

Supernova Remnants with magnetars



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Outline

- Origin of magnetars: two possible theories
- Looking for differences: spectroscopy
- Looking for differences: photometry
- Conclusions

Origin of magnetars

Magnetic field conservation:

(e. g. Ferrario & Winkramasinge 2006, Spruit 2008)

- For a progenitor with $\sim 10M_{\text{sun}}$
→ B-flux $\sim 5 \times 10^{27} \text{ G cm}^2$.
Sufficient for a magnetar, but very optimistic.

Alpha-dynamo effect:

(e. g., Duncan & Thompson, 1992)

- vigorous convection during $\sim 10\text{s}$ after the formation of the neutron star produces the high magnetic field.
- It causes an excess of rotational energy not detected yet in the SNR (Vink & Kuiper 2006).
- This energy can be emitted in others channels (e. g., neutrinos)

*Do we find differences
in the ionization levels of the lines
between SNRs with magnetars
and the rest?*

Looking for differences: spectroscopy

- We analyse four SNRs: Kes 73, CTB 109, N 49 (LMC) & Kes 75 (Chandra archival analysis, Kumar & Safi-Harb 2008)
- We use XMM-Newton data: EPIC-PN & EPIC-MOS in full-frame mode.

Total exp. Time (s)	PN	MOS 1	MOS 2
Kes 73	12630	12145	12143
CTB 109	40546	106340	132824
N 49	72172	4652	5771

- Reduction package: SAS v11.0.0
- Analysis package: HEASOFT v6.13 (XSPEC v12.8.0)

Looking for differences: spectroscopy

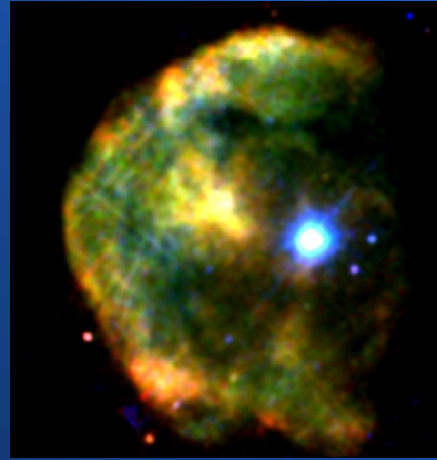


Kes 73 (AXP 1E 1814-045)

- $B \sim 7.3 \times 10^{14}$ G
- $T \sim 4$ kyr

Dimensions: 4.5' x 4.7'

Distance: 7.5-9.8 kpc

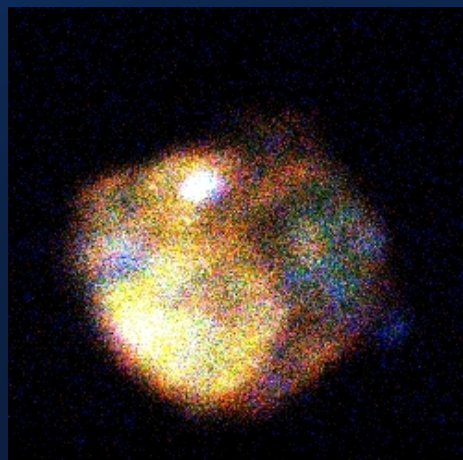


CTB 109 (AXP 1E 2259+586)

- $B \sim 5.9 \times 10^{13}$ G
- $T \sim 229$ kyr

Dimensions: 30' x 45'

Distance: 3.2 kpc



N 49 (SGR 0526-66)

- $B \sim 7.3 \times 10^{14}$ G
- $T \sim 2$ kyr

Dimensions: 1.5' x 1.5'

Distance: 50 kpc



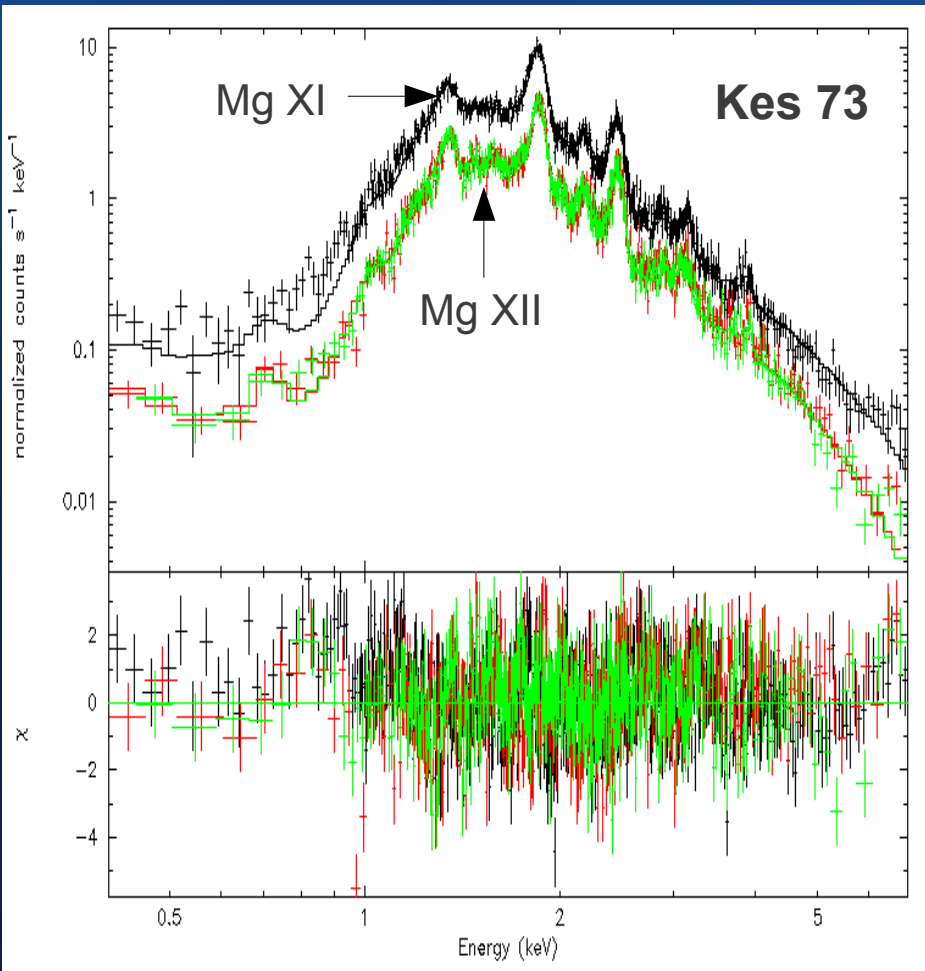
Kes 75 (PSR J1846-0258)

- $B \sim 4.9 \times 10^{13}$ G
- $T \sim 0.7$ kyr

Dimensions: 3.7' x 3.4'

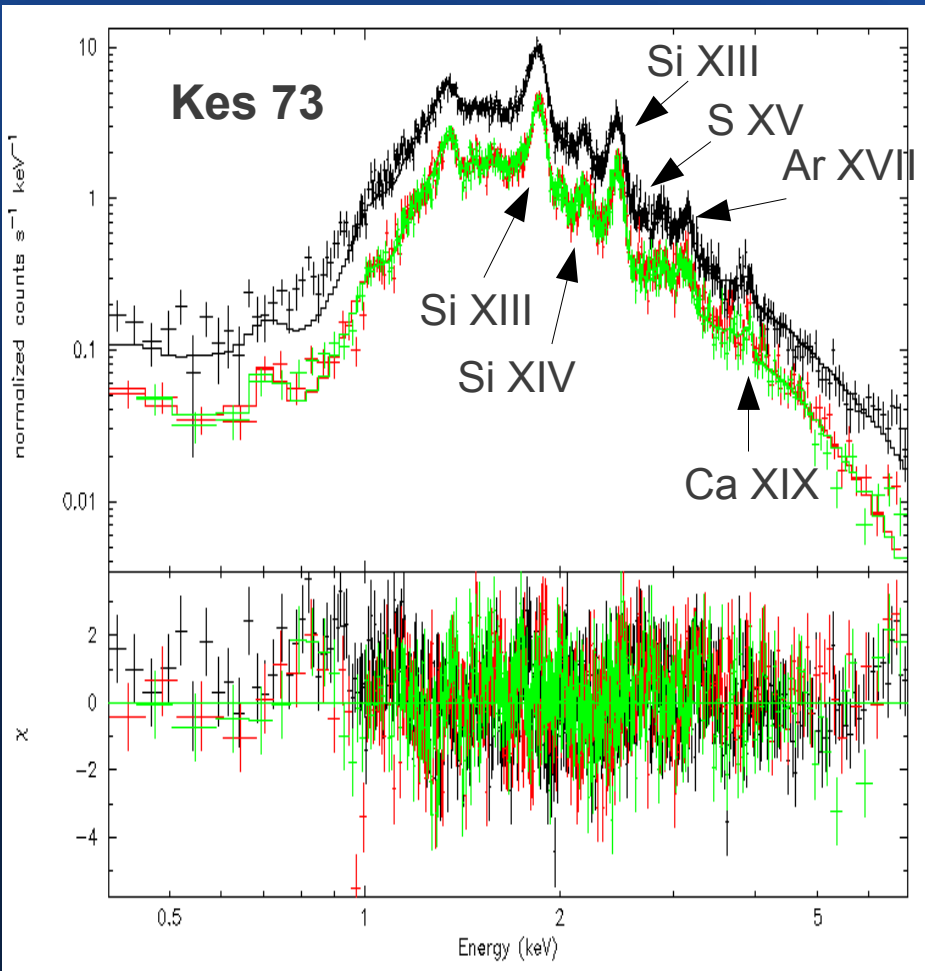
Distance: 21 kpc

Looking for differences: spectroscopy



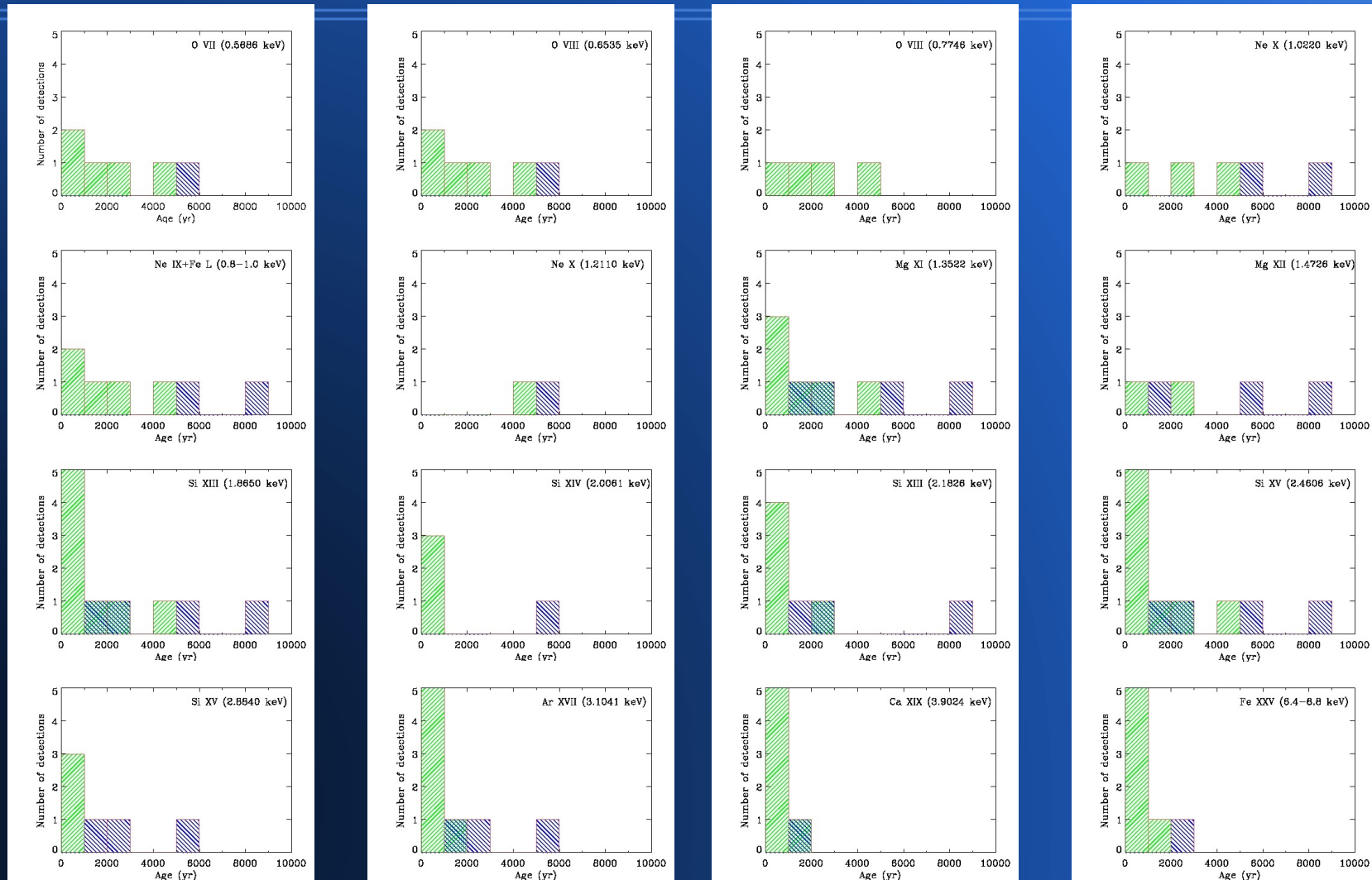
SNR	Galaxy	Age (yr)	Element			
			O VII (7 → 1) (0.5686 KeV)	O VIII (3,4 → 1) (0.6535 KeV)	O VIII (6,7 → 1) (0.7746 KeV)	Ne IX (7 → 1)+Fe L (0.8-1.0 KeV)
Kes73	MW	1100-1500				
CTB109	MW	7900-9700				X
Kes75	MW	900-4300				
N49	LMC	5000	X	X		X
G1.9+1.3	MW	110-170				
Kepler	MW	408				
Tycho	MW	440				
SN1006	MW	1006	X	X	X	X
Cas A	MW	316-352	X	X	X	X
MSH11-54	MW	2930-3050	X	X	X	X
Puppis A	MW	3700-5500	X	X	X	X
B0509-67.5	LMC	400	X	X		X
			Ne X (3,4 → 1) (1.0220 KeV)	Ne X (6,7 → 1) (1.2110 KeV)	Mg XI (2,5,6,7 → 1) (1.3522 KeV)	Mg XII (3,4 → 1) (1.4726 KeV)
Kes73	MW	1100-1500			X	X
CTB109	MW	7900-9700	X		X	X
Kes75	MW	900-4300			X	
N49	LMC	5000	X	X	X	X
G1.9+1.3	MW	110-170				
Kepler	MW	408			X	
Tycho	MW	440				
SN1006	MW	1006			X	
Cas A	MW	316-352	X		X	X
MSH11-54	MW	2930-3050	X		X	X
Puppis A	MW	3700-5500	X	X	X	
B0509-67.5	LMC	400			X	

Looking for differences: spectroscopy



			Si XIII (2,5,6,7 → 1) (1.8650 KeV)	Si XIV (3,4 → 1) (2.0061 KeV)	Si XIII (13 → 1) (2.1826 KeV)	S XV (2,5,6,7 → 1) (2.4606 KeV)
Kes73	MW	1100-1500	X		X	X
CTB109	MW	7900-9700	X		X	X
Kes75	MW	900-4300	X		X	X
N49	LMC	5000	X	X		X
			S XV (13 → 1) (2.8840 KeV)	Ar XVII (2,5,6,7 → 1) (3.1041 KeV)	Ca XIX (2,5,6,7 → 1) (3.9024 KeV)	Fe XXV (2,5,6,7 → 1) (6.4-6.8 KeV)
G1.9+1.3	MW	110-170	X		X	X
Kepler	MW	408	X	X	X	X
Tycho	MW	440	X	X	X	X
SN1006	MW	1006	X	X	X	X
Cas A	MW	316-352	X	X	X	X
MSH11-54	MW	2930-3050	X		X	X
Puppis A	MW	3700-5500	X		X	X
B0509-67.5	LMC	400	X		X	X
Kes73	MW	1100-1500	X	X	X	
CTB109	MW	7900-9700	X	X	X	
Kes75	MW	900-4300	X	X	X	
N49	LMC	5000	X	X		X
G1.9+1.3	MW	110-170		X	X	X
Kepler	MW	408	X	X	X	X
Tycho	MW	440	X	X	X	X
SN1006	MW	1006	X	X	X	X
Cas A	MW	316-352	X	X	X	X
MSH11-54	MW	2930-3050				
Puppis A	MW	3700-5500				
B0509-67.5	LMC	400		X	X	X

Looking for differences: spectroscopy



Looking for differences: spectroscopy

- We do not see differences in the ionization levels of the lines.
- The lines detected in all SNRs are quite standard.
- Same conclusion as Vink & Kuiper 2006 using a different analysis.

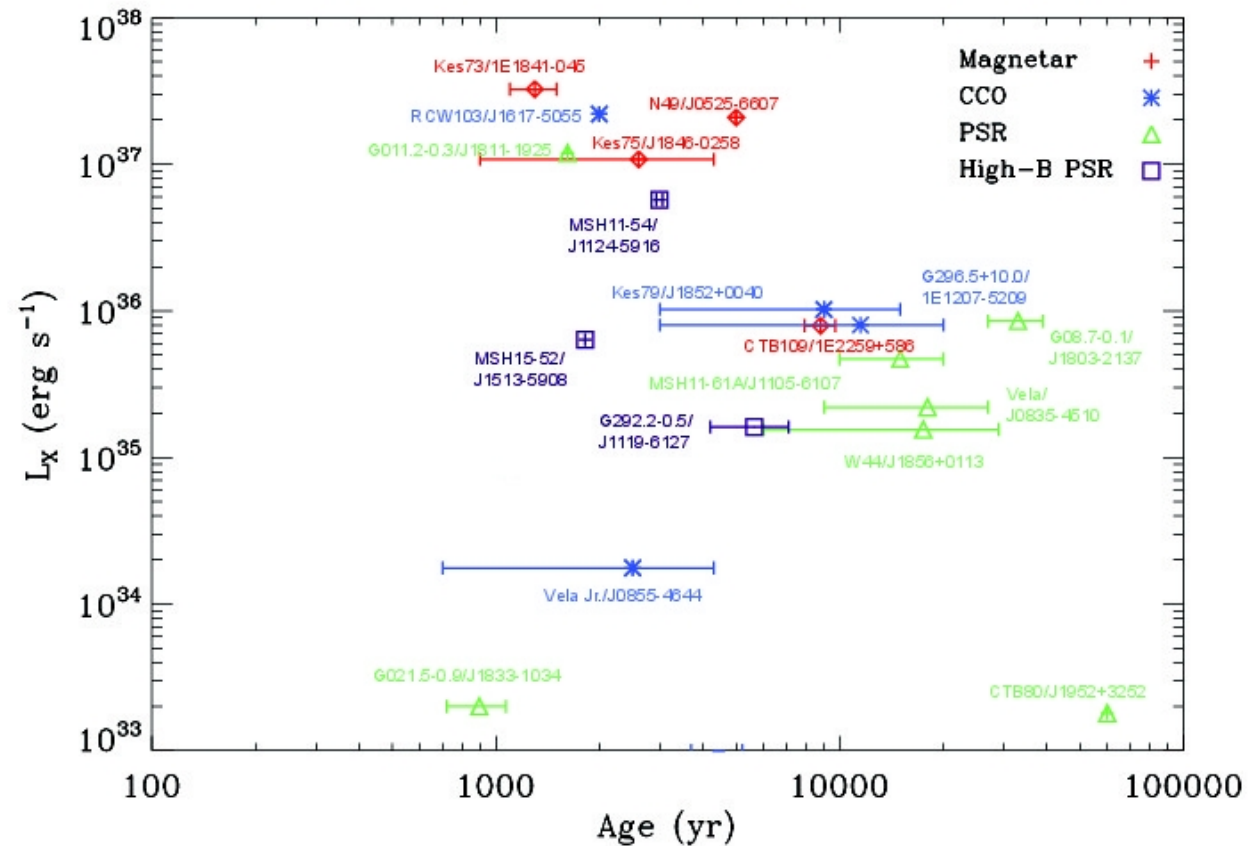
*Are SNRs with magnetars
brighter in X-rays?*

Looking for differences: photometry

- We compiled data of SNRs including parameters as its central source, the age, luminosity, radius, etc.
- In the case that they have a PSR or a CCO with known period and period derivative, we include also the magnetic field and the spin-down luminosity.
- This data compiles all the X-ray SNR with an associated identified CS.

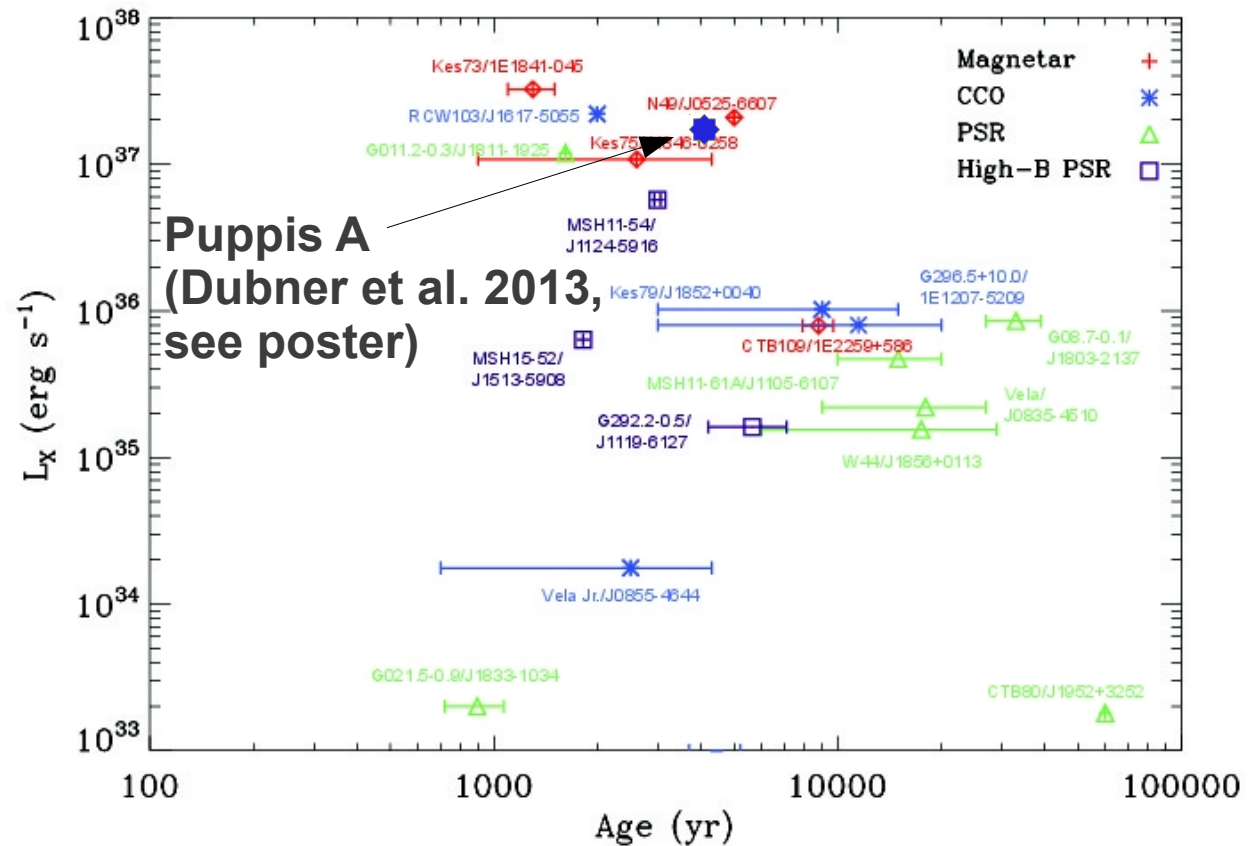
Looking for differences: photometry

- There is a hint that SNRs with magnetar are brighter (in a general view)
- G011.2-0.3 is a clear exception
- SNRs with CCO are also very bright. Maybe they are related with high B-fields buried inside the crust.



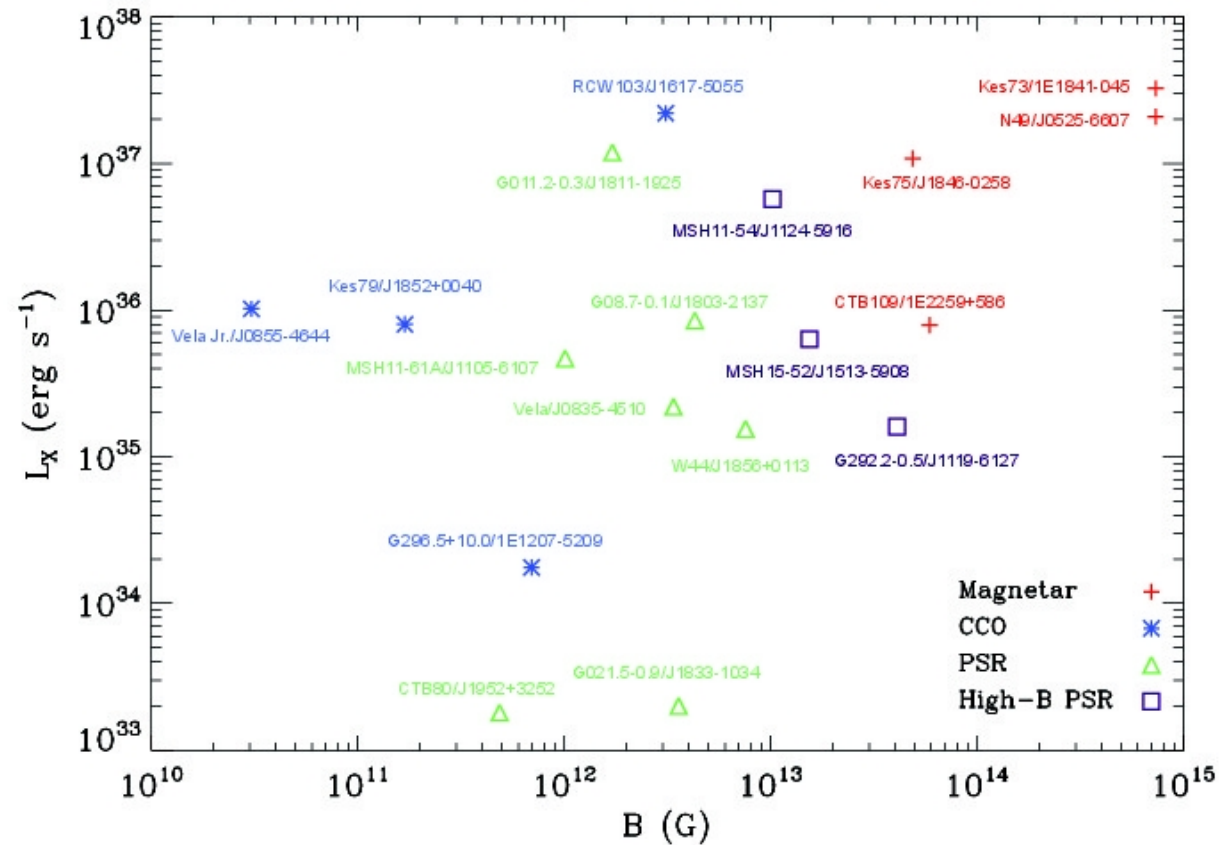
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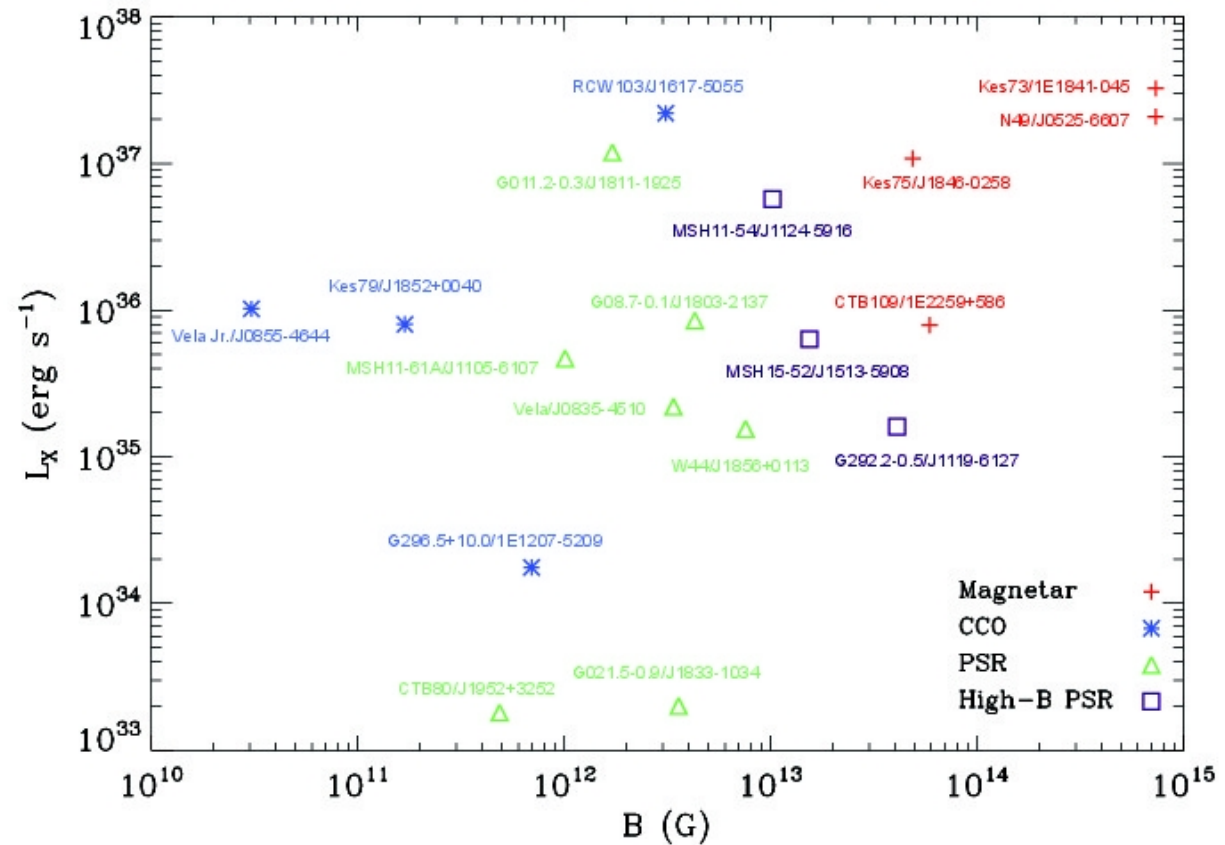
Looking for differences: photometry

- Spearman correlation probability: 0.16
- Kendall correlation probability: 0.13
- There is a hint (but not significant) correlation between the X-ray luminosity and the magnetic field of the neutron star



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Conclusions

- We have performed a spectral analysis of Kes 73, CTB 109, N 49 & Kes 75 using XMM-Newton and Chandra data.
- We do not see differences in the ionization levels of the lines between SNRs with magnetars and the rest.
- There is a hint that SNRs with magnetar are more luminous in X-ray than the others (at the same age), but it is not statistically significant yet.