

PSR J1119-6127 and the X-ray Emission from High Magnetic Field Radio Pulsars

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NSs and PSRs: ~40 years after discovery

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Overview

- Rotation-Powered Pulsars with High B Field
 - Relation to magnetars
 - X-ray Properties
- The case of PSR J1119-6127
- Emission Models
- Implications

High B Pulsars vs Magnetars

- Magnetars: emission properties powered by high B field.
- Rotation-powered pulsars with high B field:
 - Overlapping spin characteristics
 - Expect “transition objects”

	High B Field Pulsars	Magnetars
Period, P	100's ms - few sec	5-12 sec
Magnetic Field, B	$\sim 10^{13}$ - 10^{14} G	(0.6-7) $\times 10^{14}$ G
L_x	$\ll \dot{E}$	$\gg \dot{E}$
X-ray spectrum	$\Gamma_{pl} \sim 1-2,$ $T_{bb} < 2$ MK	$\Gamma_{pl} \sim 3-4,$ $T_{bb} \sim 5$ MK

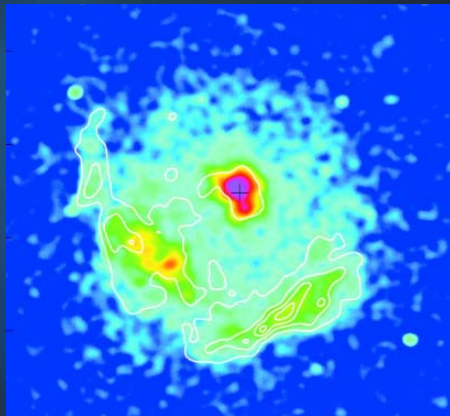
X-ray Properties

- Many rotation-powered pulsars with inferred magnetic fields in the $\sim 10^{13}$ - 10^{14} G range. E.g.,

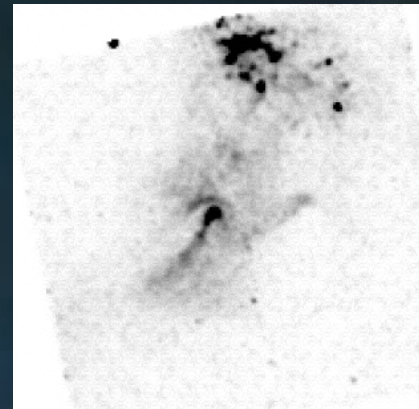
PSR	J1847-0130	J1718-3718	J1814-1744	J1846-0258	B0154+61	B1509-58
P, sec	6.7	3.4	4	0.32	2.35	0.15
B, 10^{13} G	9.4	7.4	5.5	4.8	2.1	1.5
τ_c , kyr	83	34	85	0.72	197	1.7
\dot{E} , ergs/s	1.7×10^{32}	1.5×10^{33}	4.7×10^{32}	8×10^{36}	5.7×10^{32}	1.8×10^{37}
X-rays?	X	Yes, thermal	X	Yes, non-thermal	X	Yes, non-thermal
Ref.	McLaughlin et al. (2003)	Kaspi & McLaughlin (2005)	Pivovarov et al. (2000)	Helfand et al. (2003)	Gonzalez et al. (2004)	Gaensler et al. (2002)

X-ray Properties

- Few X-ray detections:
 - Young ($<10^4$ yrs), high \dot{E} ($>10^{36}$ ergs/s): show nonthermal emission and bright PWNe (PSRs J1846-0258 and B1509-58)



J1846-0258 (Helfand et al 2003)



B1509-58 (Gaensler et al 2002)

- Older ($>10^5$ yrs), lower \dot{E} ($<10^{33}$ ergs/s): undetected, except for the faint thermal emission from PSR J1718-3718

→ No magnetar-like radiative properties

PSR J1119-6127

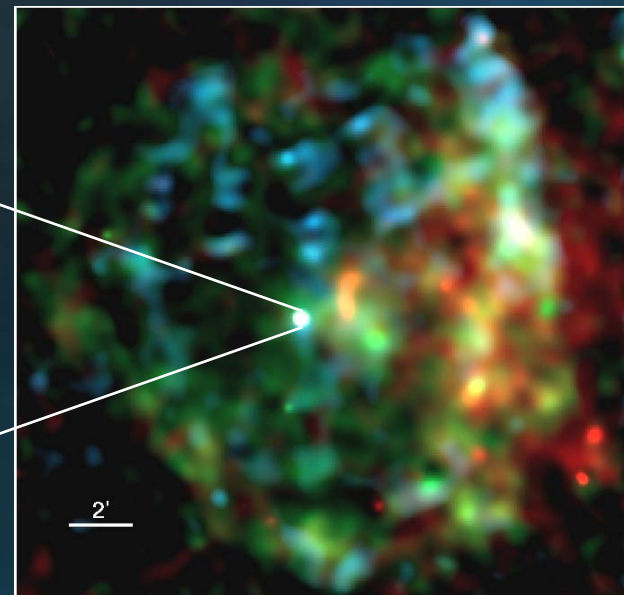
→ The case of PSR J1119-6127:

- $P = 0.41$ sec
- $B = 4.1 \times 10^{13}$ G
- $\dot{E} = 2.3 \times 10^{36}$ ergs/s
- $\tau_c = 1,700$ yrs
- $n = 2.91 \pm 0.05$

- Located at the center of SNR G292.2-0.5 (D~8 kpc)
- Faint, arc-second scale PWN resolved with Chandra (Gonzalez & Safi-Harb 2004)
 - Extended emission mainly above 2 keV



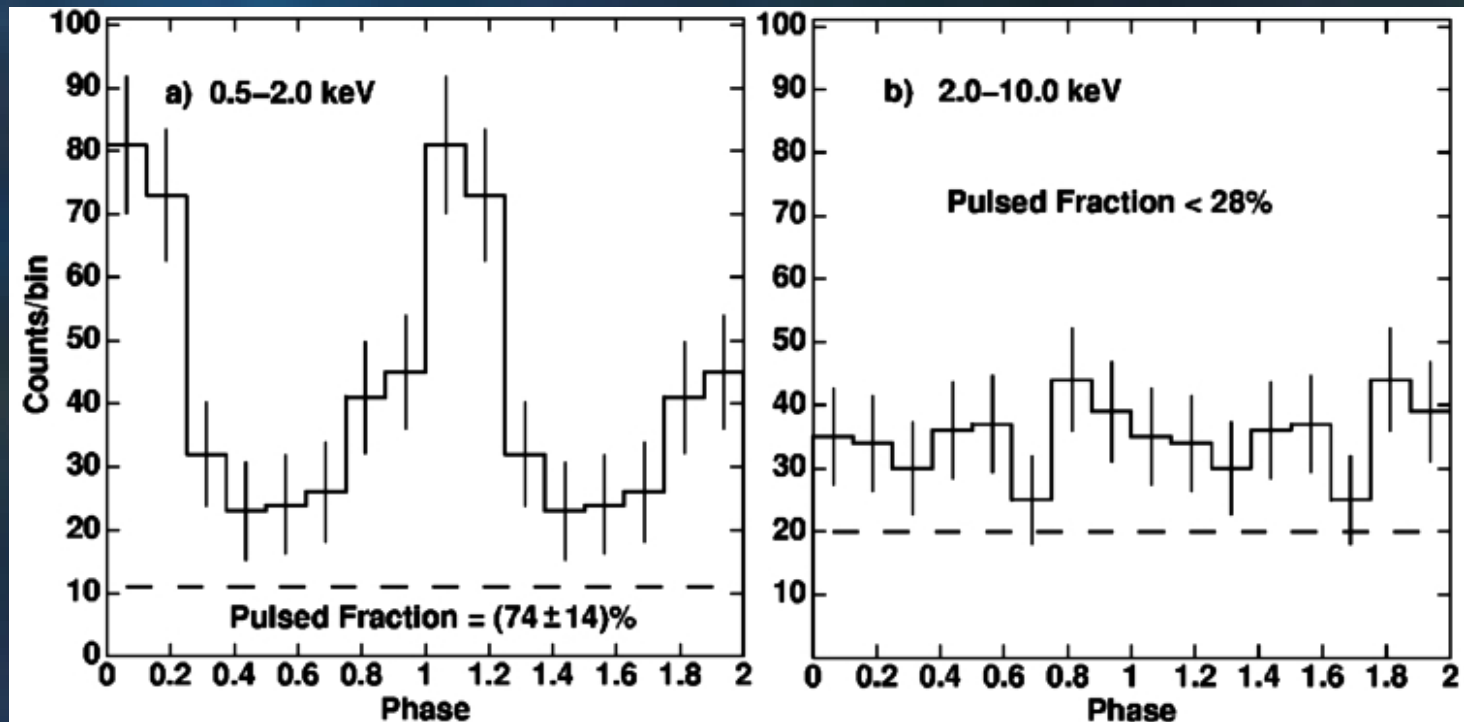
Chandra



XMM

PSR J1119-6127

- Unusual X-ray pulse profile:
 - Single peak, although only coarse determination of pulse profile was possible
 - Very high pulsed fraction of $\sim 74\% \pm 14\%$
 - Only detect pulsations at low energies

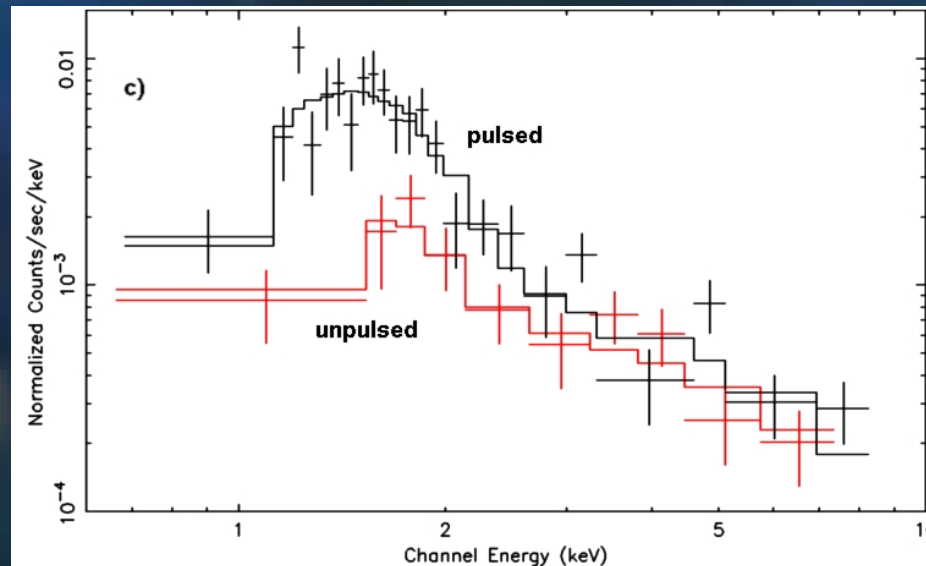


PSR J1119-6127

- Thermal spectrum:

	BB	Atm.
Radius / Distance	3.4 km / 8.4 kpc	27 km / 8.4 kpc
Temp.	2.4 MK	0.9 MK

- Unusual pulsations arise from thermal emission



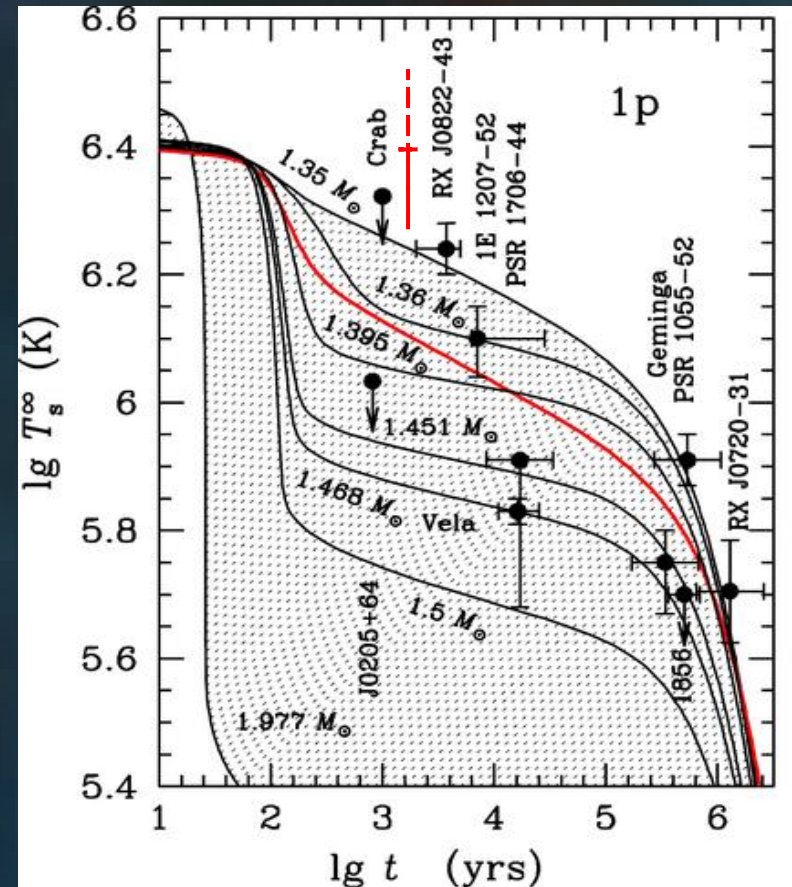
PSR J1119-6127

- Thermal emission:
 - Radio pulsar with smallest characteristic age with detected thermal emission
 - Not expected from reheated polar caps:

	Observed	Expected
L_x/\dot{E}	~ 0.001	$< 10^{-5}$

- Cooling emission?

Yakovlev & Pethick 2004



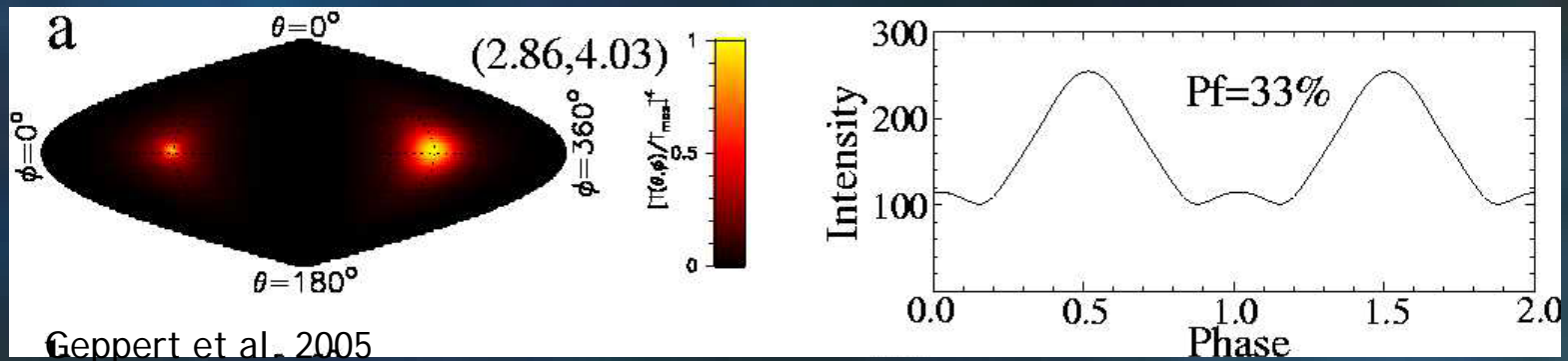
Minimal non-superfluid cooling model (red line) and superfluid cooling models (solid lines)

PSR J1119-6127

- Thermal emission:
 - High temperature (higher than predicted from cooling models)
 - Smaller emitting area than total surface of a NS
 - Very high pulsed fraction
 - Small fraction of available \dot{E}
- Not magnetar-like emission, but unusual for thermal origin: related to high inferred B field?

Emission Models

- Recent work on emission from highly magnetized NSs (Geppert et al 2004, 2005; Perez-Azorin et al. 2006):
 - Anisotropic temperature distribution: high temperature and small emitting area



- But, derived pulsed fractions much lower than in PSR J1119-6127 and some magnetars
 - Take beaming into account?

Further Issues

- Could these models be applied to explain the emission from PSR J1119-6127?
 - How is this emission related to those of magnetars?
 - Why no other high-B field pulsar shows this? Especially PSR J1846-0258
 - Why does PSR 1852+0040 also show a high pulsed fraction and temperature but has an estimated $B < 3 \times 10^{12}$ G (Gotthelf et al 2005)?

Summary

- Unusual thermal emission detected from the young, high-B field pulsar J1119-6127:
 - Radio pulsar with smallest characteristic age with detected thermal emission.
 - Thermal emission: high temperature, small emitting area, very high pulsed fraction.
 - Characteristics related to high-B field effects?
 - Anisotropic temperature distribution due to high B field
 - Still need to account for pulse profile characteristics

Summary

- Why is it so special among high-B field rotation-powered pulsars?* Or is it?
- Why no magnetar-like emission from these sources?
- A broader study of the population and further theoretical work are needed...
- Related works at this meeting:
 - Janssen (P1) and Vranwsevic (P9): radio observations of several high B field radio pulsars; no clear differences from general population but very faint sources.
 - Melikidze (P45): polar cap emission possible?

* More observations to constrain (and confirm) properties would be nice