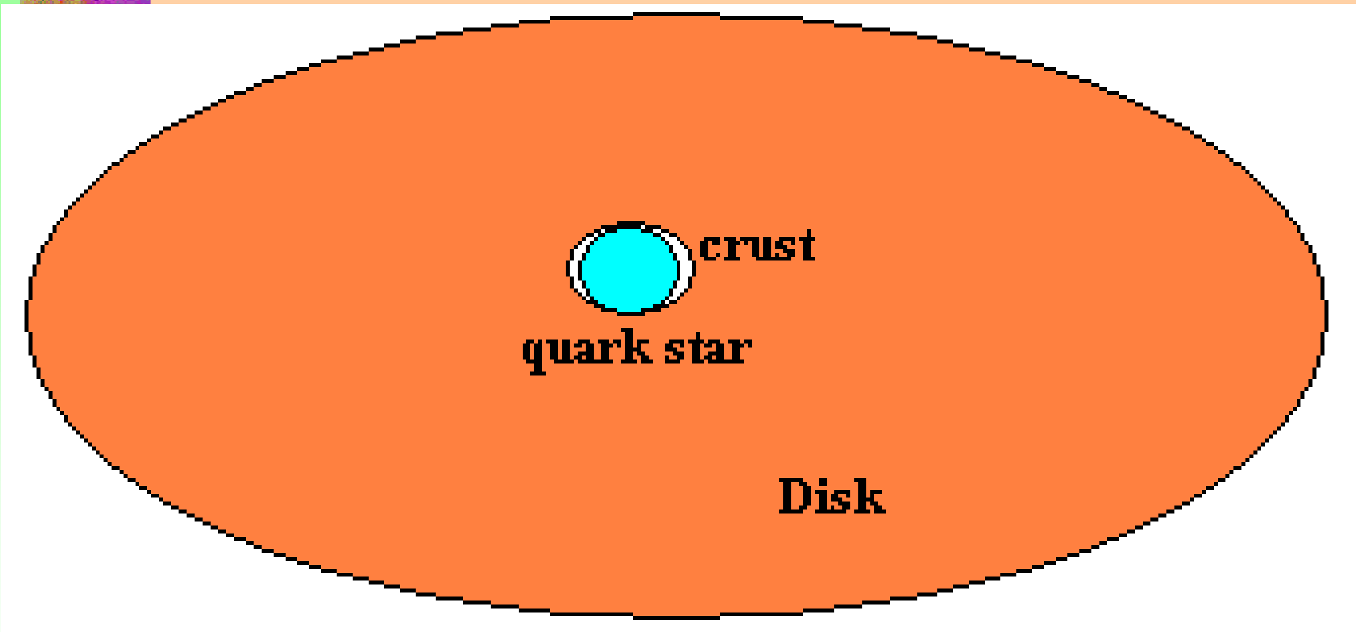


n
ψ
R₀
χ
R
a
Normal star
Neutron star



k=0.2
$r_{sh}=1/\sqrt{10}$
Neutron star
a

SGR & AXP :
A Quark Stars + Crust + fall back disk =>Quarctar



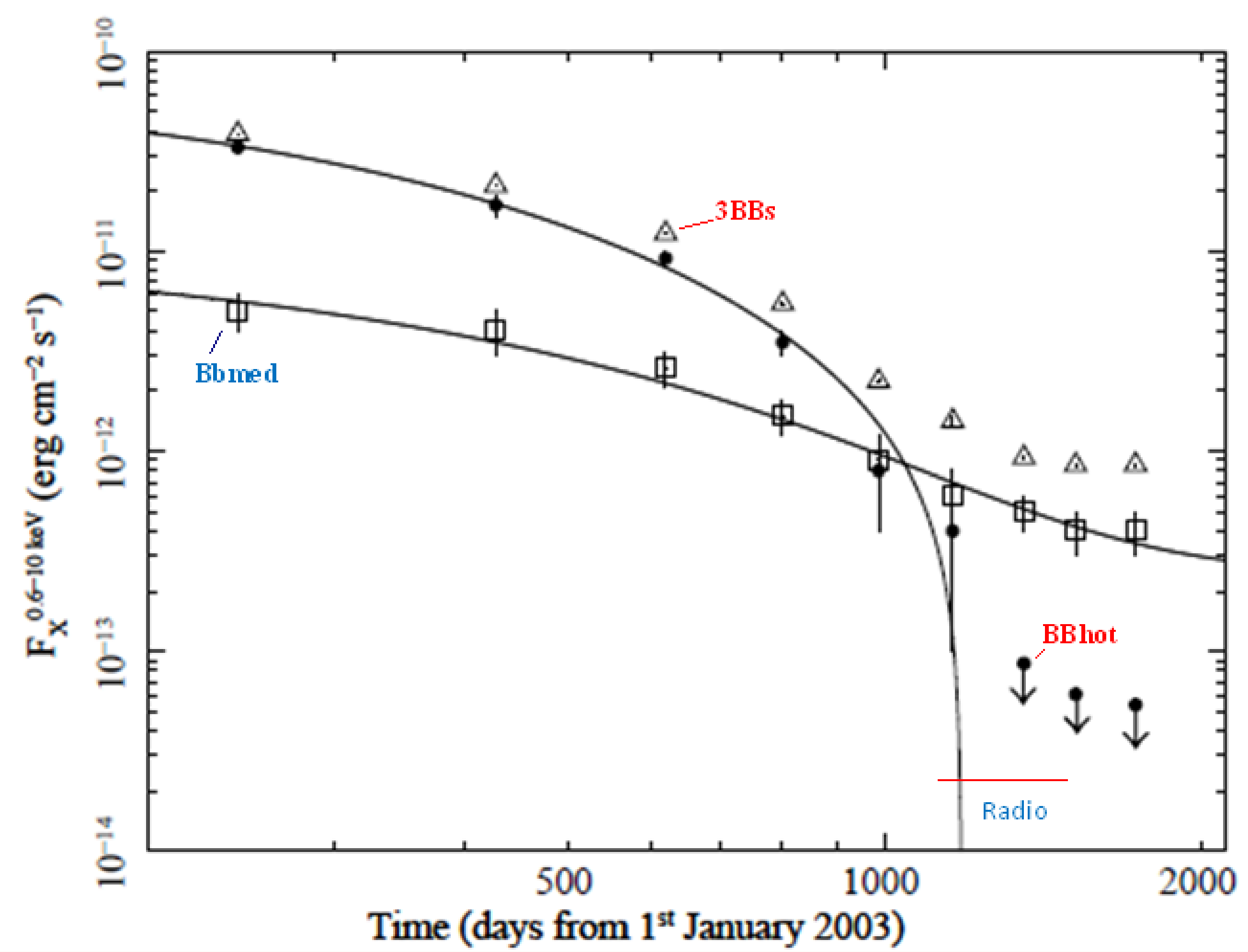
Wang et al.2006
Ertan et al. 2009

Conclusion & discussion

1. Do "magnetars" really exist?
2. What the AXPs & SGRs are?

Thank you !

1810-197: X-ray obs. Sep. 2003 – Sep. 2007



Evolution of the 0.6 – 10 keV flux

Bernardini et al. 2009