Origin and evolution of magnetars

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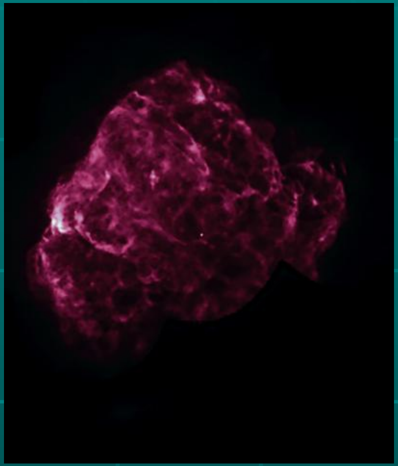
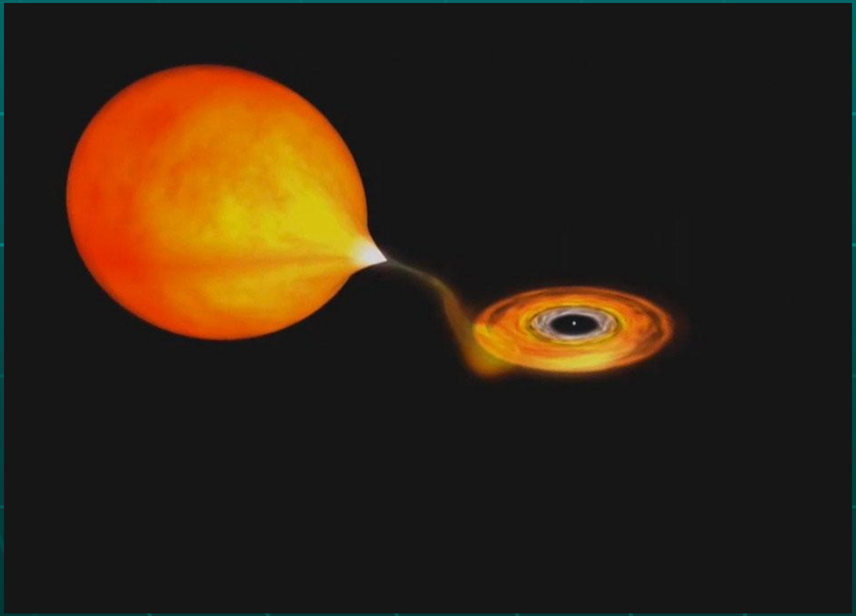
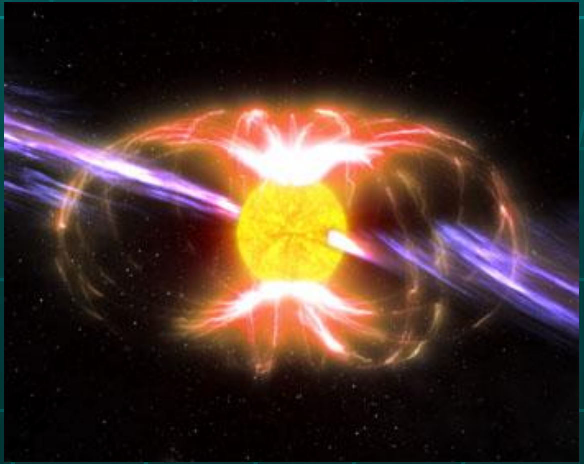
Plan of the talk

- Origin of magnetars. Role of binaries
- Evolution of magnetars. Binaries as probes.
- Frozen magnetars in CCOs

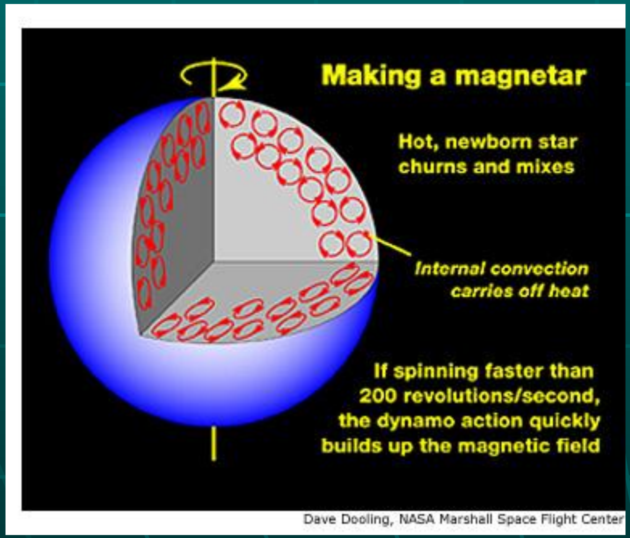






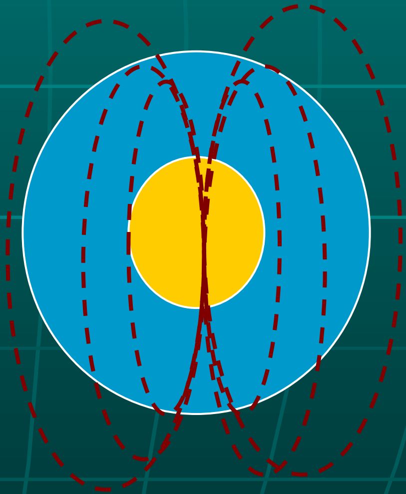
Origin of magnetars field

Generated



Classical dynamo scenario starting from DT in 90s

Fossil



Critisized by Spruit (2008)

Dynamo mechanism conditions

Rapid rotation is necessary!

P_0~ few msec
This is difficult to achieve due to slowdown of
a stellar core rotation (Heger et al. 2004, Meynet, Maeder 2005).
The same problem appear in GRB scenario.

Stellar rotation can be enhanced only in binaries.

There are different possibilities
to gain additional angular momentum
due to mass transfer or tidal interaction.

We need to to perform population
synthesis calculations.

Binary evolution channels. I.

Among all possible evolutionary paths that result in formation of NSs we select those that lead to angular momentum increase of progenitors.

- Coalescence prior to a NS formation.
- Roche lobe overflow by a primary without a common envelope.
- Roche lobe overflow by a primary with a common envelope.
- Roche lobe overflow by a secondary without a common envelope.
- Roche lobe overflow by a secondary with a common envelope.

This is an optimistic scenarion, as it is assumed that angular momentum is not lost in significant amount after it has been gained (astro-ph/0505406)

Products of binaries. I.

In the "optimistic" scenario we obtain that rapidly rotating cores are mainly produced by mergers and by first RLO (i.e. the secondary companion gets angluar momentum).

Mostly, compact objects formed via these channels are isolated.

Table 1. Results of calculations for moderate mass loss

Name	Bi–Maxwell		Maxwell, $V_p = 127$ km/s		Maxwell, $V_p = 370$ km/s	
	$\alpha_q = 0$	$\alpha_q = 2$	$\alpha_q = 0$	$\alpha_q = 2$	$\alpha_q = 0$	$\alpha_q = 2$
Total number of tracks	100 000	100 000	100 000	100 000	100 000	100 000
Total number of NSs	113 805	126 698	109 857	128 205	113 442	133 085
Number of binary NSs	6 604	7 065	16 466	17 814	3 116	3 242
Fraction of binary NSs	3.1%	3.1%	7.8%	7.8%	1.5%	1.4%
Number of 'magnetars"	18 369	20 494	16 884	18 096	18 629	20 875
Number of 'binary magnetars"	114	208	397	307	84	145
Fraction of 'magnetars"	8.6%	9.0%	8.0%	7.9%	8.7%	9.0%
From coalescence	60.1%	35.7%	65.4%	40.4%	59.3%	35.0%
From primary components	2.5%	1.6%	2.7%	1.7%	2.4%	1.5%
From secondary components	37.4%	62.7%	31.9%	57.9%	38.3%	63.5%

Table 2. Results of calculations for strong mass loss

Name	Bi–Maxwell		Maxwell, $V_p = 127$ km/s		Maxwell, $V_p = 370$ km/s	
	$\alpha_q = 0$	$\alpha_q = 2$	$\alpha_q = 0$	$\alpha_q = 2$	$\alpha_q = 0$	$\alpha_q = 2$
Total number of tracks	100 000	100 000	100 000	100 000	100 000	100 000
Total number of NSs	126 845	145 289	121 571	137 610	126 607	145 869
Number of binary NSs	8 303	9 101	20 217	22 516	4 020	4 359
Fraction of binary NSs	3.7%	3.7%	9.1%	9.5%	1.8%	1.8%
Number of 'magnetars"	30 180	29 226	26 348	23 652	31 068	30 621
Number of 'binary magnetars"	157	296	514	795	133	223
Fraction of 'magnetars"	13.3%	11.9%	11.9%	10.0%	13.7%	12.5%
From coalescence	56.7%	29.4%	65.0%	36.3%	55.1%	28.1%
From primary components	0.7%	1.8%	0.8%	2.2%	0.7%	1.7%
From secondary components	42.6%	68.8%	34.2%	61.5%	44.2%	70.2%

astro-ph/0505406

Binary evolution channels. II.

"Easy come – easy go". Angular momentum can be lost
after it was increased in a binary.

Here we consider only tidal synchronization on late stages
(end of helium burning, or carbon burning).
I.e. a core gets additional momentum not long before the collapse.

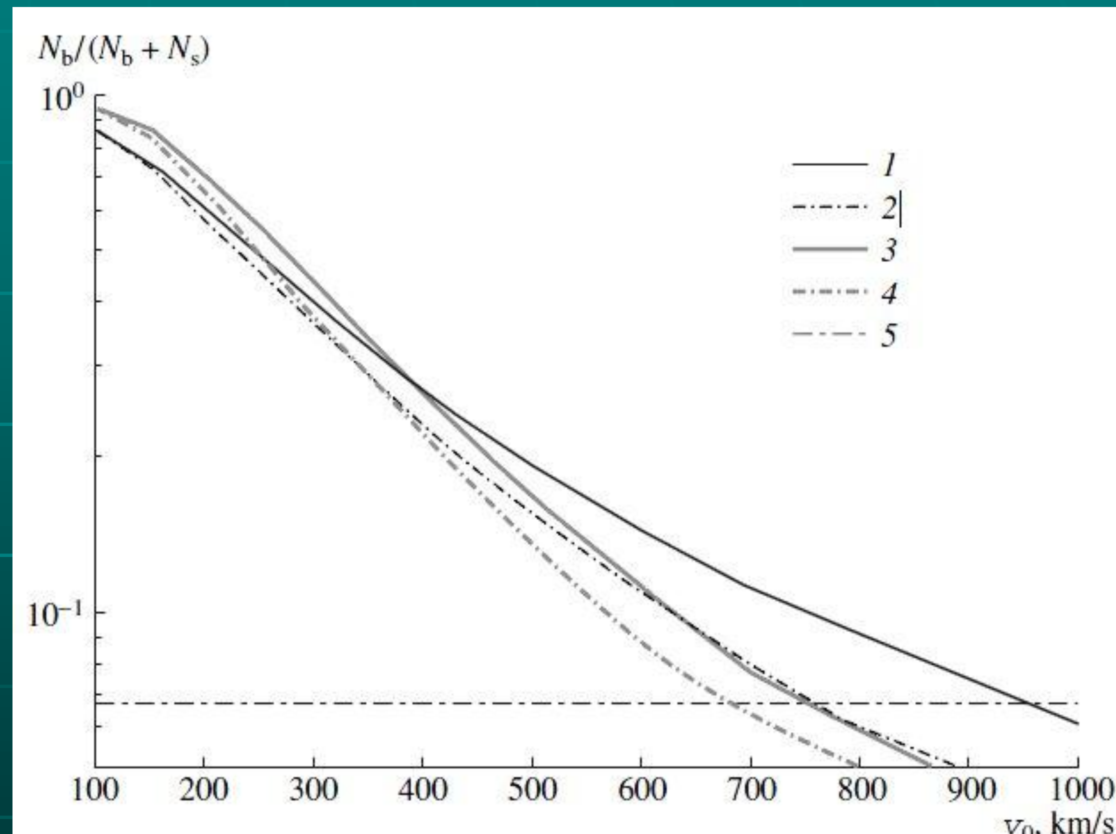
This is possible only in very narrow systems (P_{orb}<10 days).
So, this is a "pessimistic" scenario (arXiv: 0905.3238).

The trick is also to explain the fact that all know well-established
magnetars (SGRs, AXPs) are isolated objects.

Different kicks and mass loss

(1) isotropic kick,
type A wind scenario;
(2) isotropic kick,
type C wind scenario;
(*3*) Kick along the spin axis,
type A wind scenario;
(*4*) Kick along the spin axis,
type C wind scenario

(arXiv: 0905.3238)

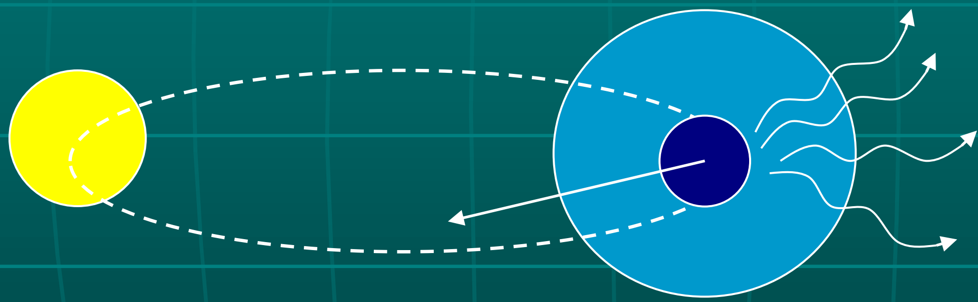


$$f(v) \sim \frac{v^2}{v_0^3} e^{-\frac{v^2}{v_0^2}},$$

Single maxwellian distribution

Products of binaries. II.

We can easily reproduce the fraction of magnetars among NSs, however, to make them all isolated we need kick velocities larger than average for NSs.

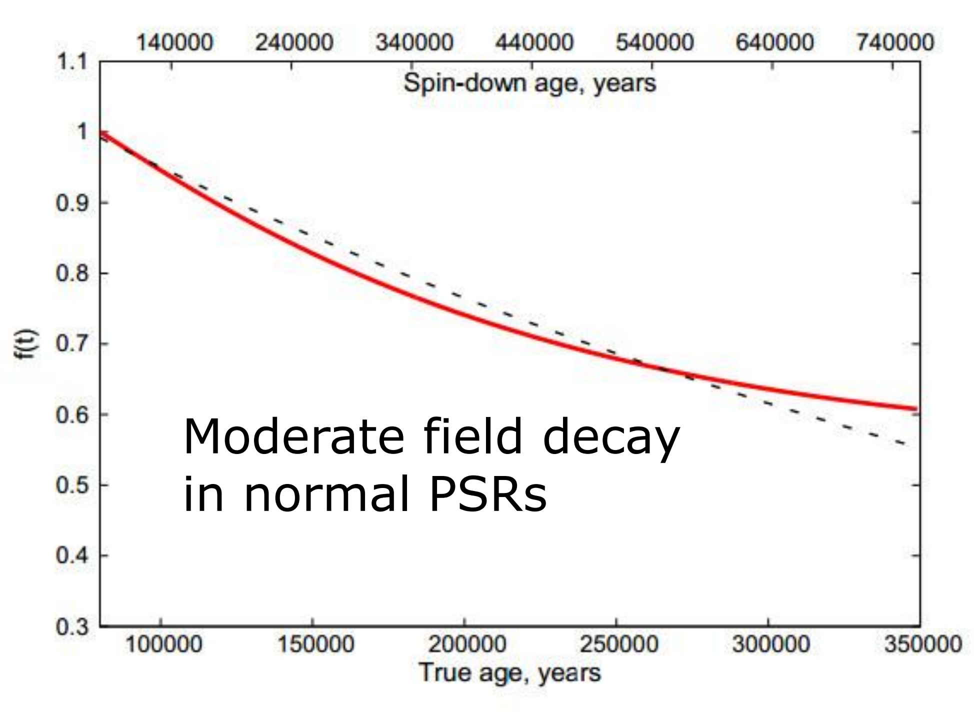


Here we come to the question:
if there are magnetars in binary systems?
I.e., shall we assume that most of them are isolated?

Binaries and field evolution

It is important to probe field evolution on different time scales and for different values of the initial magnetic field.

- standard fields, < few Myrs
  Normal PSRs
- large fields, ~ tens kyrs
  SGRs AXPs
- large fields, ~hundred kyrs
  Magnificent seven (?)
- All fields, Gyrs
  Accreting isolated NSs
  (in future?
  See arXiv: 1004.4805)



Preliminary arXiv:1309.4917

Binaries provide an additional possibility to probe the time scale unavailable for INSs.

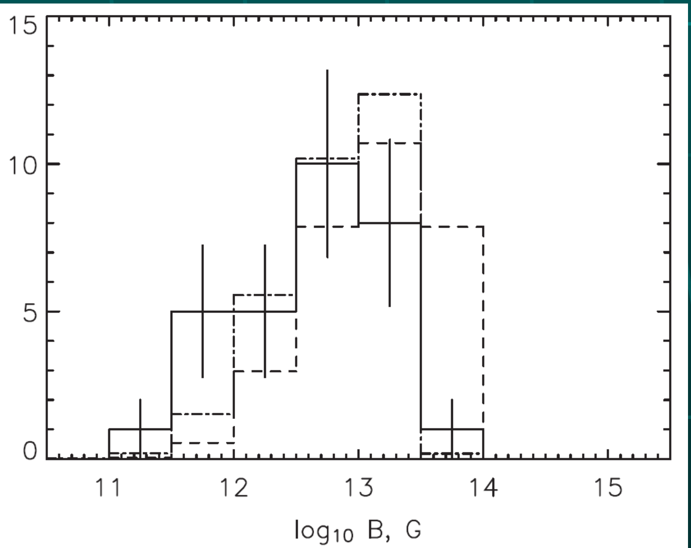
Accreting magnetars in binaries

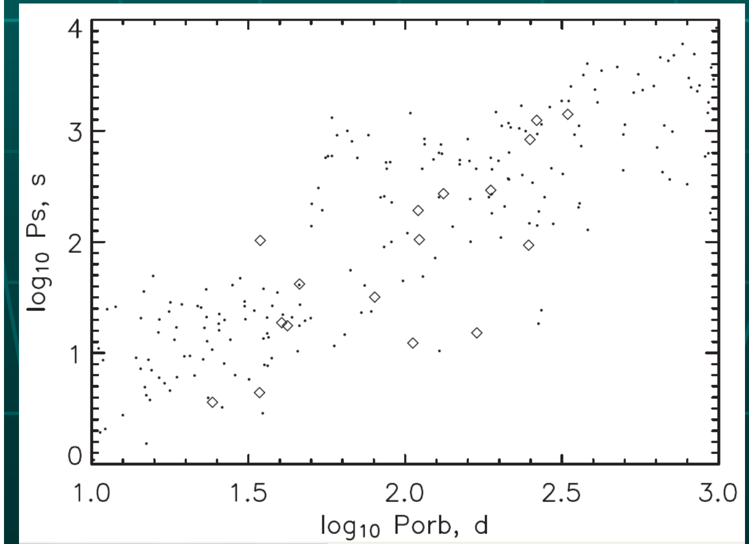
HMXBs are good probes of NS evolution on the time scale up to few 10^7 yrs.

It is possible to estimate the magnetic field of a NS in a binary **IF** you know the correct model of accretion (see a list, for example, in Postnov et al. 2013).

Some authors (see Klus et al. 2013, Ho et al. 2013 and references therein) claim that only large magnetic fields can explain properties of several objects.

Some studies can explain the data without large fields.

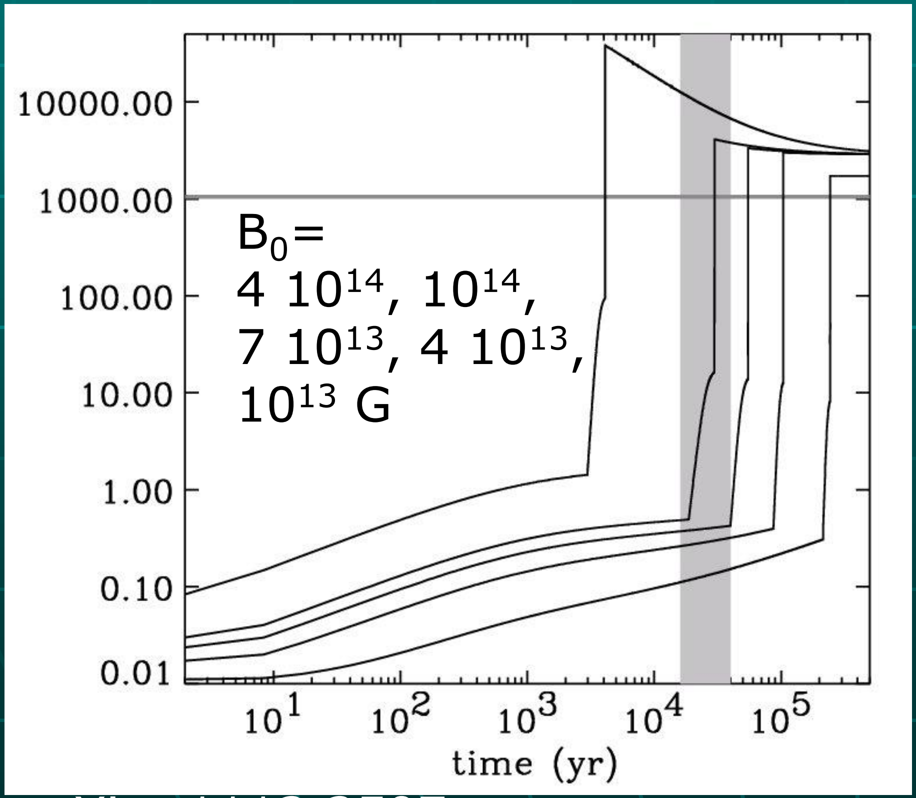




Set of 42 Be/Xray binaries in SMS can be explained in the framework of decaying field model of Pons et al. (arXiv: 1112.1123)

SXP 1062

A crucial thing for studying magneto-rotational evolution is to have an independent age estimate.
In the case of HMXBs a unique source with known age is SXP1062 (H´enault-Brunet et al. 2012, Haberl et al. 2012).



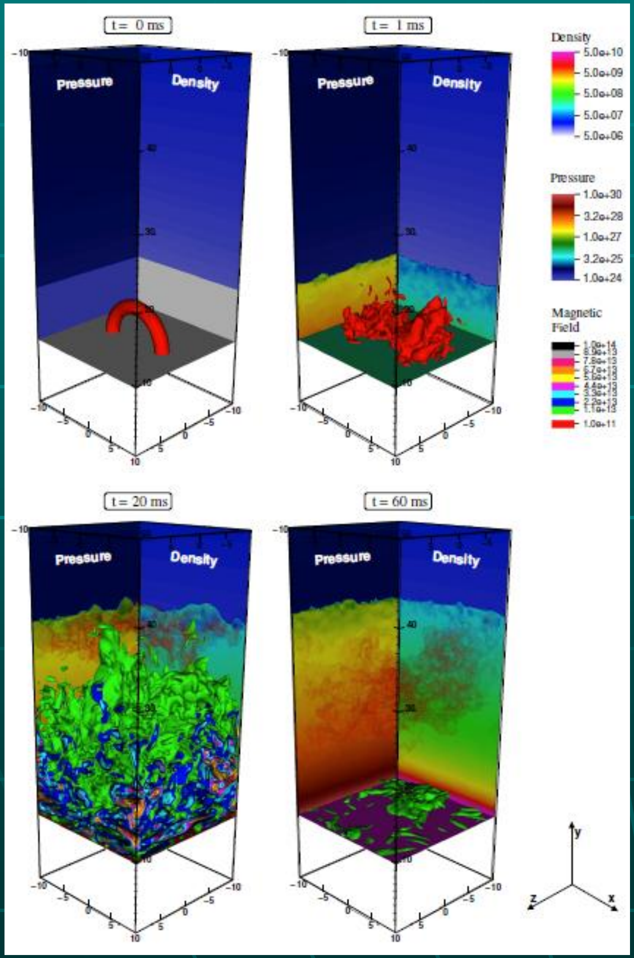
arXiv: 1112.2507

We were able to reproduce properties of SXP 1062 assuming a magnetic field decay.

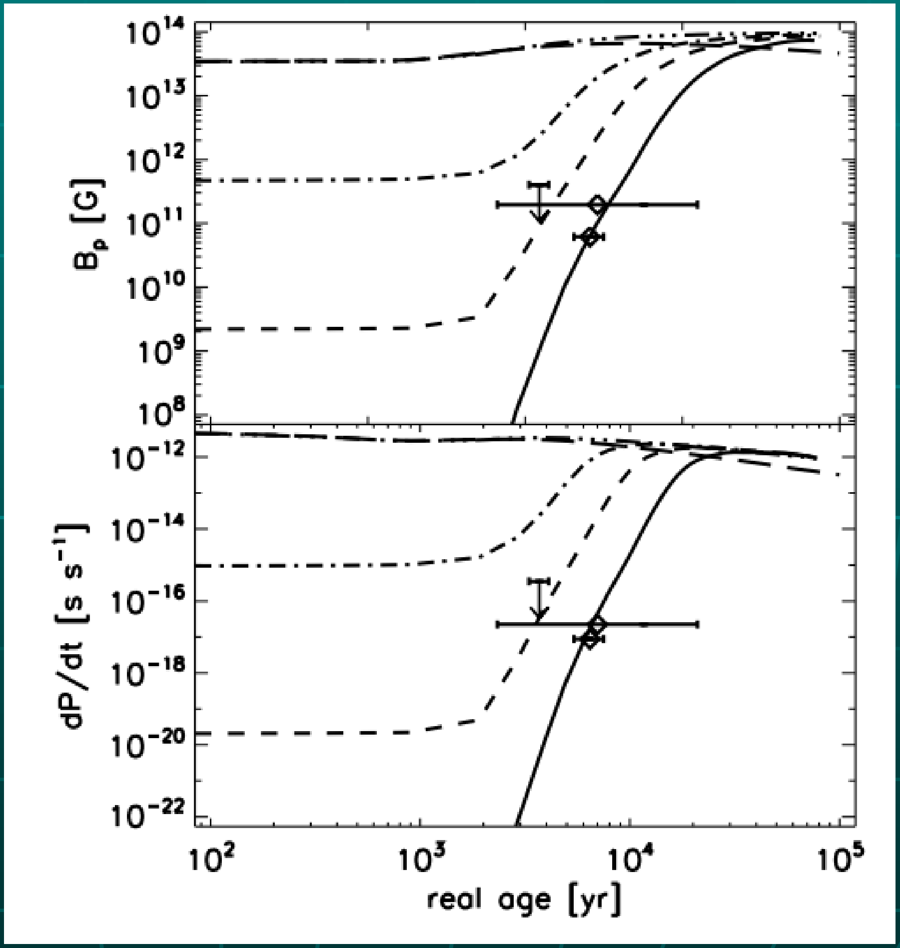
I.e., initially the NS was a magnetar but now it has s standard magnetic field.
The crucial element of this model is the new accretion model by Shakura et al. (2013).

The final element for the GUNS?

The field is buried by fall-back, and then re-emerges on the scale ~10^4 yrs.



Bernal, Page, Lee 2013

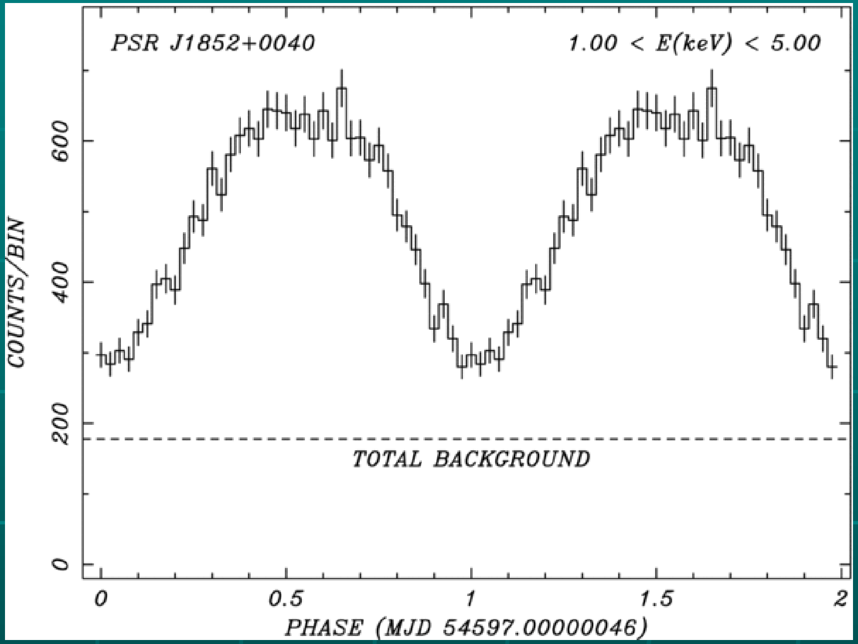


Vigano, Pons 2012

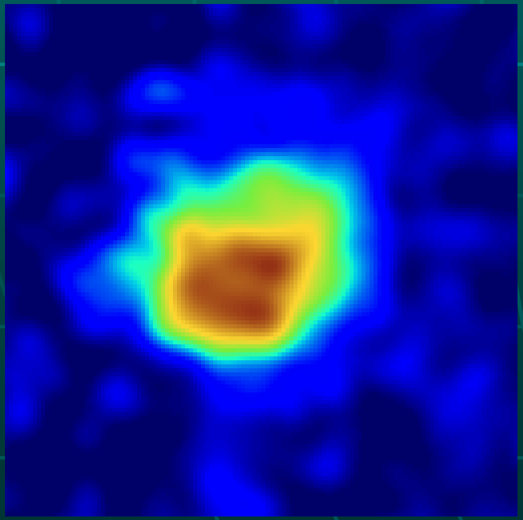
“Frozen” magnetars

Kes 79. PSR J1852+0040. P~0.1 s

Shabaltas & Lai (2012) show that large pulse fraction of the NS in Kes 79 can be explained if its magnetic field in the crust is very strong: few $\times 10^{14}$ G.



Halpern, Gotthelf 2010



Kes 79

- Submergence of the field happens rapidly, so the present day period represents the initial one
- Then, the field of PSR 1852 was not enhanced via a dynamo mechanism
- Detection of millisecond “frozen” magnetars will be a strong argument in favour of dynamo.

arXiv: 1307.3127

Conclusions

- Binary systems can provide evolutionary channels to produce progenitors with enhanced rotaion
- Studies of NSs in binaries can be used as a probe of magnetic field evolution on the time scale 1-20 Myrs
- Studies of 'frozen' magnetars can shed light on the initial properties of this type of NSs